Limberlost Creek Watershed
Sediment and Nutrient TMDL Development

Final June 7, 2007

Prepared for
Indiana Department of Environmental Management

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1.0 INTRODUCTION

The Limberlost Creek watershed is located in the upper Wabash River watershed in east-central Indiana (0). The watershed drains an area of approximately 43 square miles that consists primarily of row crops, pasture/hay, and small pockets of forest. There are also several small towns (population less than 1,500). Nineteen stream segments in the Limberlost Creek watershed were cited on Indiana's 2006 Section 303(d) list as being impaired for biotic communities (Table 1).

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters on the Section 303(d) lists. A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The Limberlost Creek watershed was prioritized for TMDL development to take advantage of a study conducted by the Indiana Department of Environmental Management (IDEM) in 2003 (Morris et al., 2003).

IDEM is in the final stages of developing nutrient and sediment TMDLs for the Limberlost Creek watershed. The overall goals and objectives of the project are to:

- Further assess the water quality of the Limberlost Creek watershed and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science to determine the maximum load of nutrients and TSS that the streams can receive and still fully support all of their designated uses.
- Use the best available science to determine current loads and sources of nutrients and TSS.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

Section 2 of this document describes the Limberlost Creek watershed and discusses several characteristics of the watershed that are significant to water quality conditions. Section 3 presents the relevant water quality standards and summarizes the available sampling data. Section 4 discusses all of the significant sources of nutrients and Section 5 discusses the technical approach that was used to evaluate the impact of the loadings on instream conditions. Section 6 allocates the existing loads to the various source categories and addresses several TMDL regulatory requirements, such as margin of safety and seasonality. Sections 7 and 8 discuss public participation and implementation, respectively.

Table 1. 2006 303(d) List Information for the Limberlost Creek Watershed

Assessment Unit	Waterbody Segment ID	Waterbody Segment Name	Cause of Impairment	TMDL Pollutant(s)
05120101050050	INB0155_00	Limberlost Creek (Flowing Into Oh)	Impaired Biotic Communities	TSS, nutrients
	INB0155_01	Limberlost Creek (Flowing Out Of Oh)	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1002	Wilson Creek-Unnamed Tributary	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1003	Wilson Creek	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1005	West Prong	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1007	Grissom Ditch (North Of Cr 930S)	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1008	West Prong-Unnamed Tributary	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1009	Young Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1010	Hartzel Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1011	East Prong	Impaired Biotic Communities	TSS, nutrients
	INB0155_T1012	Franks Drain	Impaired Biotic Communities	TSS, nutrients
05120101050060	INB0156_00	Limberlost Creek (Upstream Of Perry Ditch)	Impaired Biotic Communities	TSS, nutrients
	INB0156_01	Limberlost Creek (Downstream Of Perry Ditch)	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1002	Haffner Ditch-Unnamed Tributary	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1003	Haffner Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1004	Davison Ditch-Glenzter Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1005	Montgomery Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1007	Metzner Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1008	Wheeler Ditch	Impaired Biotic Communities	TSS, nutrients
	INB0156_T1009	Perry Ditch	Impaired Biotic Communities	TSS, nutrients

Note: TSS = Total Suspended Solids

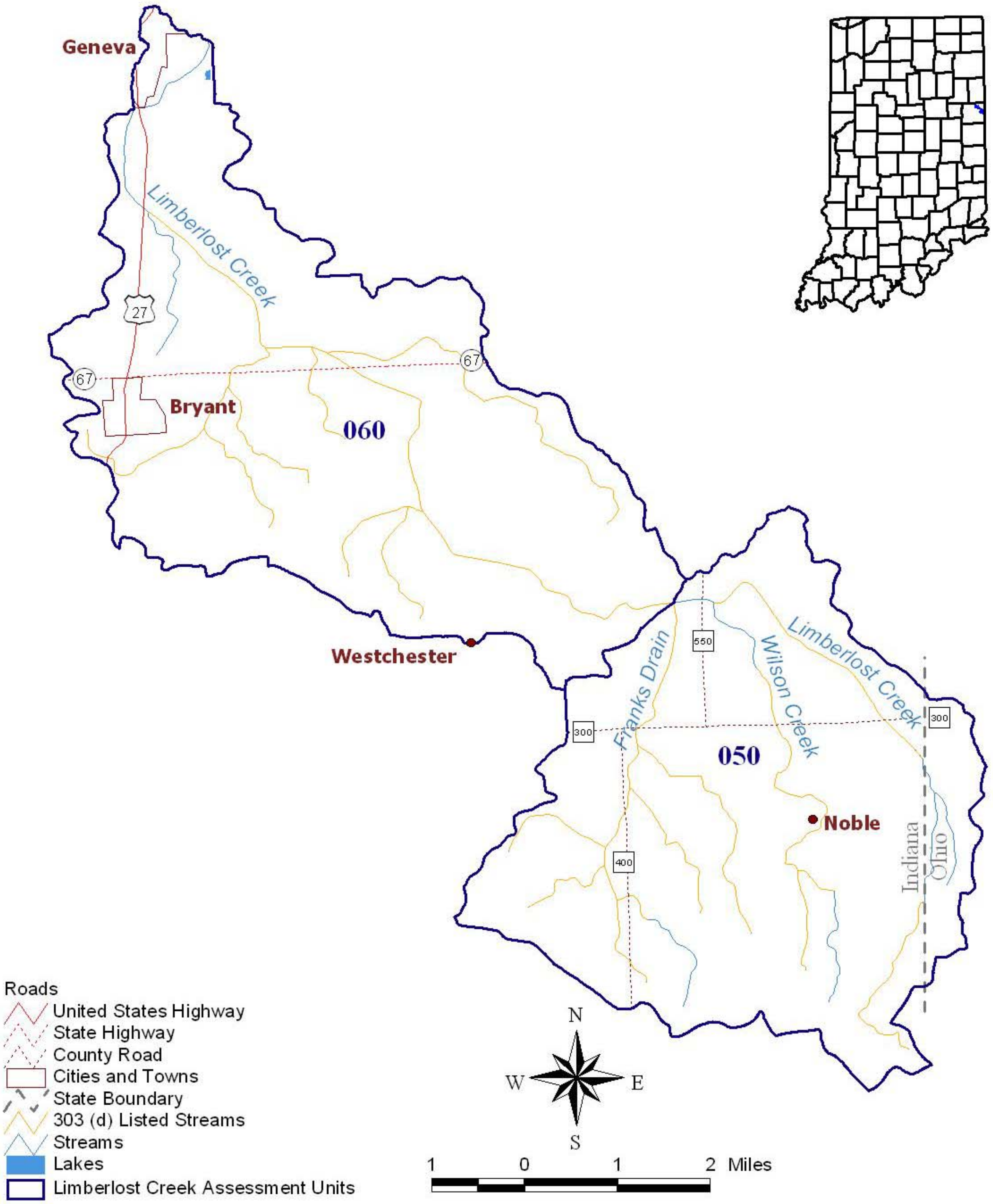

Figure 1. Location of the Limberlost Creek Watershed.

2.0 DESCRIPTION OF THE WATERSHED

The Limberlost Creek watershed is located in the upper Wabash River watershed in east-central Indiana and the segments of interest for this TMDL extend from the Indiana/Ohio border downstream to the city of Geneva. The watershed associated with the listed segments is 43 square miles and within Indiana is completely in Jay County (0). The Limberlost Creek watershed consists of the following two U.S. Geological Survey (USGS) Hydrologic Unit Codes: 05120101050050 and 05120101050060.

The sections below provide information on the population, land uses, topography, and climate associated with the watershed. Obtaining an understanding of these topics is a critical first step in developing a TMDL. These topics provide information on the potential sources of nutrients and sediment, as well as characteristics of the watershed that might affect water quality.

2.1 Population

The population of the Limberlost Creek watershed is approximately 2,500 with the majority concentrated in the towns of Bryant and Geneva (Table 2). The major population center in the watershed is Geneva, with a population of approximately 1,400 people (US Census Bureau, 2000). (Note that portions of Geneva are outside the Limberlost Creek watershed; therefore the population shown in Table 2 was estimated based on the portion of Geneva that is located within the watershed.) Population growth in the watershed between 1990 and 2000 was approximately three percent. There are no Municipal Separate Storm Sewer Systems (MS4s) within the Limberlost Creek watershed.

Table 2. Population data for cities within the Limberlost Creek Watershed

Town	County	1990 Population	2000 Population	Percent Change
Bryant	Jay	282	272	-3.55%
Geneva[1]	Adams	540	577	6.85%
	Totals	822	849	3.28%

[1]Note that portions of Geneva are outside the Limberlost Creek watershed; therefore the population shown in the table was estimated based on the portion of the city that is located within the watershed.

2.2 Topography

The Limberlost Creek watershed lies in the Tipton Till Plain, a physiographic region characterized by flat to gently rolling terrain. Topography in the watershed is a result of continental glaciation during the most recent ice age. Figure 2 presents the general topography within the watershed. Elevation ranges from 820 feet to 980 feet in the headwaters (USGS, 1993). The average slope in the watershed is very low – around 1.19 percent (calculated by measuring the average slope of each 98 foot by 98 foot parcel of land in the watershed with a geographic information system (GIS)).

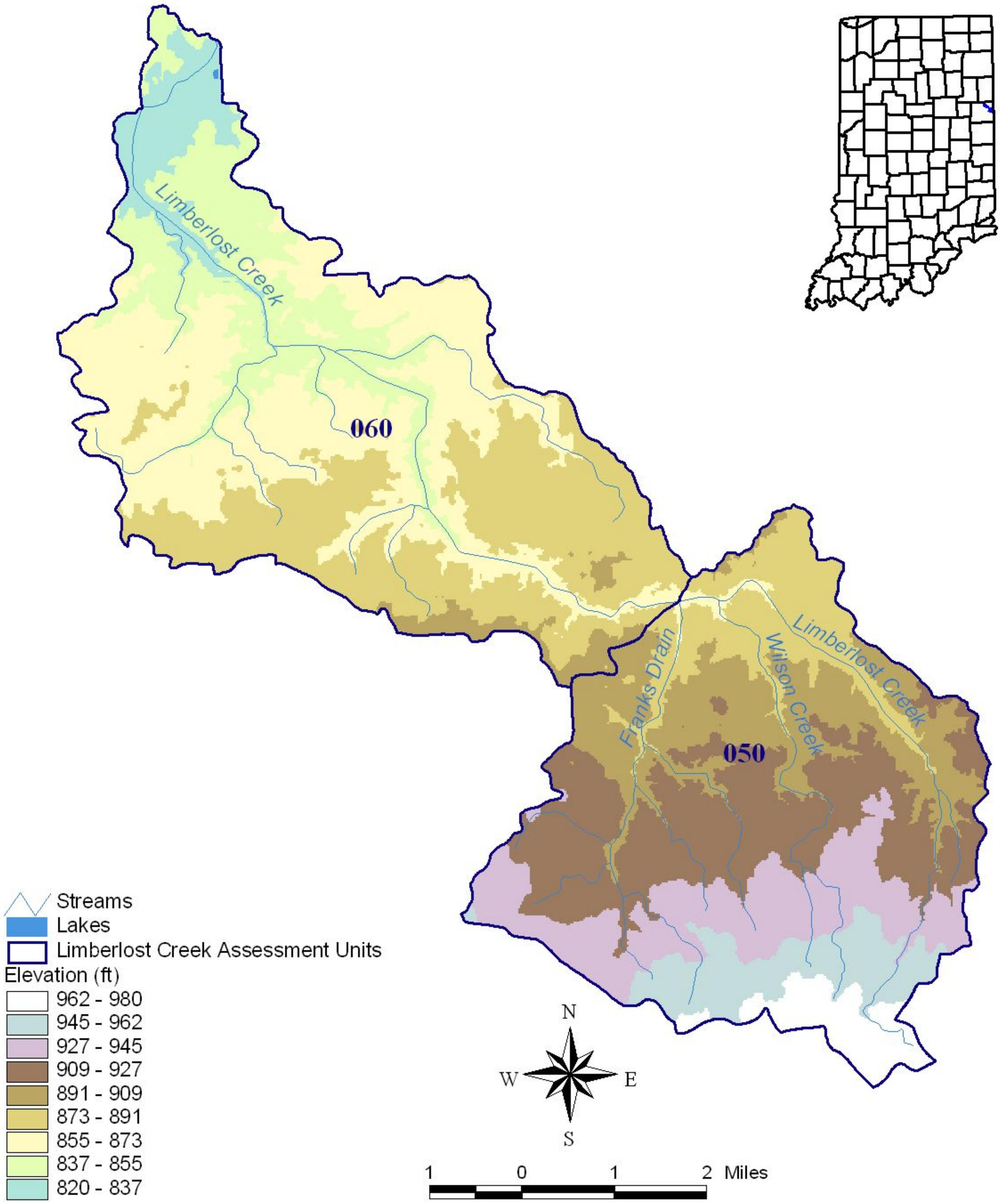

Figure 2. Topography in the Limberlost Creek Watershed.

2.3 Land Use

Land use information for the Limberlost Creek watershed is available from the Multi-Resolution Land Characteristics Consortium (MRLC). The land use data are derived from images acquired by Landsat's Thematic Mapper satellite during the early 1990s. These data categorize the land use for each 98 foot by 98 foot parcel of land in the watershed. Figure 3 displays the spatial distribution of the land uses and Table 3 and 4 provide a breakdown of the land uses in the watershed. The watershed is mostly row crop agriculture with areas of low-density residential lands concentrated around the cities of Bryant and Geneva.

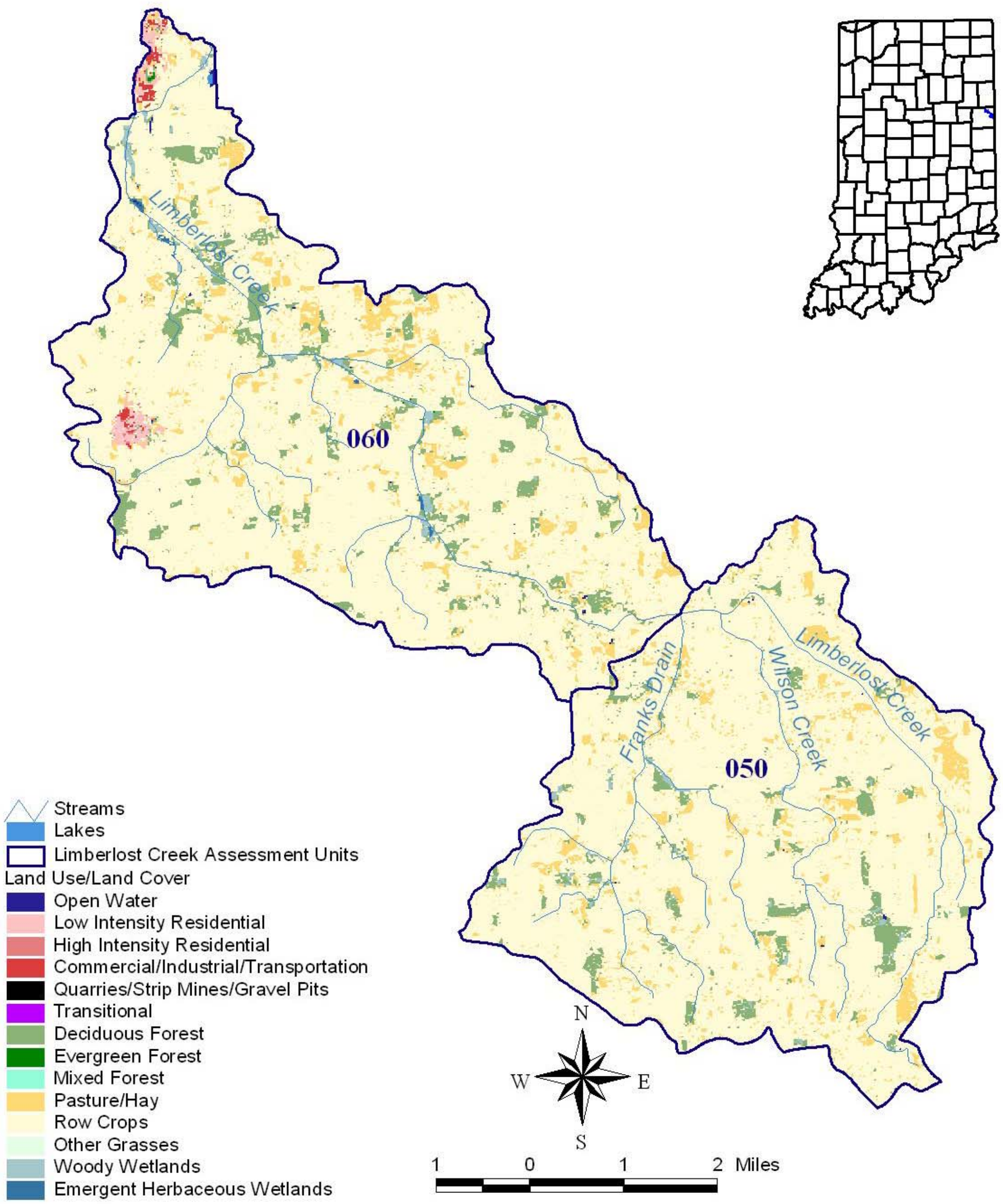

Figure 3. Land Use in the Limberlost Creek Watershed.

Table 3. Land Use and Land Cover in Limberlost Creek Assessment Unit 050

Land Use Code	Land Use	Acres	% of Total
82	Row Crops	11,288	86.135
81	Pasture/Hay	1,136	8.668
41	Deciduous Forest	601	4.586
91	Woody Wetlands	76	0.580
11	Water	3	0.023
23	Commercial/Industrial/Transportation	0.16	0.001
43	Mixed Forest	0.16	0.001
92	Emergent Herbaceous Wetlands	0.16	0.001
21	Low Intensity Residential	0.15	0.001
	Total	13,105	100

Table 4. Land Use and Land Cover in Limberlost Creek Assessment Unit 060

Land Use Code	Land Use	Acres	% of Total
82	Row Crops	11,839	82.187
81	Pasture/Hay	1,268	8.802
41	Deciduous Forest	972	6.748
21	Low Intensity Residential	118	0.819
91	Woody Wetlands	100	0.694
23	Commercial/Industrial/Transportation	52	0.361
92	Emergent Herbaceous Wetlands	20	0.139
11	Water	15	0.104
22	High Intensity Residential	9	0.062
85	Other Grasses	6	0.042
42	Evergreen Forest	5	0.035
43	Mixed Forest	0.47	0.003
	Total	14,405	100.000

2.4 Soils

Soils data from the Natural Resources Conservation Service (NRCS) were used to characterize soils in the watershed. General soils data and map unit delineations are available through the State Soil Geographic (STATSGO) database. GIS coverages provide accurate locations for the soil map units at a scale of 1:250000 (USDA, 2002). A map unit is composed of several soil series having similar properties. Identification fields in the GIS coverages can be linked to a database that provides information on chemical and physical soil characteristics, which can in turn be used in setting up and calibrating a watershed model.

The hydrologic soil group classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have lower infiltration rates, while sandy soils that are well drained have the greatest infiltration rates. NRCS has defined four hydrologic groups for soils (Table 5). The corresponding spatial distribution of hydrologic soil groups in the Limberlost Creek watershed is illustrated in Figure 4. Most of the watershed consists of moderately drained soils with low organic content (Group C).

Table 5. Characteristics of hydrologic soil groups (Source: NRCS, 1972)

Soil Group	Characteristics	Minimum Infiltration Capacity (inches/hour)
A	Sandy, deep, well drained soils; deep loess; aggregated silty soils	0.30 to 0.45
B	Sandy loams, shallow loess, moderately deep and moderately well drained soils	0.15 to 0.30
C	Clay loam soils, shallow sandy loams with a low permeability horizon impeding drainage (soils with a high clay content), soils low in organic content	0.05 to 0.15
D	Heavy clay soils with swelling potential (heavy plastic clays), water-logged soils, certain saline soils, or shallow soils over an impermeable layer	0.00 to 0.05

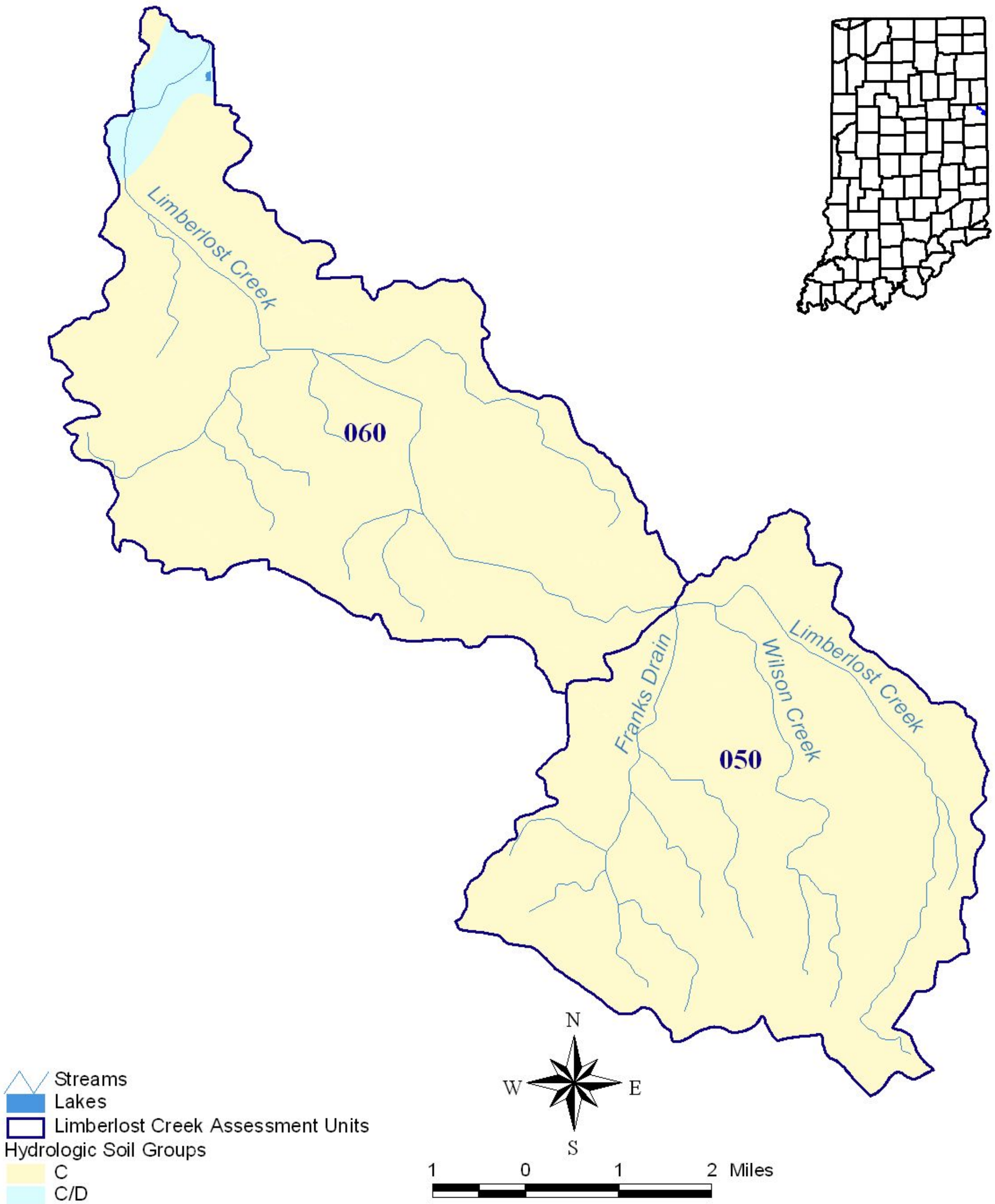

Figure 4. Hydrologic soil groups in the Limberlost Creek Watershed.

2.5 Climate

The Limberlost Creek watershed has a climate characterized by warm summers and cool winters. Average temperatures range from around 24 degrees Fahrenheit in January to 73 degrees Fahrenheit in July (MRCC, 2002). The Fort Wayne National Climatic Data Center (NCDC) weather station is located near the watershed in Allen County (station IN3037) (Figure 5). This station records climatic variables such as temperature, precipitation, wind speed, and potential evapotranspiration.

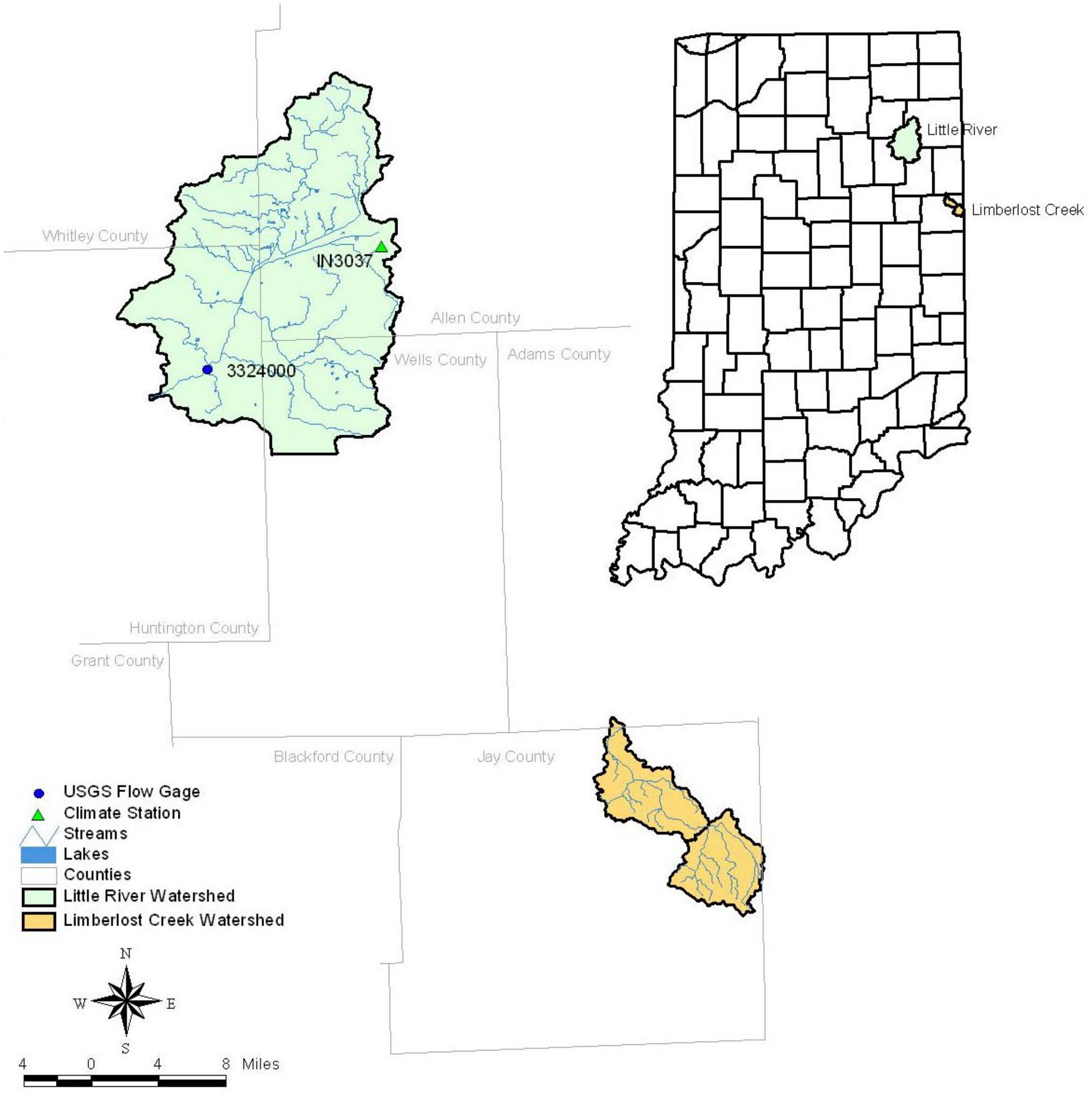

Figure 5. Location of Climate and USGS flow stations, Little River and Limberlost Creek Watersheds.

2.6 Hydrology

The U. S. Geological Survey (USGS) does not operate any stream flow gaging stations in the Limberlost Creek watershed. Since there are no continuous flow data for the Limberlost Creek watershed, hydrologic model parameters had to be calibrated by applying the model to a neighboring "surrogate" watershed. This is a standard practice when developing TMDLs for ungaged watersheds and is appropriate when the two watersheds are located close to one another and have similar land use and soil characteristics (see Section 5).

The Little River watershed was chosen as a "surrogate" due to its proximity to the Limberlost Creek watershed and its similar hydrologic characteristics. Both watersheds are located in the upper Wabash River watershed (0) and the centers of each watershed are approximately 40 miles from one another. Land use in both watersheds is mostly row crops, pasture and hay, and deciduous forest (Table 6) and both watersheds consist primarily of Group C soils.

Table 6. Land Use and Land Cover distribution in Limberlost Creek Watershed and Little River Watershed.

	Limberlost Creek		Little River	
Land Use	**Acres**	**Percent**	**Acres**	**Percent**
Row Crops	23,128	84.07	107,947	72.64
Pasture/Hay	2,405	8.74	18,958	12.76
Deciduous Forest	1,572	5.72	11,891	8
Woody Wetlands	177	0.64	2,068	1.39
Low Intensity Residential	118	0.43	3,512	2.36
Commercial/Industrial/Transportation	53	0.19	1,738	1.17
Emergent Herbaceous Wetlands	20	0.07	124	0.08
Water	17	0.06	438	0.29
High Intensity Residential	9	0.03	223	0.15
Evergreen Forest	5	0.02	69	0.05
Other Grasses	6	0.02	1,010	0.68
Mixed Forest	0.63	0	10	0.01
Quarries/Strip Mines/Gravel Pits	0	0	443	0.3
Transitional	0	0	172	0.12
Total	27,510.63	100	148,603	100

The location of the Little River flow gage is shown in 0 and the period of record is from April 1, 1944 to August 24, 2006. Figure 6 displays the average daily flows at this gage, which are believed representative of the trends that would be observed in Limberlost Creek (the magnitude of flows in Limberlost Creek would be less due to the smaller drainage area). Flows are highest during winter and spring, and lowest during the summer months of August and September.

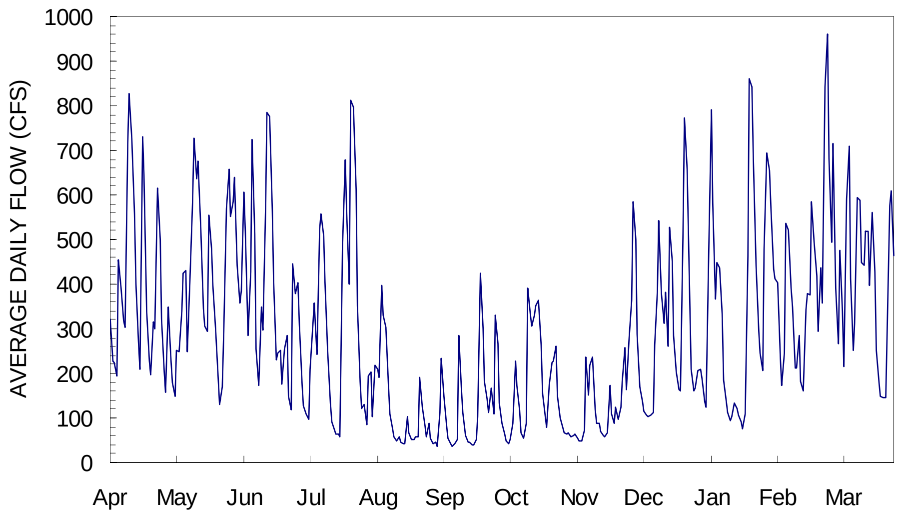

Figure 6. Average daily flow for the Little River at USGS Gage 03324000 (April 1996 - March 2004).

3.0 INVENTORY AND ASSESSMENT OF WATER QUALITY INFORMATION

This section of the report provides information on the water quality standards and targets that are being applied to the Limberlost Creek watershed and discusses the available biological, habitat, and water quality data.

3.1 Water Quality Standards

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of several different components:

- **Designated uses** reflect how the water can potentially be used by humans and how well it supports a biological community. Examples of designated uses include aquatic life support, drinking water supply, and full body contact recreation. Every waterbody in Indiana has a designated use or uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support the designated uses. **Numeric criteria** represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. **Narrative criteria** are the general water quality criteria that apply to all surface waters. These criteria state that all waters must be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that may cause algal blooms

The Indiana narrative biological criterion [327 IAC 2-1-3(2)] for the Limberlost Creek Watershed states: "all waters, except those designated as limited use, will be capable of supporting a well-balanced, warm water aquatic community." The water quality regulatory definition of a "well-balanced aquatic community" is "an aquatic community which is diverse in species composition, contains several different trophic levels, and is not composed mainly of strictly pollution tolerant species" [327 IAC 2-1-9(49)].

3.2 TMDL Target Values and Pollutant Linkage to Impaired Biotic Communities

The pollutants identified for TMDL development in the Limberlost Creek watershed to address the Impaired Biotic Community (IBC) impairment are sediments (as measured by total suspended solids (TSS)) and nutrients. The following sections present the TMDL target values for these pollutants along with an explanation of how they impact aquatic community health.

3.2.1 Target Values

Like most states, Indiana has not yet adopted numeric water quality criteria for nutrients. However, IDEM has identified the following nutrient benchmarks that are used to assess potential nutrient impairments:

- Total phosphorus should not exceed 0.3 mg/L[1].
- Nitrate + nitrite should not exceed 10 mg/L (Indiana Drinking Water Standard).
- Dissolved oxygen should not be below the water quality standard of 4.0 mg/L and should not consistently be close to the standard (i.e., in the range of 4.0 to 5.0 mg/L). Values should also not be consistently higher than 12 mg/L and average daily values should be at least 5.0 mg/L per calendar day (IAC 327 2-1-6).
- No pH values should be less than 6.0 or greater than 9.0. pH should also not be consistently close to the standard (i.e., 8.7 or higher) (IAC 327 2-1-6).
- Algae growth should not be “excessive” based on field observations by trained staff (IAC 327 2-1-6).

IDEM considers a segment to be impaired for “nutrients” when two or more of these benchmarks are exceeded based on a review of all recent data. The total phosphorus (0.30 mg/L) and nitrate + nitrite (10 mg/L) values were used as TMDL targets during the development of the Limberlost Creek TMDL.

IDEM has also not yet adopted numeric water quality criteria for total suspended solids (TSS). However, 30 mg/L was used as the TMDL target value to ensure consistency with IDEM’s National Pollutant Discharge Elimination System (NPDES) permitting process. (Note that the TSS permit limit for 10:1 dilution ratio wastewater systems is 75 mg/L).

3.2.2 Pollutant Linkage to Impaired Biotic Communities

Limberlost Creek has been identified as having impaired biotic communities and sediments and nutrients have been identified as the pollutants for TMDL development. This determination is based on the fact that sediment and nutrient concentrations are elevated in the watershed, sediment and nutrient impairments are pervasive throughout the Midwest, and there are numerous studies documenting their detrimental impact on aquatic community health as a result of human activities (e.g., Baker, 1985; Johnson et al., 1997; Miltner and Rankin, 1998; OEPA, 1999). The discussion below provides a summary of the means by which nutrients and sediment can impact aquatic life.

Total suspended solids are particles in the water that can be trapped by a filter. High concentrations of TSS can reduce the amount of sunlight available to aquatic organisms and decrease water clarity. This leads to a number of effects including: reduction of aquatic plants available for consumption by higher

[1] The phosphorus benchmark for Indiana is based on the May 1, 1986 EPA Quality Criteria for Water document. The 0.03 mg/l value referenced in the EPA document was used in conjunction with Indiana’s narrative criteria to determine the concentration necessary to assess impairments in surface waters in Indiana for phosphorus. This number was determined to be 0.30 mg/L.

level organisms, lower dissolved oxygen, and the impaired ability of fish to see and catch food. TSS particles can also hold heat resulting in increased stream temperature. Further, TSS can clog fish gills, retard growth rates, decrease resistance to disease, and prevent egg and larval development. When TSS settles on the bottom of a waterbody, eggs of fish and invertebrates are smothered, larvae can suffocate, and habitat quality is degraded (OEPA, 1999).

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life; in fact, nutrients are essential in minute amounts for the proper functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of these minute needs can exert negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Increased plant production increases turbidity, decreases average dissolved oxygen concentrations, and increases fluctuations in diurnal dissolved oxygen and pH levels. Such changes shift aquatic species composition away from functional assemblages comprised of intolerant species, benthic insectivores, and top carnivores that are typical of high quality streams towards less desirable assemblages of tolerant species, generalists, omnivores, and detrivores that are typical of degraded streams (OEPA, 1999). Such a shift in community structure lowers the diversity of the system.

IDEM believes that attaining the TSS and nutrient targets identified in Section 3.2.1 will result in the waterbody attaining the aquatic life use.

3.3 Confirmation of Impairment and its Extent

IDEM conducted an intensive study of the Limberlost Creek watershed in 2003 (Morris et al., 2003). Fish community sampling was performed and water quality data were sampled at 57 sample sites in the watershed for 38 different parameters. The data were collected in June and August of 2003 and Figure 7 presents the locations of the monitoring sites. Table 7 summarizes the available TSS and nutrient water quality data and all of the monitoring data are included in Appendix B.

Table 7. Summary statistics for TSS and nutrients sampled in June and August, 2003 in the Limberlost watershed

Pollutant	JUNE				AUGUST			
	Mean	Minimum	Maximum	Std. Dev.	Mean	Minimum	Maximum	Std. Dev.
Total Suspended Solids (mg/L)	27.31	5.00	142.00	23.64	34.32	8.00	138.00	27.11
Nitrate+Nitrite-N (mg/L)	13.65	0.30	32.00	6.25	0.92	0.05*	9.90	1.61
Total Phosphorus (mg/L)	0.12	0.03*	0.40	0.08	1.05	0.03*	31.00	4.81

*Below Method Detection Limit

IDEM's intensive study concluded that the overall biological integrity of the Limberlost Creek watershed was poor. More than 50 percent of the watershed failed established criteria (Table 8) for aquatic life support during each sampling event and the remaining sites that met established criteria did not achieve levels suitable for classification above "fair" condition (Figure 8 and Figure 9).

Table 8. Aquatic Life Use Support Criteria

Parameter	Fully Supporting	Partially Supporting	Not Supporting
Qualitative habitat use evaluation (QHEI)	QHEI > 64	64 > QHEI > 51	QHEI < 51
Fish community Index of Biotic Integrity (IBI) (White, East Fork; Whitewater; and Upper Wabash basins)	IBI > 34	34 > IBI > 32	IBI < 32

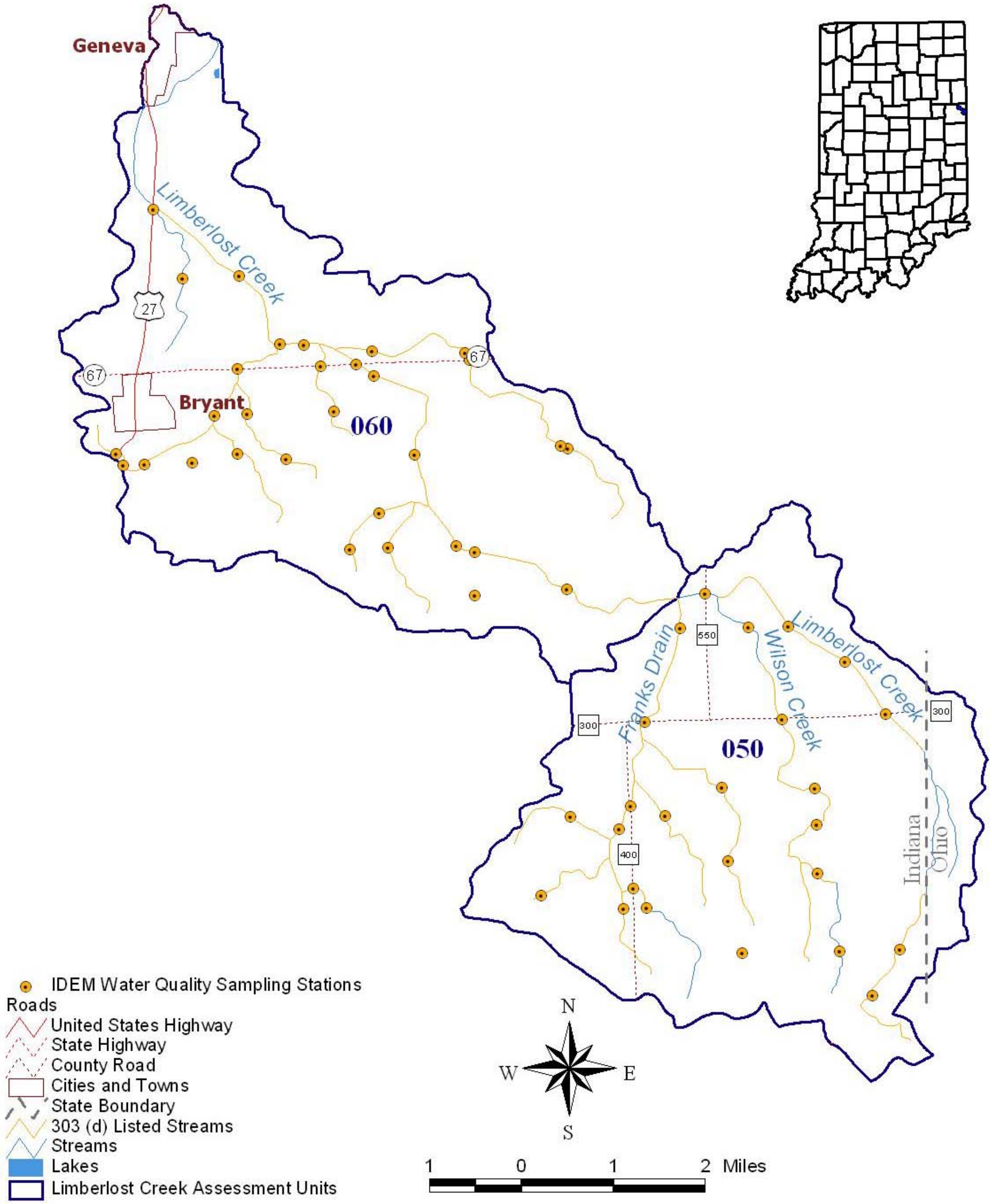

Figure 7. Location of IDEM surface water quality sample sites.

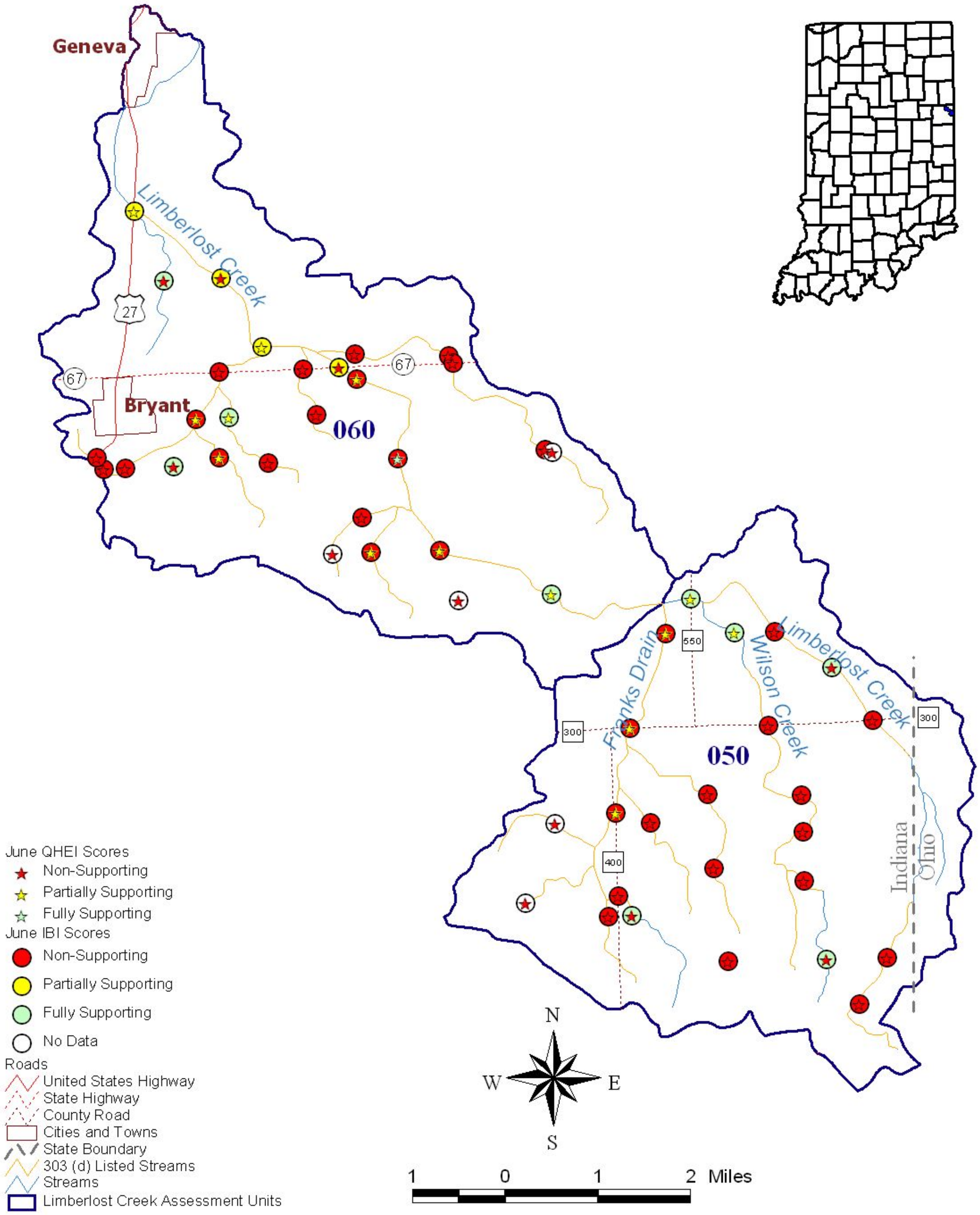

Figure 8. Qualitative Habitat Evaluation Index (QHEI) and IBI sampling results for June in the Limberlost Creek Watershed

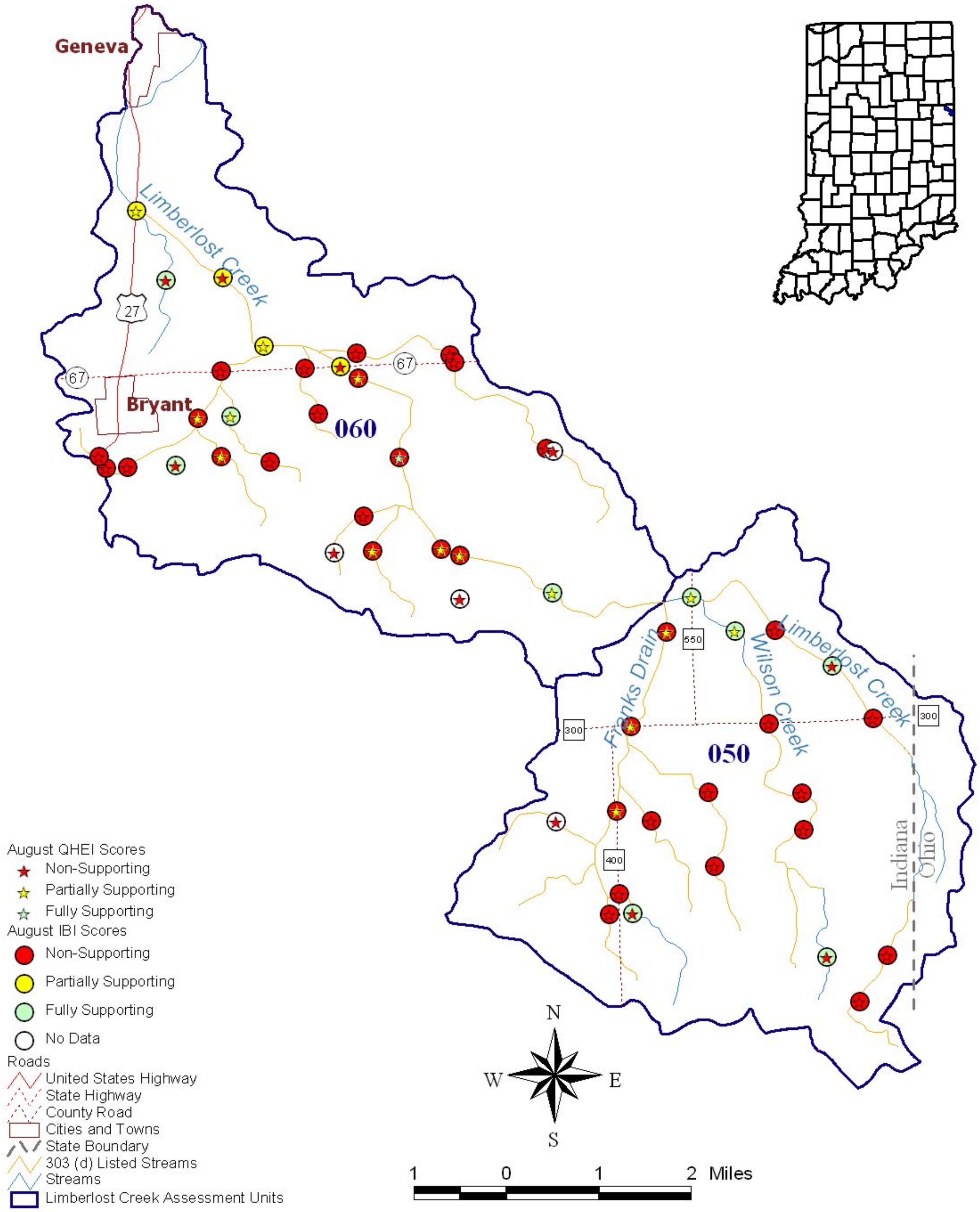

Figure 9. Qualitative Habitat Evaluation Index (QHEI) and IBI sampling results for August in the Limberlost Creek Watershed.

4.0 SOURCE ASSESSMENT

This section summarizes the available information on significant sources of nutrients and sediment in the Limberlost Creek watershed and describes the approach that was used to estimate loads from each source. Estimating the magnitude of loadings from the various source categories is critical to the TMDL development process as it allows for more focused implementation activities.

4.1 Point Sources

The term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a waterbody. It also includes vessels or other floating craft from which pollutants are or may be discharged. By law, the term "point source" also includes: concentrated animal feeding operations (which are places where animals are confined and fed); storm water runoff from Municipal Separate Storm Sewer Systems (MS4s); and illicitly connected "straight pipe" discharges of household waste.

4.1.1 Wastewater Treatment Plants (WWTPs)

Treated municipal sewage is a point source of nutrients. WWTPs release water with elevated concentrations of nutrients into streams. Typical values are 13 mg/L TN and 7 mg/L TP (USEPA, 1997) which are both above the proposed TMDL target values identified in Section 3.2. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating WWTPs that discharge pollutants into waters of the United States.

There is only one WWTP in the Limberlost Creek watershed – the Bryant Sewage Treatment Plant (permit number IN0055158) which discharges to Perry Ditch (Figure 10). This facility uses a waste stabilization lagoon and is allowed to discharge only at a 10 to 1 dilution ratio. Loading estimates from this facility were input to the model based on information provided by the facility to IDEM in its discharge monitoring reports (see Section 6).

The Bryant Sewage Treatment Plant is estimated to contribute about one percent of the nitrogen load and 5 percent of the phosphorus load in the Limberlost Creek watershed. Effluent from the plant only impacts a small portion of Limberlost Creek since Perry Ditch enters Limberlost Creek near its most downstream point (approximately four miles upstream of the confluence with the Wabash River).

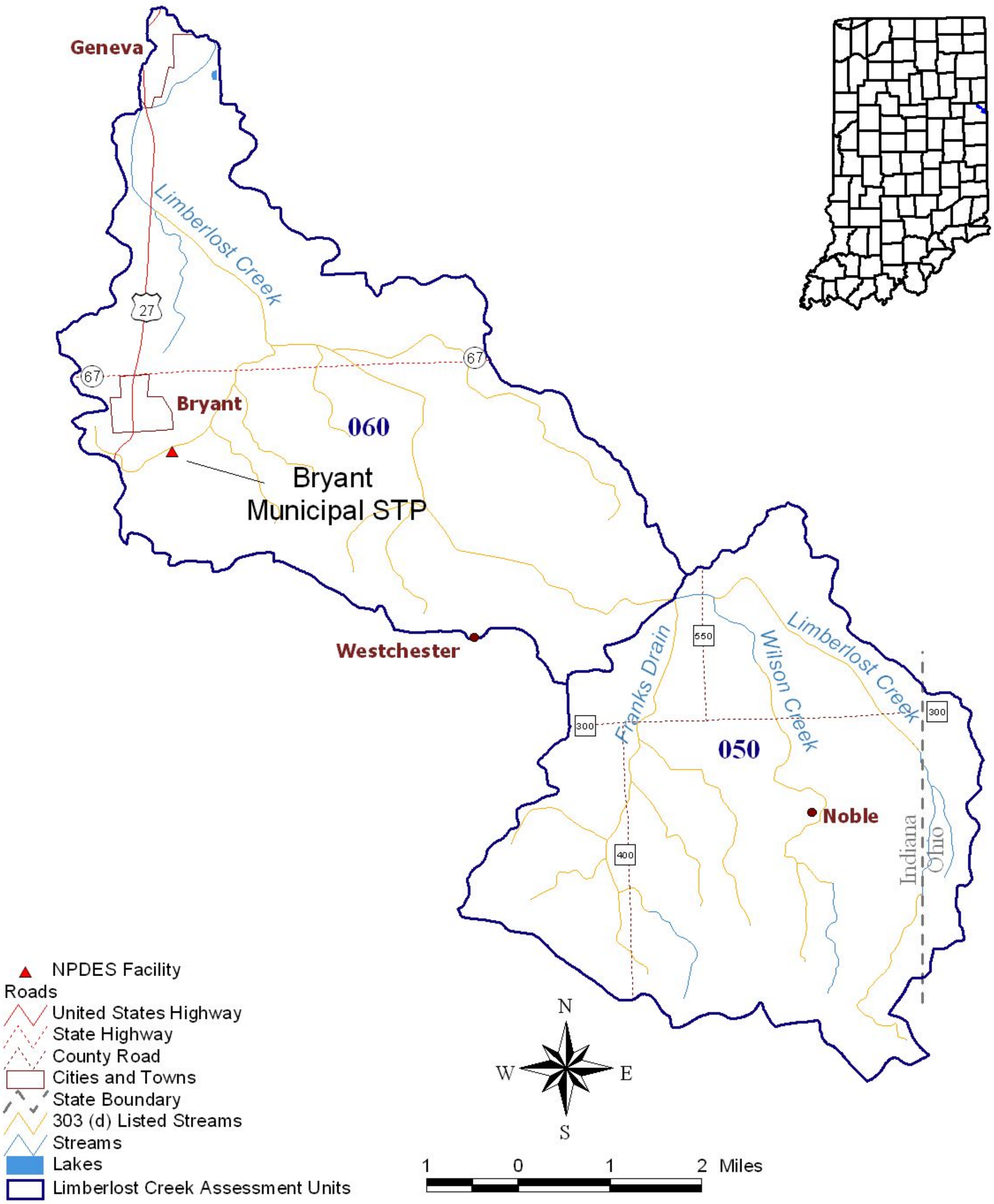

Figure 10. Location of NPDES Facility IN0055158 in the Limberlost Creek Watershed.

4.1.2 Confined Feeding Operations

The removal and disposal of the manure, litter, or processed wastewater that is generated as the result of confined feeding operations falls under the regulations for confined feeding operations (CFOs) and concentrated animal feeding operations (CAFOs). The CFO and CAFO regulations (327 IAC 16, 327 IAC 15) require that operations “not cause or contribute to an impairment of surface waters of the state”. IDEM regulates these confined feeding operations under IC 13-18-10, the Confined Feeding Control Law. The rules at 327 IAC 16, which implement the statute regulating confined feeding operations, was effective on March 10, 2002. The rule at 327 IAC 15-15, which regulates concentrated animal feeding operations and complies with most federal CAFO regulations, became effective on March 24, 2004, with two exceptions. 327 IAC 15-15-11 and 327 IAC 15-15-12 became effective on December 28, 2006. Point Source rules can be found at 327 IAC 5-4-3 (effective 12/28/06) and 327 IAC 5-4-3.1 (effective 3/24/04).

The animals raised in confined feeding operations produce manure that is stored in pits, lagoons, tanks and other storage devices. The manure is then applied to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. Confined feeding operations, however, can also pose environmental concerns, including the following:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or ground water.
- Manure overapplication can adversely impact soil productivity.

The locations of confined feeding operations in the Limberlost Creek watershed are shown in Figure 11 and additional information on the operations is presented in Table 9 and Table 10. No information was available to estimate loads associated with each individual operation in the watershed; however, Table 10 and Table 11 were used during the setup of the watershed model described in Section 6 and Appendix A.

Due to size some confined feeding operations are defined as CAFOs. For purposes of discussion, it is important to remember that all CAFOs are confined feeding operations. The CAFO regulation, however, contains more stringent operational requirements and slightly different application requirements. There are four CAFO’s in the Limberlost Creek watershed: Scwieterman, Journay Farms, Link, and Minnich Poultry, LLC.

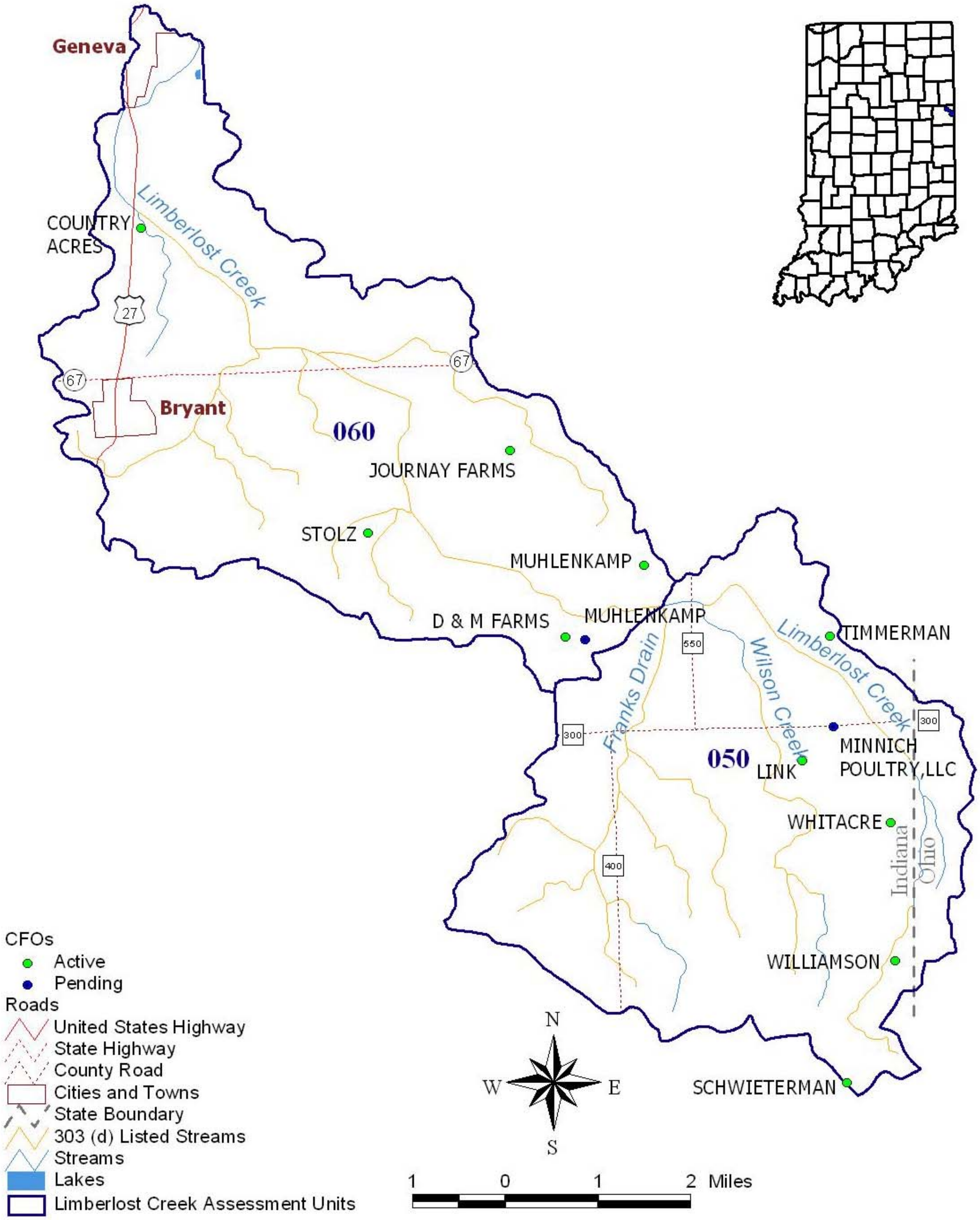

Figure 11. Confined Feeding Operations in the Limberlost Creek Watershed.

Table 9. Confined Feeding Operations in the Limberlost Creek Watershed.

Log #	Name	Status	Pigs	Cows	Poultry
1050	Timmerman	Active	2,000	0	0
1983	Schwieterman	Active	1,958	0	79,000
4409	Muhlenkamp	Active	0	471	0
4414	Williamson	Active	1,312	0	0
4651	D & M Farms	Active	692	0	0
4663	Country Acres	Active	0	0	186,000
4938	Journay Farms	Active	0	0	70,000
4968	Whitacre	Active	2,000	0	0
6019	Stolz	Active	3,000	0	0
6088	Link	Active	4,000	0	0
3533	Minnich Poultry,Llc	Pending	0	0	1,211,000
4888	Muhlenkamp	Pending	0	300	0
574	Alvin Muhlenkamp Farms Inc	Voided	N/A	N/A	N/A
591	Muhlenkamp	Voided	N/A	N/A	N/A
3763	Jonas Schwartz	Voided	N/A	N/A	N/A
4365	Barry Retter	Voided	N/A	N/A	N/A
4958	Bruggeman	Voided	N/A	N/A	N/A
4963	Hampson	Voided	N/A	N/A	N/A
6077	David Post	Voided	N/A	N/A	N/A

Table 10. Confined Feeding Operation Animals in the Limberlost Creek Watershed Assessment Units

Assessment Unit	Beef Cows	Dairy Cows	Swine	Chickens
050	0	0	11,270	1,290,000
060	471	300	3,692	256,000
Total	471	300	14,962	1,546,000

4.1.3 Combined Sewer Systems and MS4s

Currently there are no combined sewer systems or Municipal Separate Storm Sewer Systems (MS4s) located within the Limberlost Creek watershed. (These are two relatively common types of pollutant sources that are categorized as point sources under NPDES regulations).

4.1.4 Illicitly Connected "Straight Pipe" Systems

Some household wastes within Indiana and potentially within the Limberlost Creek watershed directly discharge to a stream or are illegally connected directly to tile-drainage pipes in agricultural watersheds, providing a direct source of pollutants to the stream (these systems are sometimes referred to as "straight pope" discharges). These systems are technically classified as point sources; however, since they are illegal they receive a wasteload allocation of zero (see Section 6.3).

4.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. In urban areas, nonpoint sources can include leaking or faulty septic systems, runoff from lawn fertilizer applications, pet waste, storm water runoff (outside of MS4 communities), and other sources. In more rural areas, major contributors can be pasture land runoff, manure storage and spreading, and wildlife.

4.2.1 Agriculture

Lands used for agricultural purposes can be a source of both nutrients and TSS. Accumulation of nutrients on cropland occurs from decomposition of residual crop material, fertilization with chemical (e.g., anyhdrous ammonia) and manure fertilizers, atmospheric deposition, wildlife excreta, irrigation water, and application of waste products from municipal and industrial wastewater treatment facilities. The majority of nutrient loading from cropland occurs from fertilization with commercial and manure fertilizers (USEPA, 2003). Use of manure for nitrogen supplementation often results in excessive phosphorus loads relative to crop requirements (USEPA, 2003). Surface erosion from bare fields and streambank erosion associated with the loss of vegetation are the two primary sources of TSS from agricultural lands.

Runoff from pastures and livestock operations can also be potential agricultural sources of nutrients and TSS. For example, animals grazing in pasturelands deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event.

Sediment and nutrient loads from agriculture in the Limberlost Creek watershed were estimated using a watershed model, as described in Section 5. Appendix A provides a detailed explanation of the data and assumptions used to run the model. Loads from agricultural runoff were found to be the most significant source of sediments and nutrients in the watershed. These loads are associated with sheet and rill erosion from bare row crops, nutrient runoff from fertilized fields, and runoff from manured and pastured fields.

4.2.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. Common soil-type limitations in central Indiana which contribute to failure are: seasonal water tables, compact glacial till, bedrock, coarse sand and gravel outwash and fragipan. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsely and Witten, 1996).

The Jay County Health Department (Dave Houck, personal communications, November 29, 2006) reports that it is unlikely there are any ponded septic systems in the county and that approximately 50 percent of the systems in the County have absorption fields and 50 percent have off site discharges. No specific numerical information is available on the systems that might be failing.

Due to the lack of site-specific information on the performance of onsite wastewater treatment systems, the following assumptions were used to estimate loads in the Limberlost Creek watershed. These assumptions are based on similar TMDL studies conducted throughout the Midwest and available information on the population of the watershed and typical characteristics of onsite wastewater effluent.

- Total number of systems derived from system density estimates available from the US Census 1990.
- Based on similar watersheds within the Midwest, ten percent of all systems were estimated to discharge directly to perennial streams (i.e., illegal straight pipe discharges).
- Based on similar watersheds within the Midwest and a screening-level GIS analysis, 25 percent of all systems were estimated to be short-circuited (located within 100 feet of a perennial stream such that incomplete treatment is achieved).
- The population served by the systems was estimated to be an average of 2.5 people per household (US Census 2000).
- The load from systems was estimated to be 12 grams of nitrogen per day per person and 2.5 grams per day of total phosphorus (Haith et al., 1992).

Loads from onsite wastewater treatment systems are estimated to be approximately two percent of the nitrogen and one percent of the total phosphorus load in the watershed (see Table 11 for details).

5.0 TECHNICAL APPROACH

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a number of techniques, ranging from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. In selecting an appropriate modeling platform to support management initiatives and development of TMDLs for the Limberlost Creek watershed, the following criteria were considered and addressed (expanding on classification of Mao, 1992):

- Technical Criteria
- Regulatory Criteria
- User Criteria

Technical criteria refer to the model's simulation of the physical system in question, including watershed and/or stream characteristics/processes and constituents of interest. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol. User criteria comprise the operational or economical constraints imposed by the end-user and include factors such as hardware/software compatibility and financial resources.

To meet the objectives defined for the Limberlost Creek watershed TMDL, it was determined that development of a comprehensive watershed model was necessary to represent the watershed. A watershed model is essentially a series of mathematical formulas applied to watershed characteristics and meteorological data to simulate naturally occurring land-based processes over an extended period of time, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using the land-based calculations as input. The reasons that a comprehensive watershed model were determined to be necessary for this project including the following:

- Land use in the Limberlost Creek watershed includes row crop agriculture, pasture, and urban land uses. Different potential sources of nutrients and TSS are associated with each of these land use types (e.g., cattle, manure application, failing septic systems, wastewater treatment plants) and each land use also has affected the natural hydrology of the watershed. The model must therefore be able to address a mixed land use watershed.
- Rainfall intensity and volume play an important role in nutrient and TSS loadings. The model should provide accurate representation of rainfall events and resulting peak runoff.
- Different sources influence receiving waters in different ways and at different times (through different transport mechanisms). For example, surface runoff impacts waterbodies differently than direct stream contributions. The model must therefore be capable of simulating these transport mechanisms.
- The selected model had to be capable of simulating daily nutrient and TSS concentrations so that applicable averaging periods and peak levels can be determined and compared to numeric targets. The selected model had to also be able to address seasonal variations in hydrology and water quality and critical conditions (i.e., periods when concentrations are at their highest) as required by TMDL regulations. Critical conditions in the Limberlost Creek watershed vary temporally and spatially and occur both when storm runoff contributes high loads of pollutants from wet weather sources, and when low flows concentrate loads from constant sources.

IDEM and its consultant selected the Generalized Watershed Loading Function or GWLF model (Haith et al., 1992) to be used to support TMDL development in the Limberlost Creek watershed. The complexity of the loading function model falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent temporal variability. GWLF provides a mechanistic (or process-based) but simplified simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water.

The strengths of the GWLF model include the fact that it best matches the required technical, regulatory, and user criteria described above. Its primary weakness is that it provides only monthly output since it does not account for in-stream processing. The monthly output therefore needs to be converted to daily loads and is likely not as accurate as other models that can provide daily and hourly output. A detailed discussion of GWLF input and calibration is included in Appendix A.

6.0 ALLOCATIONS

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

To develop nutrient and sediment TMDLs for the Limberlost Creek watershed, the following approach was taken:

- Identify most significant sources of sediments and nutrients
- Assess source loading alternatives
- Determine the TMDL and source allocations

6.1 Identifying Most Significant Sources

Information on the key pollutant sources identified in Section 4 was combined with the modeling results (Appendix A) to determine the most significant pollutant sources within the watershed. The model was run with the Bryant WWTP discharging at their permitted design flow and permit limits to represent existing nonpoint source loading conditions and permitted point source discharge conditions. This model run therefore allows for an evaluation of in-stream water quality under the “worst currently allowable” scenario.

The model was run over an extended time period (1996 to 2004) to ensure that wet, dry, and average weather years were captured in the analysis. The results are shown in Table 11 and indicate that runoff from row crops and pastures are the largest sources of sediment, nitrogen, and phosphorus. This is due to the fact that the vast majority of the watershed is devoted to these land uses (more than 92 percent) and relatively high runoff concentrations are assigned to agricultural land uses compared to forest (see Appendix B for details). Sources such as the WWTP and failing onsite septic systems contribute a relatively small portion of the total annual load, but are more significant during low periods when dilution in the stream is reduced.

Table 11. Average annual loads in assessment units 050 and 060

Assessment Unit	Source	Area (ha)	Existing Total-N Load (kg/yr)	Existing Total-P Load (kg/yr)	Existing Total-TSS Load (kg/yr)
050	Row Crops	4568.23	68,400	10,240	9,880,100
	Pasture/Hay	459.7	15,290	2,180	99,420
	Deciduous Forest	242.98	40	<1	52,550
	Mixed Forest	0.07	<1	<1	20
	Woody Wetlands	30.94	490	40	<1
	Herbaceous Wetlands	0.07	<1	<1	<1
	Low Intensity Residential	0.06	<1	<1	<1
	Commercial	0.07	<1	<1	<1
	Groundwater	--	26,480	170	<1
	Point Source	--	0	0	0
	Septic Systems	--	1,810	130	<1
	Total	**5,303**	**112,510**	**12,760**	**10,032,090**
060	Row Crops	4791.08	69,340	10,310	983,530
	Pasture/Hay	513.09	16,220	2,310	105,330
	Deciduous Forest	393.09	60	<1	80,700
	Coniferous Forest	1.97	<1	<1	400
	Mixed Forest	0.19	<1	<1	<1
	Woody Wetlands	40.51	640	50	<1
	Herbaceous Wetlands	8.2	60	30	<1
	Low Intensity Residential	46.68	30	<1	<1
	High Intensity Residential	3.82	20	<1	<1
	Commercial	21.2	130	<1	<1
	Recreational Grasses	2.23	<1	<1	<1
	Groundwater	--	29,160	190	<1
	Point Source	--	1,420	760	<1
	Septic Systems	--	2,000	150	<1
	Total	**5,828**	**119,080**	**13,800**	**1,169,960**

6.2 Assess Source Loading Alternatives

After determining the most significant pollutant sources, the GWLF model was run repeatedly to identify the load reductions necessary to achieve the TMDL target values presented in Section 3.2. Loads from illicitly connected onsite systems were eliminated (WLA equal to zero) and then reductions were made to all other controllable sources. Large reductions were needed from row crops and pasture lands which comprise more than 90 percent of the watershed and contribute significantly to overall loads. The resulting allocations are presented in Section 6.3

6.3 Wasteload Allocations (WLAs)

There is one permitted WWTP in Limberlost Creek watershed – the Bryant Municipal Sewage Treatment Plant. According to its NPDES permit, the plant is allowed to discharge any time flow in Perry Ditch is sufficient to support a 10:1 dilution ratio (e.g., in-stream flow must be 1 cfs to allow a 0.1 cfs discharge). Values of 7 mg/L total phosphorus and 13 mg/L total nitrogen were used to estimate existing loads from this facility during the modeling process based on the typical range of values published in the literature (Thomann and Mueller, 1987; USEPA, 1997). This approach is appropriate based on the most recent and available information at the time the TMDL was developed. The NPDES permit includes effluent limits for ammonia-nitrogen after a 3-year schedule of compliance. The facility should have begun monitoring and reporting for ammonia-nitrogen in December of 2006. The TMDL strategy may be amended as new information is developed in the watershed to better account for contributing sources of the impairment and to determine where load reductions are most appropriate. Additional instream sampling is recommended for total phosphorus and total nitrogen below the WWTP. WLAs were calculated *for information purposes only* for the permitted facility based on the design flow and potential permit limits shown in Table 12. The WLAs are not intended to be included in the facility's next permit because Indiana is continuing to develop its approach for setting nutrient water quality standards (and thus NPDES permit limits).

The WLA for CFOs and CAFOs in the Limberlost Creek TMDL are for zero load from production areas. The zero allocation is based on the Effluent Limitations Guidelines and New Source Performance Standards requiring, in general, zero discharge from these areas. This limit on load is reasonable due to the requirement for the proper design, construction, operation, and maintenance of the structures to contain all manure, litter, and process wastewater including the runoff and direct precipitation from a 25 year, 24-hour rainfall event. Further, the allocation is based on the conditions of the NPDES general permit providing that water quality standards shall not be exceeded in the event of an overflow from production areas.

WLAs from illicitly connected onsite systems (i.e., straight pipe dischargers) are set equal to zero.

WLAs were also calculated within Assessment Unit 050 (even though no WWTP currently exists) to provide a reserve for future growth. An assumption was made that a WWTP similar in size and type to the Bryant Sewage Treatment Plant would be located in the Assessment Unit.

Table 12. WLA for the Bryant Municipal Sewage Treatment Plant (for *informational purposes only* and not intended to be included in next permit).

Month	Design Flow (MGD)	TP WLAs (kg/day)	TP Limit (mg/L)	TN WLAs (kg/day)	TN Limit (mg/L)	TSS WLAs (kg/day)	TSS Limit (mg/L)
Apr	.08	2	7	4	13	23	75
May	.08	2	7	4	13	23	75
Jun	.08	2	7	4	13	23	75
Jul	.08	2	7	4	13	23	75
Aug	.08	2	7	4	13	23	75
Sep	.08	2	7	4	13	23	75
Oct	.08	2	7	4	13	23	75
Nov	.08	2	7	4	13	23	75
Dec	.08	2	7	4	13	23	75
Jan	.08	2	7	4	13	23	75
Feb	.08	2	7	4	13	23	75
Mar	.08	2	7	4	13	23	75

Notes: MGD = million gallons per day. WLAs were specified for every month of the year because the plant is allowed to discharge whenever the receiving stream flow is sufficient to accommodate a 10:1 dilution ratio and this could potentially occur in any month.

6.4 Load Allocations (LAs)

The load allocations for the Limberlost Creek watershed TMDL are summarized in Table 13 to Table 18 (along with the baseline loads and the WLAs). The LAs are presented on a daily basis and were developed to meet TMDL targets under a range of observed conditions as described in Section 6.2.

Relatively large reductions are needed in certain months for the following reasons:

- Large nonpoint source reductions in phosphorus are recommended for the months when manure is assumed to be spread in the watershed (June/July and October through March). It is acknowledged that this is a relatively large source of uncertainty in the current model as good information on the timing of manure applications was not available.
- Large nonpoint source reductions in TSS are recommended for most months due to pervasively high simulated concentrations that exceed the target of 30 mg/L.
- Moderate nonpoint source reductions in nitrogen are recommended for the summer months because of manure application that is assumed in the model for July and August, coupled with low flow conditions in these months that reduce the dilution capacity of the stream.

Table 13. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050050 Total Phosphorus TMDL.

Month	Baseline Point Source Loads (kg/day)[1]	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	0	2	4	19	21	0%	0%
May	0	2	7	15	17	0%	0%
Jun	0	2	54	14	16	0%	0%
Jul	0	2	73	10	12	0%	86%
Aug	0	2	6	3	5	0%	46%
Sep	0	2	4	2	4	0%	0%
Oct	0	2	26	5	7	0%	79%
Nov	0	2	23	9	11	0%	63%
Dec	0	2	44	16	18	0%	63%
Jan	0	2	55	16	18	0%	71%
Feb	0	2	70	18	20	0%	74%
Mar	0	2	56	19	21	0%	66%

[1]Though there are currently no point sources in this assessment unit, the TMDL includes a reserve for future growth to accommodate potential new point sources.

Table 14. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050050 Total Nitrogen TMDL.

Month	Baseline Point Source Loads (kg/day)[1]	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = MOS + WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	0	4	191	708	712	0%	0%
May	0	4	173	578	582	0%	0%
Jun	0	4	431	538	542	0%	0%
Jul	0	4	505	396	400	0%	22%
Aug	0	4	68	163	167	0%	0%
Sep	0	4	48	119	123	0%	0%
Oct	0	4	206	243	247	0%	0%
Nov	0	4	211	346	350	0%	0%
Dec	0	4	390	599	603	0%	0%
Jan	0	4	450	595	599	0%	0%
Feb	0	4	555	664	668	0%	0%
Mar	0	4	485	703	707	0%	0%

[1]Though there are currently no point sources in this assessment unit, the TMDL includes a reserve for future growth to accommodate potential new point sources.

Table 15. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050050 Total Suspended Solids TMDL.

Month	Baseline Point Source Loads (kg/day)[1]	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	0	21	333	2115	2137	0%	0%
May	0	21	1592	1724	1745	0%	0%
Jun	0	21	2333	1606	1627	0%	31%
Jul	0	21	5161	1178	1200	0%	77%
Aug	0	21	2258	480	502	0%	79%
Sep	0	21	1667	348	370	0%	79%
Oct	0	21	1935	720	742	0%	62%
Nov	0	21	1667	1029	1050	0%	37%
Dec	0	21	4194	1789	1810	0%	57%
Jan	0	21	5140	1776	1797	0%	65%
Feb	0	21	6071	1983	2004	0%	67%
Mar	0	21	4839	2099	2120	0%	56%

[1]Though there are currently no point sources in this assessment unit, the TMDL includes a reserve for future growth to accommodate potential new point sources.

Table 16. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050060 Total Phosphorus TMDL.

Month	Baseline Point Source Loads (kg/day)	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	2	2	5	21	23	0%	0%
May	2	2	8	17	19	0%	0%
Jun	2	2	9	16	18	0%	0%
Jul	2	2	78	11	13	0%	86%
Aug	2	2	35	4	6	0%	90%
Sep	2	2	4	2	4	0%	0%
Oct	2	2	28	6	8	0%	78%
Nov	2	2	24	10	12	0%	61%
Dec	2	2	47	18	20	0%	62%
Jan	2	2	58	18	20	0%	69%
Feb	2	2	75	20	22	0%	73%
Mar	2	2	60	21	23	0%	64%

Table 17. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050060 Total Nitrogen TMDL.

Month	Baseline Point Source Loads (kg/day)	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	4	4	209	779	783	0%	0%
May	4	4	188	635	639	0%	0%
Jun	4	4	186	592	596	0%	0%
Jul	4	4	539	434	438	0%	20%
Aug	4	4	240	180	184	0%	25%
Sep	4	4	52	131	135	0%	0%
Oct	4	4	221	268	272	0%	0%
Nov	4	4	227	381	385	0%	0%
Dec	4	4	419	658	662	0%	0%
Jan	4	4	482	654	658	0%	0%
Feb	4	4	595	728	732	0%	0%
Mar	4	4	520	773	777	0%	0%

Table 18. Allocations for the Limberlost Creek Watershed Assessment Unit 05120101050060 Total Suspended Solids TMDL.

Month	Baseline Point Source Loads (kg/day)	WLAs (kg/day)	Baseline Nonpoint Source Loads (kg/day)	LAs (kg/day)	TMDL = WLA + LA (kg/day)	Point Source Percent Reduction	Nonpoint Source Percent Reduction
Apr	23	23	333	2325	2348	0%	0%
May	23	23	1666	1895	1918	0%	0%
Jun	23	23	2333	1765	1788	0%	24%
Jul	23	23	5666	1291	1314	0%	77%
Aug	23	23	2333	528	551	0%	77%
Sep	23	23	1666	383	406	0%	77%
Oct	23	23	2333	792	815	0%	66%
Nov	23	23	1666	1131	1154	0%	32%
Dec	23	23	4333	1962	1985	0%	55%
Jan	23	23	5666	1952	1975	0%	66%
Feb	23	23	6000	2174	2197	0%	64%
Mar	23	23	5000	2307	2330	0%	54%

6.5 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991).

A 15 percent explicit MOS was incorporated for the TMDLs by basing the allocation decisions on achieving the numeric criteria minus 15 percent (e.g., the allocation decisions were based on not exceeding 8.5 mg/L, 0.255 mg/L, and 25.5 mg/L rather than 10 mg/L, 0.30 mg/L, and 30 mg/L for TN, TP, and TSS respectively). A relatively large MOS was chosen based on the lack of water quality data with which to obtain a better calibrated model (i.e., the model is believed to be reducing less uncertainty than it would if more data were available for calibration).

6.6 Seasonal Variation

A TMDL must consider seasonal variation in the derivation of the allocation. By using continuous simulation (modeling over a period of several years), seasonal variations in hydrologic conditions and source loadings were inherently taken into account. The total phosphorus, total nitrogen, and TSS concentrations simulated on a monthly time step by the model were compared to TMDL targets and an allocation that would meet these targets throughout the year was developed.

7.0 PUBLIC PARTICIPATION

Public participation is an important and required component of the TMDL development process. The following public meetings have been held in the watershed to discuss this project:

- A **Kickoff Meeting** was held at the Anderson Public Library on March 20, 2006 during which IDEM and Tetra Tech described the TMDL Program and provided a summary of the available data and the proposed modeling approach.
- A **Draft TMDL Meeting** was held at the Anderson Public Library on March 15, 2007 during which IDEM and Tetra Tech described the results and recommendations contained within the draft TMDL report.

IDEM also accepted written comments on the draft report between March 13, 2007 and April 13, 2007 and received two written comments (Appendix C). IDEM appreciates receiving these comments and the concern that is expressed for the welfare of our waterways. The Friends of the Limberlost as well as Jay County Soil and Water District are two groups that are very interested in improving the water quality and physical appearance of the Limberlost River watershed. They are both valuable resources available to anyone who wishes to help improve water quality in the watershed.

8.0 IMPLEMENTATION AND REASONABLE ASSURANCE

Nonpoint source pollution, which is the primary cause of impairments in this watershed, can be reduced by the implementation of Best Management Practices (BMPs). BMPs are practices used in agriculture, forestry, urban land development, and industry to reduce the potential for damage to natural resources from human activities. A BMP may be structural, that is, something that is built or involves changes in landforms or equipment, or it may be managerial, that is, changing a specific way of using or handling infrastructure or resources. BMPs should be selected based on the goals of a watershed management plan. Livestock owners, farmers, and urban planners can implement BMPs outside of a watershed management plan, but the success of BMPs is typically enhanced if coordinated as part of a watershed management plan. Following are examples of BMPs that may be used to reduce nutrient and sediment loads:

- Riparian Area Management - Management of riparian areas protects stream banks and river banks with a buffer zone of vegetation, either grasses, legumes, or trees.
- Manure Collection and Storage - Collecting, storing, and handling manure in such a way that nutrients or bacteria do not run off into surface waters or leach down into ground water.
- Contour Row Crops - Farming with row patterns and field operations aligned at or nearly perpendicular to the slope of the land.
- Manure Nutrient Testing - If manure application is desired, sampling and chemical analysis of manure should be performed to determine nutrient content for establishing the proper manure application rate in order to avoid overapplication and run-off.
- Drift Fences - Drift fences (short fences or barriers) can be installed to direct livestock movement. A drift fence parallel to a stream keep animals out and prevents direct input of *E. coli* to the stream.
- Pet Clean-up / Education - Education programs for pet owners can improve water quality of runoff from urban areas.
- Septic Management/Public Education - Programs for management of septic systems can provide a systematic approach to reducing septic system pollution. Education on proper maintenance of septic systems as well as the need to remove illicit discharges could alleviate some anthropogenic sources of pathogens.

8.1 Reasonable Assurance Activities

Reasonable assurance activities are programs that are in place or will be in place to assist in meeting the Limberlost Creek Watershed TMDL allocations and the Nutrient and TSS Water Quality Standards (WQS). Following is a list of reasonable assurance activities that pertain to the Limberlost Creek Watershed.

National Pollutant Discharge Elimination System (NPDES) Permitted Dischargers
During the next permitting cycle IDEM will assure that the Bryant Sewage Treatment Plant (permit number IN0055158) is complying with Water Quality Standards.

Confined Feeding Operations (CFOs) and Confined Animal Feeding Operations (CAFOs)
CFOs and CAFOs are required to manage manure, litter, and process wastewater pollutants in a manner that does not cause or contribute to the impairment of *E. coli* WQS. IDEM inspects these facilities on a regular basis for compliance.

Watershed Projects
The Friends of the Limberlost have purchased and are in the process of restoring 1399 acres of wetlands and wetland associated uplands. Currently (June 2007) an adult Bald Eagle has been seen fishing in the Loblolly Marsh and a pair of Sandhill Cranes have been regularly seen. These restored wetland acres

have reduced the chemical residue and nutrients in the open streams in the Limberlost and Loblolly watershed by taking the land out or agriculture. The Friends of the Limberlost plan to continue seeking funds to purchase additions to the wetland areas and will also seek funds to improve the water quality of the Limberlost and Loblolly watershed and Wabash River, with a goal of securing 2000 acres of contiguous restored wetlands.

Potential Future Activities

Nonpoint source pollution can be reduced by the implementation of BMPs. BMPs are practices used in agriculture, forestry, urban land development, and industry to reduce the potential for damage to natural resources from human activities. A BMP may be structural, that is, something that is built or involves changes in landforms or equipment, or it may be managerial, that is, a specific way of using or handling infrastructure or resources. BMPs should be selected based on the goals of a watershed management plan. Livestock owners, farmers, and urban planners, can implement BMPs outside of a watershed management plan, but the success of BMPs would be enhanced if coordinated as part of a watershed management plan. Section 8.0 lists potential BMPs for the Limberlost Creek watershed.

Watershed Groups

The Friends of the Limberlost as well as Jay County Soil and Water District are two groups that are very interested in improving the water quality and physical appearance of the Limberlost.

The Friends of the Limberlost is an organization created to benefit the Limberlost cabin, the wetlands and forests, and the families and community of Geneva, Indiana. They have many worthwhile projects which require volunteers on a regular basis. If interested in helping out this organization and the Limberlost Creek watershed contact one of the officers at 260-368-7428 or write to P.O. Box 571, Geneva, Indiana 46740.

Indiana's soil and water conservation districts develop and implement conservation programs based on a set of resource priorities, and channel resources from all levels of government into action at the local level. The Jay County Soil and Water Conservation District can be contacted at 260-726-4373 extension 3 or at 1331 W. Highway 27 Portland, IN 47371. (http://www.in.gov/isda/soil/swcd/index.html)

9.0 MONITORING

Future monitoring of the Limberlost Creek watershed will take place during IDEM's five-year rotating basin schedule and/or once TMDL implementation methods are in place. Monitoring will be adjusted as needed to assist in continued source identification and elimination. IDEM will monitor at an appropriate frequency to determine if Indiana's water quality standards are being met. When these results indicate that the waterbody is meeting the water quality standards, the waterbody will then be removed from the 303(d) list.

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Appendix A: Development of Watershed Loading Model

Loading of water, sediment, and nutrients in the Limberlost Creek watershed was simulated using the Generalized Watershed Loading Function or GWLF model (Haith et al., 1992). The complexity of the loading function model falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent temporal variability. GWLF provides a mechanistic, but simplified simulation of precipitation-driven runoff and sediment delivery, yet is intended to be applicable without calibration. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water.

GWLF simulates runoff and streamflow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (NRCS) Curve Number method (SCS, 1986). The Curve Number determines the amount of precipitation that runs off directly, adjusted for antecedent soil moisture based on total precipitation in the preceding 5 days. A separate Curve Number is specified for each land use by hydrologic soil grouping. Infiltrated water is first assigned to unsaturated zone storage where it may be lost through evapotranspiration. When storage in the unsaturated zone exceeds soil water capacity, the excess percolates to the shallow saturated zone. This zone is treated as a linear reservoir that discharges to the stream or loses moisture to deep seepage, at a rate described by the product of the zone's moisture storage and a constant rate coefficient.

Flow in streams may derive from surface runoff during precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land uses are those with predominantly impervious surfaces. It is often appropriate to divide certain land uses into pervious ("rural") and impervious ("urban") fractions for simulation. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987). Thus, erosion can occur when there is precipitation, but no surface runoff to the stream; delivery of sediment, however, depends on surface runoff volume. Sediment available for delivery is accumulated over a year, although excess sediment supply is not assumed to carry over from one year to the next. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids.

GWLF Model Inputs

GWLF application requires information on land use, land cover, soil, and parameters that govern runoff, erosion, and nutrient load generation.

The U. S. Geological Survey (USGS) does not operate any active stream flow gaging stations in the Limberlost Creek watershed. Therefore the Little River watershed was used as a surrogate watershed for estimating flow characteristics in the Limberlost River watershed. The GWLF model was calibrated to observed data for the Little River and then the same model parameters were applied to the Limberlost Creek watershed. The GWLF modeling inputs for the Little River watershed are summarized in the following sections.

Land Use/Land Cover

Digital land use/land cover (LULC) data for the Little River watershed were obtained from the National Land Cover Dataset (NLCD). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper (TM) satellite imagery data. The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. The imagery was acquired by the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of federal agencies that produce or use land cover data. The imagery was acquired in 1992. Table 1 summarizes the acreage in each land use category in the Little River watershed.

Table 1. Land Use and Land Cover in Little River Watershed, 1992.

Land Use Code	Land Use	Acres	% of Total
11	Open Water	438	0.3
21	Low Intensity Residential	3,512	2.4
22	High Intensity Residential	223	0.2
23	Commercial/Industrial/Transportation	1,738	1.2
32	Quarries/Strip Mines/Gravel Pits	443	0.3
33	Transitional	172	0.1
41	Deciduous Forest	11,891	8.0
42	Evergreen Forest	69	0.1
43	Mixed Forest	10	0.0
81	Pasture/Hay	18,958	12.8
82	Row Crops	107,947	72.7
85	Urban/Recreational Grasses	1,010	0.7
91	Woody Wetlands	2,068	1.4
92	Herbaceous Wetlands	124	0.1
	Total	148,602	100

Soils data for the Little River watershed were obtained from the NRCS State Soil and Geographic (STATSGO) database (http://www.ftw.nrcs.usda.gov/stat_data.html). Attribute data associated with soil map units were used to assign soil hydrologic groups and to estimate values for some of the USLE parameters, as described in sections below.

The Little River watershed, land uses, and the soils coverages were overlain in a Geographic Information System (GIS) environment. For the purposes of the GWLF modeling of runoff and erosion, the land use categories were grouped as summarized in Table 2. Runoff and erosion potential are expected to be affected both by land use and by the soil hydrologic group, so each land use group was divided into sub-categories based on the hydrologic group (A, B, C or D) of the underlying soil type. Finally, the high density residential land uses, which include both pervious and impervious areas, were further subdivided into pervious and impervious areas based on an assumed percent imperviousness of 80 percent.

Table 2. Land Use Groupings for GWLF Modeling

MRLC Land Use	Group Code	Pollutant Simulation
Open Water	Water	Rural
Low Intensity Residential	LI Residential	Urban
High Intensity Residential	HI Residential	Urban
Commercial/Industrial/Transportation	Commercial	Urban
Quarries/Strip Mines/Gravel Pits	Quarries/SM	Urban
Transitional	Transitional	Urban
Deciduous Forest	Deciduous Forest	Rural
Evergreen Forest	Coniferous Forest	Rural
Mixed Forest	Mixed Forest	Rural
Pasture/Hay	Pasture/Hay	Rural
Row Crops	Row Crops	Rural
Urban/Recreational Grasses	Recreational Grasses	Urban
Woody Wetlands	Woody Wetlands	Rural
Herbaceous Wetlands	Herbaceous Wetlands	Rural

Rainfall and Runoff Input Data and Parameters

<u>Meteorology:</u>
Hydrology in GWLF is simulated by a water-balance calculation, based on daily observations of precipitation and temperature. A search was made of available Midwestern Regional Climate Center reporting stations. Based on this review, the most appropriate available meteorological data were determined to be from the station at Fort Wayne (Station ID: 3037), located at 41.02° N, 85.21° W, in Allen County. This station supplies daily data on precipitation and minimum and maximum temperature. Daily mean temperature was estimated as the mean of the minimum and maximum values.

<u>Runoff Curve Numbers:</u>
The direct runoff fraction of precipitation in GWLF is calculated using the curve number method from the SCS TR55 method literature based on land-use and soil hydrologic group (SCS 1986). Curve numbers vary from 25 for undisturbed woodland with good soils, to, in theory, 100, for impervious surfaces. The hydrologic soil group was determined from available soils data and curve numbers were calculated for each land use category/soil hydrologic group. Curve numbers assigned for the Little River watershed are summarized in Table 3. For each land use, the table also indicates whether GWLF simulates nutrient loading via the USLE equation ("rural" areas) or a buildup-washoff formulation ("urban" areas).

Table 3. Runoff Curve Numbers for the Little River Watershed.

GWLF Land Use Group	GWLF Loading Methodology	SCS Curve Number
Water	USLE Equation	100
LI Residential	Build-up Washoff Formulation	81
HI Residential	Build-up Washoff Formulation	90
Commercial	Build-up Washoff Formulation	94
Quarries/SM	Build-up Washoff Formulation	86
Transitional	Build-up Washoff Formulation	72
Deciduous Forest	USLE Equation	69
Coniferous Forest	USLE Equation	64
Mixed Forest	USLE Equation	67
Pasture/Hay	USLE Equation	84
Row Crops	USLE Equation	86
Recreational Grasses	Build-up Washoff Formulation	74
Woody Wetlands	USLE Equation	97
Herbaceous Wetlands	USLE Equation	95

Evapotranspiration Cover Coefficients:

The portion of rainfall returned to the atmosphere is determined by GWLF based on temperature and the amount of vegetative cover. For all land uses the cover coefficent was determined based on season. Evapotranspiration values assigned to each month are displayed in Table 4. These cover coefficients were chosen based on several calibration runs of the model.

Table 4. Evapotranspiration Cover Coefficients for the Little River Watershed.

Month	ET Cover Coef.
April	0.80
May	0.84
June	0.90
July	0.90
August	0.90
September	0.80
October	0.75
November	0.70
December	0.45
January	0.45
February	0.45
March	0.55

Soil Water Capacity:

Water stored in soil may evaporate, be transpired by plants, or percolate to ground water below the rooting zone. The amount of water that can be stored in soil (the soil water capacity) varies by soil type and rooting depth. Based on soil water capacities reported in the STATSGO database, soil types present in the watershed, and GWLF user's manual recommendations, a GWLF soil water capacity of 10 cm was used.

Recession and Seepage Coefficients:

The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a ground water recession and a deep seepage coefficient. The recession coefficient was set to 0.05 per day and the deep seepage coefficient to 0.015, based on several calibration runs of the model.

Erosion Parameters

GWLF simulates rural soil erosion using the Universal Soil Loss Equation (USLE). [Note: For land uses indicated as "Buildup-Washoff" in Table 4, solids loads are generated separately, as described below in the section entitled Parameters Governing Nutrient Load Generation.] This method has been applied extensively, so parameter values are well established. This computes soil loss per unit area (sheet and rill erosion) at the field scale by

$$A = R * K * LS * C * P$$

where,
A = rate of soil loss per unit area,
R = rainfall erosivity index,
K = soil erodibility factor,
LS = length-slope factor,
C = cover and management factor, and
P = support practice factor.

Soil loss or erosion at the field scale is not equivalent to sediment yield, as substantial trapping may occur, particularly during overland flow or in first-order tributaries or impoundments.

GWLF accounts for sediment yield by (1) computing transport capacity of overland flow, and (2) employing a sediment delivery ratio (DR) which accounts for losses to sediment redeposition.

Rainfall Erosivity (RE):

Rainfall erosivity accounts for the impact of rainfall on the ground surface, which can make soil more susceptible to erosion and subsequent transport. Precipitation-induced erosion varies with rainfall intensity, which shows different average characteristics according to geographic region. The factor is used in the Universal Soil Loss Equation and is determined in the model as follows:

$$RE_t = 64.6 * a_t * R_{t_t} 1.81$$

where

RE_{t_t} = Rainfall erosivity (in megajoules mm/ha-h),

a_{t_t} = Location- and season-specific factor, and

R_t = Rainfall on day t (in cm).

The erosivity coefficient (a_t) was assigned a value of 0.3 for the growing season and 0.12 for the dormant season, based on erosivity coefficients provided in the GWLF User's Manual.

Soil Erodibility (K) Factor:

The soil erodibility factor indicates the inherent erodibility of a given soil type, and is a function of soil physical properties and slope. Soil erodibility factors were extracted from the STATSGO soil coverage. For each land use category, the K factors of the soil types underlying all land of this category were area-averaged to result in an overall K factor for the land use category.

Length-Slope (LS) Factor:

Erosion potential varies by slope as well as soil type. The LS factor is calculated following Wischmeier and Smith (1978):

$$LS = (0.138 * x_k)b * (65.41 * \sin^2\Phi_k + 4.56 * \sin\Phi_k + 0.065)$$

where

Φ_k = tan - 1(ps_k/100), where ps_k is percent slope

x_k = slope length (ft)

b = a factor of percent slope, as follows:

Percent Slope	b
0-1	0.2
1 - 3.5	0.3
3.5 - 5	0.4
5 +	0.5

Slopes were extracted from the STATSGO soils database. For each soil type, slope was assumed to be the mid-point of the minimum and maximum slope given by STATSGO. As with the K factor, slope for each land use was calculated as an area-weighted average of the slopes of underlying soil types. The slope length was calculated using the following equation:

$$L= [\lambda/72.6]^m$$

where λ is the slope length in feet (98 ft), 72.6 feet is the length of a standard erosion plot, and m is a variable slope length exponent. It is important to note that slope length, λ, is the horizontal projection of the plot length, not the length measured along the slope. A list of slope length exponents is given in Table 5. LS values used in Littler River are shown in Table 6.

Table 5. Slope Length Exponent values, m. (McCool, et al., 1993)

Percent Slope	Rill/interill ratio		
	Low	Medium	High
0.20	0.02	0.04	0.07
0.50	0.04	0.08	0.16
1.00	0.08	0.15	0.26
2.00	0.14	0.24	0.39
3.00	0.18	0.31	0.47
4.00	0.22	0.36	0.53
5.00	0.25	0.40	0.57
6.00	0.28	0.43	0.60
8.00	0.32	0.48	0.65
10.00	0.35	0.52	0.68
12.00	0.37	0.55	0.71
14.00	0.40	0.57	0.72
16.00	0.41	0.59	0.74
20.00	0.44	0.61	0.76
25.00	0.47	0.64	0.78
30.00	0.49	0.66	0.79
40.00	0.52	0.68	0.81
50.00	0.54	0.70	0.82
60.00	0.55	0.71	0.83

Table 6. LS values for Little River Watershed Land Uses

GWLF Land Use Group	LS
Water	0.0000
Low Intensity Res	0.1813
High Intensity Res	0.1783
Commercial/Industrial/Transportation	0.1227
Deciduous Forest	0.2489
Coniferous Forest	0.3397
Mixed Forest	0.4191
Pasture/Hay	0.1882
Row Crops	0.0930
Grasses	0.2132
Woody Wetlands	0.1371
Herbaceous Wetlands	0.0978
Transitional	0.1103
Quarries/SM	0.2314

Cover and Management (C) and Practice (P) Factors:

The mechanism by which soil is eroded from a land area and the amount of soil eroded depends on soil treatment resulting from a combination of land uses (e.g., forestry versus row-cropped agriculture) and the specific manner in which land uses are carried out (e.g., no-till agriculture versus non-contoured row cropping). Land use and management variations are represented by cover and management factors in the universal soil loss equation and in the erosion model of GWLF. Cover and management factors were drawn from several sources (Wischmeier and Smith, 1978; Haith et al., 1992; Novotny and Olem, 1994), and are summarized in Table 7. Practice (P) factors were generally set to 1, consistent with recommendations for non-agricultural land. A factor of 0.6 was applied to pasture/hay and row crops to account for conservation tillage practices that are used within the watershed.

Table 7. Cover and Management Factors for Little River Watershed Land Uses*

GWLF Land Use Group	C	P
Water	0.000	1
Low Intensity Res	0.001	1
High Intensity Res	0.001	1
Commercial/Industrial/Transportation	0.001	1
Deciduous Forest	0.002	1
Coniferous Forest	0.002	1
Mixed Forest	0.002	1
Pasture/Hay	0.010	0.6
Row Crops	0.300	0.6
Grasses	0.003	1
Woody Wetlands	0.000	1
Herbaceous Wetlands	0.000	1
Transitional	0.700	1
Quarries/SM	1.000	1

* C and P factors are not required for the "urban" land uses which are modeled in GWLF via a buildup-washoff formulation rather than USLE.

Sediment Delivery Ratio:

The sediment delivery ratio (DR) converts erosion to sediment yield, and indicates the portion of eroded soil that is carried to the watershed mouth from land draining to the watershed. The BasinSim program (a Windows version of GWLF) includes a built-in utility which calculates the sediment delivery ratio based an empirical relationship of DR to watershed area (SCS, 1973). The sediment delivery ratio for the entire Little River watershed was calculated at 0.0732. During calibration this value was adjusted to 0.2 to better simulate observed data. This higher value possibly accounts for sediment loads associated with streambank erosion that are apparent in the observed data but not accounted for in the GWLF estimates of sheet and rill erosion.

Parameters Governing Nutrient Load Generation

Groundwater Nutrient Concentrations:

The GWLF model requires input of groundwater nutrient concentrations excluding loads due to septic systems, which are accounted for separately. Even in the absence of septic system loads, groundwater concentrations are expected to increase with a shift from forest to either agriculture or development, due to the input of fertilizer on crops, lawns, and gardens. The effect is greatest for nitrate, which is highly soluble, but some elevation of groundwater concentrations of phosphorus is also expected with increased development.

Groundwater nutrient concentrations were estimated using recommendations from the GWLF Manual. The resulting groundwater concentrations for the watershed were 0.013 mg/L phosphorus and 2.00 mg/L nitrogen.

Dissolved and Solid Phase Nutrient Concentrations for Rural Land Uses:
GWLF requires a dissolved phase concentration for surface runoff from rural land uses. Particulate concentrations are taken as a general characteristic of area soils, determined by bulk soil concentration and an enrichment ratio indicating preferential association of nutrients with the more erodible soil fraction, and not varied by land use. The estimates of dissolved phase and solid phase nutrient concentrations were selected from the GWLF User's Manual and are shown in Table 8.

Table 8. Dissolved and Solids Phase Nutrient Concentrations for Rural Land Uses.

GWLF Land Use Group	Nitrogen		Phosphorus	
	Dissolved Phase (mg/L)	Solids Phase (mg/kg)	Dissolved Phase (mg/L)	Solids Phase (mg/kg)
Deciduous Forest	0.37	4180	0.007	600
Coniferous Forest	0.21	4180	0.004	600
Mixed Forest	0.28	4180	0.006	600
Pasture/Hay	3.1	4180	0.25	600
Row Crops	3.2	4180	0.26	600
Woody Wetlands	3.2	4180	0.26	600
Herbaceous Wetlands	2.0	4180	0.93	600
Water	3.1	4180	0.15	600

Buildup/Washoff Parameters for Urban Land Uses:
Nutrients and solids generated from urban land uses are described by a buildup/washoff formulation. Pollutant accumulation is summarized by an exponential buildup rate, and GWLF assumes that 95 percent of the limiting pollutant storage is reached in a 20-day period without washoff. The resulting buildup parameters are summarized in Table 9.

Table 9. Pollutant Buildup Rates for Urban Land Uses.

Land use	Nitrogen build up (kg/ha-d)	Phosphorus build up (kg/ha-d)
Recreational Grasses	0.07	0.008
LI Residential	0.013	0.0016
HI Residential	0.05	0.0045
Commercial	0.055	0.0015
Quarries/SM	0.055	0.0005
Transitional	0.05	0.0045

Septic Systems:
GWLF contains routines for the simulation of nutrient loading from both normal and failing septic systems. The number of septic systems in the Little River Watershed was estimated based on census data. Several assumptions had to be made to categorize the systems according to their performance. These assumptions were based on the data provided by the public health

departments, where available, and best professional judgment otherwise. Table 10 summarizes the results of these assumptions.

Table 10. Estimated Number of People Served by Septic Systems in Little River Watershed.

Estimated Number of People Served by Septic Systems	Estimated Number of People Served by Category			
	Normal	Ponded	Short-circuited	Direct Discharge
9,748	4,874	2,437	1,462	975

Normal: Septic systems conform to EPA standards and operating effectively.
Ponded: System failure results in surfacing of effluent.
Short-circuited: Systems are close enough to surface water (< 15 meters) that negligible absorption of phosphorus takes place.
Direct Discharge: Illegal systems discharge effluent directly into surface waters.

Parameters affecting nutrient loading from septic systems were specified at GWLF default values. Effluent phosphorus from failing septic systems was set to 2.5 g/day (default for areas with phosphate detergents), while effluent nitrogen was set to 12.0 g/day. Plant uptake rates were assumed to be 1.6 g/day nitrogen and 0.4 g/day phosphorus.

Point Sources:
Nutrient loads from point sources are calculated outside of the GWLF model and then added to the model as direct loads. Monthly loads from the active facilities in the watershed were estimated based on the average nutrient discharge concentrations and flows provided by the EPA. Effluent nutrient concentrations were not available so average values from similar plants were used instead.

Manure Application:
GWLF provides an option for manure nutrient contributions to be modeled. The number of rural land uses using applied manure/fertilizer is input as well as start and end months. Default snowmelt runoff concentrations from manured land were applied to the model (Gilbertson et al., 1979) then calibrated to Little River. Table 11 shows the assumed nutrient concentrations that were applied from November to April.

Table 11. Snowmelt Runoff from manured land.

Land Use	Nitrogen mg/l	Phosphorus mg/l
Row Crops	8	0.65
Pasture/Hay	20	1.25

Calibration Results

The results of calibrating the GWLF model for the Little River watershed are summarized in the following table and figures. The results indicate that the simulated flow modeling period agrees well with observed stream flow data. The greatest errors occur in simulated winter volumes. In general, the hydrologic calibration appears adequate in that it reflects the total water yield, annual variability, and magnitude of individual storm events in the basin.

The results of the water quality calibration results are presented in Figures 3, 4, and 5 below and indicate good agreement between simulated and observed sediment, nitrogen, and phosphorus loads. The loads for some months are significantly under-or over-predicted but most are within the 95 percent confidence interval range.

Table 12. Little River Watershed Calibration Results for the Simulation Period April 1996 to March 2004. Units shown are cm/yr.

Total Simulated In-stream Flow:	38.92	Total Observed In-stream Flow:	43.31
Total of highest 10% flows:	10.79	Total of Observed highest 10% flows:	12.51
Total of lowest 50% flows:	7.62	Total of Observed lowest 50% flows:	6.85
Simulated Summer Flow Volume:	6.41	Observed Summer Flow Volume:	6.99
Simulated Fall Flow Volume:	7.09	Observed Fall Flow Volume:	7.59
Simulated Winter Flow Volume:	12.16	Observed Winter Flow Volume:	14.25
Simulated Spring Flow Volume:	13.27	Observed Spring Flow Volume:	14.47
Errors (Simulated-Observed)	%	*Recommended Criteria*[1]	
Error in total volume:	-10.12%	10	
Error in 50% lowest flows:	11.24%	10	
Error in 10% highest flows:	-13.81%	15	
Seasonal volume error - Summer:	-8.37%	30	
Seasonal volume error - Fall:	-6.63%	30	
Seasonal volume error - Winter:	-14.65%	30	
Seasonal volume error - Spring:	-8.34%	30	

[1]Recommended criteria are form Lumb et al., 1994

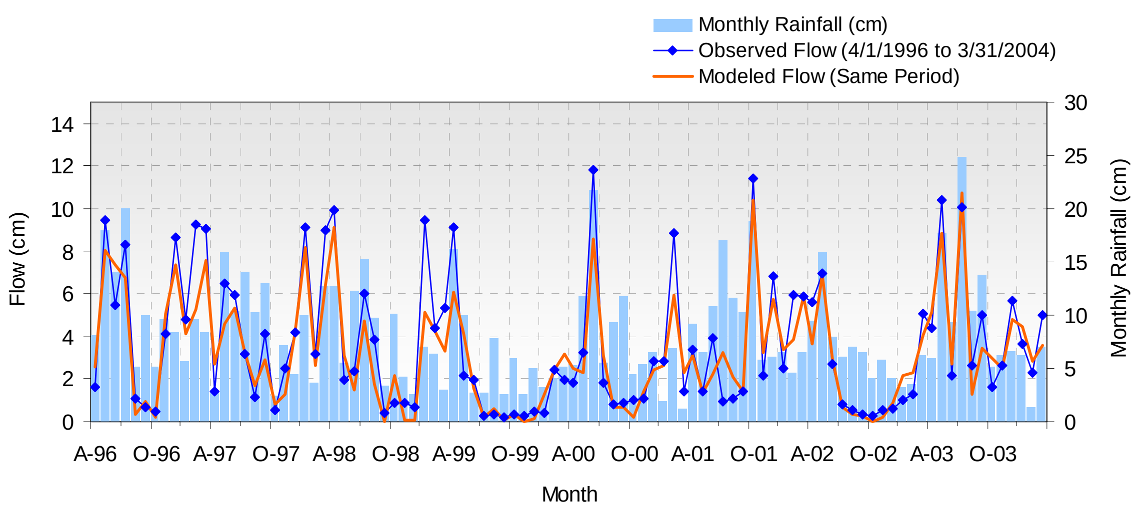

Figure 1. Little River observed versus simulated monthly streamflows (April 1, 1996 to March 31, 2004). R^2 = 0.86.

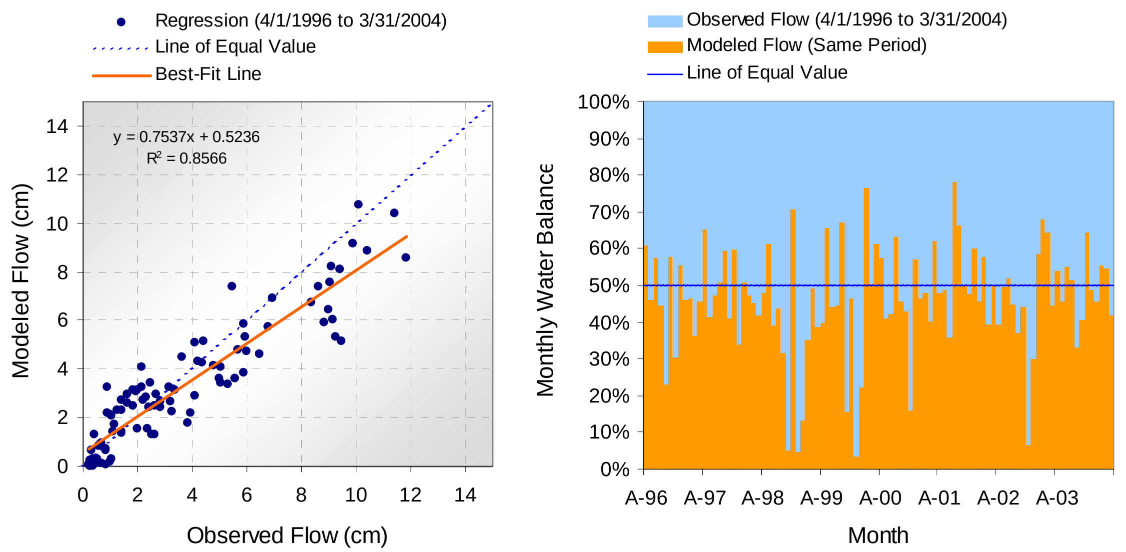

Figure 2. Time series hydrologic calibration results for Little River (April 1, 1996 to March 31, 2004).

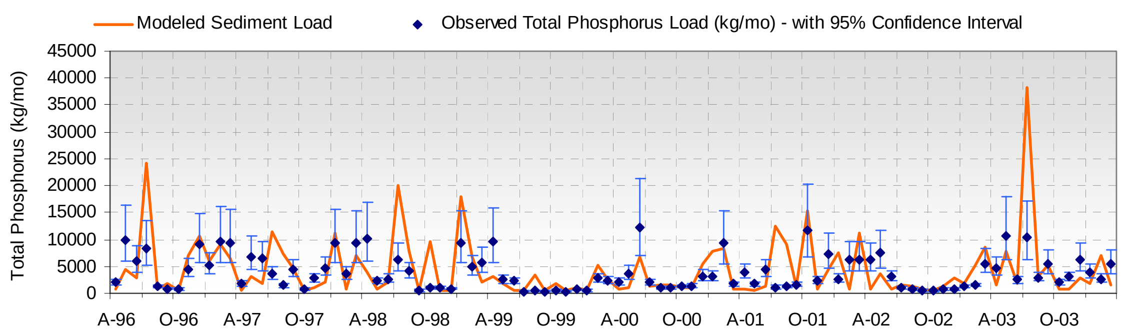

Figure 3. Comparison of predicted and observed total phosphorus data for Little River at station 03324000. R^2 = 0.29.

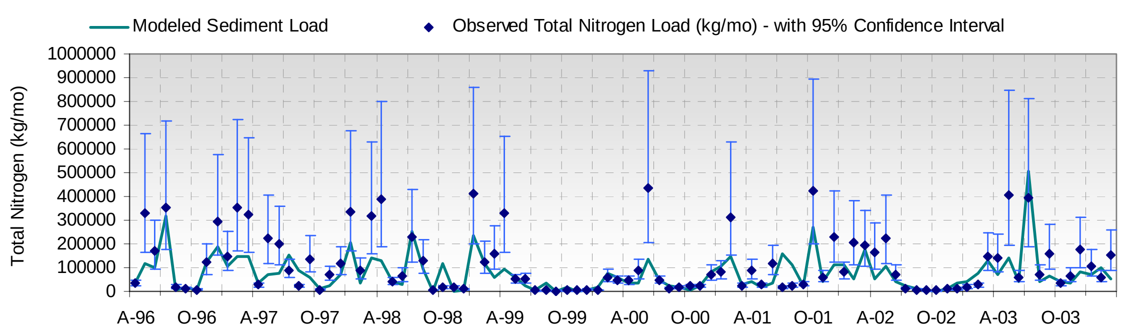

Figure 4. Comparison of predicted and observed total nitrogen data for Little River at station 03324000. R^2 = 0.56.

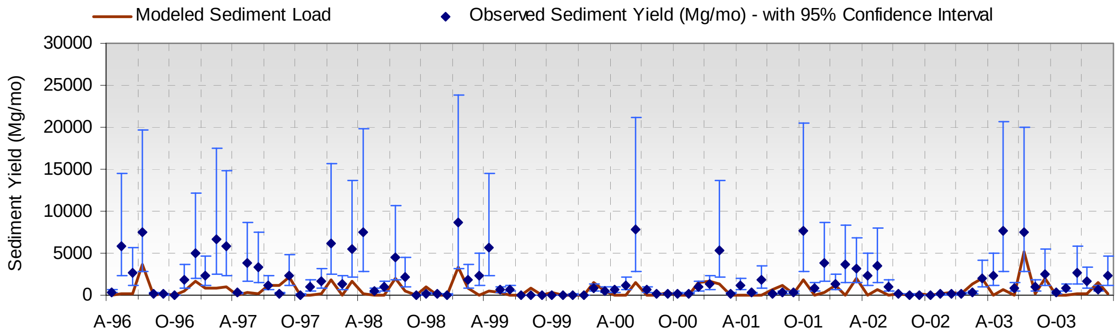

Figure 5. Comparison of predicted and observed total solids data for Little River at station 03324000. R^2 = 0.35.

Limberlost Creek GWLF Model Inputs

Loading of water, sediment, and nutrients in the Limberlost Creek watershed was simulated using GWLF based on calibration parameters developed for the Little River. The following sections highlight parameters that were specific to Limberlost Creek. The Limberlost Creek watershed was divided into two subwatersheds corresponding to the assessment units appearing on the 303(d) list as having impairments.

Land Use/Land Cover

Digital land use/land cover (LULC) data for Limberlost Creek assessment units were obtained from the National Land Cover Dataset (NLCD) (the same data source used for the Little River modeling). Tables 13 and 14 summarize the acreage in each land use category in the Limberlost Creek assessment units.

Table 13. Land Use and Land Cover in Limberlost Creek Assessment Unit 0120101050050, 1992.

Land Use Code	Land Use	Acres	% of Total
11	Water	3	0.02
21	Low Intensity Residential	0.15	0.00
22	High Intensity Residential	0.00	0.00
23	Commercial/Industrial/Transportation	0.16	0.00
32	Quarries/Strip Mines/Gravel Pits	0.00	0.00
33	Transitional	0.00	0.00
41	Deciduous Forest	601	4.58
42	Evergreen Forest	0.00	0.00
43	Mixed Forest	0.16	0.00
81	Pasture/Hay	1,136	8.67
82	Row Crops	11,288	86.14
85	Other Grasses	0.00	0.00
91	Woody Wetlands	76	0.58
92	Emergent Herbaceous Wetlands	0.16	0.00
	Total	13,105	100.00

Table 14. Land Use and Land Cover in Limberlost Creek Assessment Unit 0120101050060, 1992.

Land Use Code	Land Use	Acres	% of Total
11	Water	15	0.10
21	Low Intensity Residential	118	0.82
22	High Intensity Residential	9	0.07
23	Commercial/Industrial/Transportation	52	0.36
32	Quarries/Strip Mines/Gravel Pits	0.00	0.00
33	Transitional	0.00	0.00
41	Deciduous Forest	972	6.75
42	Evergreen Forest	5	0.03
43	Mixed Forest	0.47	0.00
81	Pasture/Hay	1,268	8.81
82	Row Crops	11,839	82.19
85	Other Grasses	6	0.04
91	Woody Wetlands	100	0.69
92	Emergent Herbaceous Wetlands	20	0.14
	Total	14,405	100.00

Erosion Parameters

Length-Slope (LS) Factor:

Erosion potential varies by slope as well as soil type. Slopes were extracted from the STATSGO soils database. For each soil type, slope was assumed to be the mid-point of the minimum and maximum slope given by STATSGO. Table 15 lists the LS values calculated for Limberlost Creek Assessment Units.

Table 15. LS values for Limberlost Creek Watershed Land Uses

GWLF Land Use Group	LS
Water	0.0000
Low Intensity Res	0.0816
High Intensity Res	0.0474
Commercial/Industrial/Transportation	0.0836
Deciduous Forest	0.0949
Coniferous Forest	0.1471
Mixed Forest	0.3346
Pasture/Hay	0.0849
Row Crops	0.0721
Grasses	0.0478
Woody Wetlands	0.0987
Herbaceous Wetlands	0.1098

Sediment Delivery Ratio:

The sediment delivery ratio (DR) converts erosion to sediment yield, and indicates the portion of eroded soil that is carried to the watershed mouth from land draining to the watershed. The BasinSim program (a Windows version of GWLF) includes a built-in utility which calculates the sediment delivery ratio based an empirical relationship of DR to watershed area (SCS, 1973). The sediment delivery ratio for Assessment Unit 0120101050050 was calculated at 0.1509. The sediment delivery ratio for Assessment Unit 0120101050060 was calculated at 0.1473

Parameters Governing Nutrient Load Generation

Septic Systems:

GWLF contains routines for the simulation of nutrient loading from both normal and failing septic systems. The number of septic systems in the Limberlost Creek Watershed was estimated based on 1990 census data. Several assumptions had to be made to categorize the systems according to their performance. These assumptions were based on the data provided by the public health departments, where available, and best professional judgment otherwise. Tables 16 and 17 summarize the results of these assumptions.

Table 16. Estimated Number of People Served by Septic Systems in Limberlost Creek Assessment Unit 0120101050050.

Estimated Number of People Served by Septic Systems	Estimated Number of People Served by Category			
	Normal	Ponded	Short-circuited	Direct Discharge
450	292	0	113	45

Table 17. Estimated Number of People Served by Septic Systems in Limberlost Creek Assessment Unit 0120101050060.

Estimated Number of People Served by Septic Systems	Estimated Number of People Served by Category			
	Normal	Ponded	Short-circuited	Direct Discharge
496	322	0	124	50

Normal: Septic systems conform to EPA standards and operating effectively.
Ponded: System failure results in surfacing of effluent.
Short-circuited: Systems are close enough to surface water (< 15 meters) that negligible absorption of phosphorus takes place.
Direct Discharge: Illegal systems discharge effluent directly into surface waters.

Point Sources:

One point source was included in the modeling of assessment unit 060, the Bryant Municipal Sewage Treatment Plant. There were no point sources in assessment unit 050.

Manure Application:

GWLF provides an option for manure nutrient contributions to be modeled. The number of rural land uses using applied manure/fertilizer is input as well as start and end months. Default snowmelt runoff concentrations from manured land were applied to the model (Gilbertson et al., 1979) then calibrated to Little River. The Little River values were then slightly increased because the number of animals per acre in the Littler River watershed is less than the number of animals per acre in the Limberlost Creek watershed. Table 18 shows the assumed nutrient concentrations that were applied in July and August and October through March.

Table 18. Snowmelt Runoff from Manured Land.

Land Use	Assessment Unit	Nitrogen mg/l	Phosphorus mg/l
Row Crops	050	12.2	1.9
Pasture/Hay		36	5.2
Row Crops	060	12.2	1.9
Pasture/Hay		36	5.2

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Appendix B: Limberlost Water Quality Data

Table 1. Limberlost Nutrient and TSS Data.

HUC to 14	Stream Name	LSITE	Sample Date	Nitrogen, Nitrate+Nitrite (mg/L)	Phosphorus, Total (mg/L)	TSS (mg/L)
050	East Prong	55	6/16/2003	26	0.08	8
050	East Prong	55	8/26/2003	0.6	0.31	19
050	East Prong	65	6/11/2003	15	< 0.03	< 4
050	East Prong	65	8/26/2003	0.3	0.1	51
050	Franks Ditch	44	6/10/2003	14	0.05	8
050	Franks Ditch	44	8/20/2003	2.2	0.06	8
050	Franks Drain	48	6/10/2003	13	0.06	9
050	Franks Drain	48	8/20/2003	< 0.1	0.06	14
050	Grissom Ditch	76	6/11/2003	5.1	7.4	46
050	Grissom Ditch	76	8/26/2003	0.4	0.19	21
050	Grissom Ditch	78	6/17/2003	21	0.11	24
050	Grissom Ditch	78	8/26/2003	< 0.1	0.15	37
050	Hartzel Ditch	80	6/17/2003	32	0.1	26
050	Hartzel Ditch	80	8/26/2003	0.2	0.33	27
050	Limberlost Cr	52	6/10/2003	11	0.18	25
050	Limberlost Cr	52	8/20/2003	1.2	0.25	8
050	Limberlost Cr	58	6/10/2003	12	0.13	14
050	Limberlost Cr	58	8/25/2003	0.5	0.23	29
050	Limberlost Cr	59	6/10/2003	13	0.4	32
050	Limberlost Cr	59	8/25/2003	0.3	0.34	13
050	Limberlost Cr	60	6/10/2003	11	0.23	23
050	Limberlost Cr	60	8/25/2003	0.1	1.2	33
050	Limberlost Cr	71	6/9/2003	18	0.39	228
050	Limberlost Cr	71	8/27/2003	0.5	0.29	41
050	Limberlost Cr	72	6/11/2003	22	5.66	100

HUC to 14	Stream Name	LSITE	Sample Date	Nitrogen, Nitrate+Nitrite (mg/L)	Phosphorus, Total (mg/L)	TSS (mg/L)
050	Limberlost Cr	72	8/27/2003	9.9	1.24	31
050	Unnamed Trib of East Prong	68	6/9/2003	20	0.07	14
050	Unnamed Trib of West Prong	75	6/17/2003	16	0.15	67
050	West Prong	53	6/16/2003	23	0.08	37
050	West Prong	53	8/26/2003	0.5	0.1	16
050	West Prong	77	6/9/2003	14	0.04	9
050	West Prong	77	8/26/2003	< 0.1	0.23	64
050	West Prong Franks Drain	11	7/2/2003	13	0.087	14
050	West Prong Franks Drain	11	8/19/2003	0.019	0.11	15
050	West Prong Franks Drain	11	10/20/2003	4.7	0.084	6
050	Wilson Creek	49	6/10/2003	18	0.06	11
050	Wilson Creek	49	8/25/2003	0.5	0.08	15
050	Wilson Creek	50	6/10/2003	18	0.05	5
050	Wilson Creek	50	8/25/2003	0.2	0.09	14
050	Wilson Creek	57	6/16/2003	31	0.16	34
050	Wilson Creek	57	8/26/2003	< 0.1	1.89	88
050	Wilson Creek	62	6/16/2003	29	0.13	33
050	Wilson Creek	62	8/26/2003	0.2	0.09	34
050	Wilson Creek	64	6/11/2003	16	0.08	25
050	Wilson Creek	70	6/9/2003	14	0.18	24
050	Wilson Creek	70	8/27/2003	0.3	0.78	80
050	Young Ditch	73	6/17/2003	12	0.11	52
050	Young Ditch	73	8/26/2003	< 0.1	0.06	49
060	Davidson Ditch	25	6/10/2003	8.5	0.04	17
060	Davidson Ditch	25	8/20/2003	0.3	0.35	138
060	Davidson Ditch	38	6/10/2003	8.3	0.05	31
060	Davidson Ditch	38	8/19/2003	< 0.1	0.08	11
060	Davidson Ditch	39	6/10/2003	8.1	0.07	33

HUC to 14	Stream Name	LSITE	Sample Date	Nitrogen, Nitrate+Nitrite (mg/L)	Phosphorus, Total (mg/L)	TSS (mg/L)
060	Davidson Ditch	39	8/19/2003	< 0.1	0.07	14
060	Limberlost Cr	1	9/29/1998	0.036	0.17	7
060	Limberlost Cr	9	8/4/1998	1.1	0.064	9
060	Limberlost Cr	15	6/9/2003	11	0.05	13
060	Limberlost Cr	15	8/18/2003	1.6	0.14	11
060	Limberlost Cr	17	6/9/2003	11	0.07	16
060	Limberlost Cr	17	8/18/2003	1.6	0.14	14
060	Limberlost Cr	21	6/9/2003	12	0.07	10
060	Limberlost Cr	21	8/18/2003	1.9	0.16	56
060	Limberlost Cr	24	6/10/2003	10	0.08	29
060	Limberlost Cr	24	8/18/2003	1.9	0.15 (HJ)	25
060	Limberlost Cr	26	6/10/2003	10	0.07	19
060	Limberlost Cr	26	8/19/2003	1.7	0.14	11
060	Limberlost Cr	36	6/19/2003	26	0.19	40
060	Limberlost Cr	36	8/19/2003	1.6	0.11	9
060	Limberlost Cr	51	6/10/2003	10	0.08	21
060	Limberlost Cr	51	8/19/2003	1.7	0.11	11
060	Limberlost Cr	54	6/10/2003	10	0.09	28
060	Limberlost Cr	54	8/19/2003	1.9	0.12	19
060	Metzner Ditch	33	6/16/2003	17	0.11	16
060	Metzner Ditch	33	8/19/2003	< 0.1	0.17	92
060	Metzner Ditch	34	6/11/2003	10	0.24	20
060	Metzner Ditch	34	8/19/2003	1.8	0.3	30
060	Montgomery Ditch	23	6/9/2003	7.9	0.15	142
060	Montgomery Ditch	23	8/20/2003	< 0.1	0.1	33
060	Montgomery Ditch	27	6/10/2003	7.3	0.4	147
060	Montgomery Ditch	27	8/20/2003	0.1	0.27	90
060	Oakley Ditch	45	6/11/2003	14	0.15	21

HUC to 14	Stream Name	LSITE	Sample Date	Nitrogen, Nitrate+Nitrite (mg/L)	Phosphorus, Total (mg/L)	TSS (mg/L)
060	Oakley Ditch	45	8/19/2003	0.4	0.4	40
060	Pape Haffner Ditch	40	6/11/2003	0.3	0.1	30
060	Pape Haffner Ditch	40	8/19/2003	0.2	0.12	9
060	Pape Haffner Ditch	46	6/16/2003	11	0.36	222
060	Pape Haffner Ditch	46	8/19/2003	< 0.1	1.6	67
060	Perry Ditch	20	6/9/2003	8	0.11	16
060	Perry Ditch	20	8/20/2003	< 0.1	0.18	48
060	Perry Ditch	28	6/11/2003	7.9	0.17	10
060	Perry Ditch	28	8/18/2003	0.2	0.44	40
060	Perry Ditch	30	6/16/2003	15	0.05	10
060	Perry Ditch	30	8/19/2003	0.1	0.09	28
060	Perry Ditch	31	6/11/2003	3.2	0.15	28
060	Perry Ditch	31	8/19/2003	0.2	0.19	32
060	Perry Ditch	32	6/16/2003	15	0.08	42
060	Perry Ditch	32	8/19/2003	< 0.1	0.43	34
060	Pontius Ditch	16	6/19/2003	7.4	0.32	61
060	Pontius Ditch	16	8/20/2003	0.1	0.33	47
060	Slentzer Perry Ditch	41	6/10/2003	7.1	0.07	34
060	Slentzer Perry Ditch	41	8/19/2003	1.3	0.11	53
060	Slentzer Perry Ditch	42	6/10/2003	6	0.08	54
060	Slentzer Perry Ditch	42	8/19/2003	1.6	0.12	94
060	Unnamed Trib of Limberlost Cr	47	6/16/2003	9.1	< 0.03	12
060	Unnamed Trib of Limberlost Cr	47	8/19/2003	0.2	0.03	11
060	Unnamed Trib of Pape Haffner D	43	6/16/2003	21	0.1	52
060	Unnamed Trib of Pape Haffner D	43	8/19/2003	2.1	0.13	58
060	Wheeller Ditch	29	6/16/2003	15	0.17	23
060	Wheeller Ditch	29	8/19/2003	0.4	0.25	26

Table 2. Limberlost Water Quality Data.

Stream Name	HUC14	LSITE	Sample Date	Alkalinity (as CaCO3) (mg/L)	Chloride (mg/L)	COD (mg/L)	Cyanide (Total) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Nitrogen, Ammonia (mg/L)
East Prong	050	55	6/16/2003	196	27	21.2	< 0.005	0.2	392	< 0.1
East Prong	050	55	8/26/2003	244	396	28.5	< 0.005	0.4	362	1
East Prong	050	65	6/11/2003	193	36	11.8	< 0.005	0.2	369	< 0.1
East Prong	050	65	8/26/2003	235	33	26.2	< 0.005	0.3	342	< 0.1
Franks Ditch	050	44	6/10/2003	191	47	12.2	< 0.005	0.2	392	< 0.1
Franks Ditch	050	44	8/20/2003	240	34	16.9	< 0.005	0.2	369	< 0.1
Franks Drain	050	48	6/10/2003	202	48	12.6	< 0.005	0.2	404	< 0.1
Franks Drain	050	48	8/20/2003	240	41	14.4	< 0.005	0.3	390	< 0.1
Grissom Ditch	050	76	6/11/2003	425	725	179	< 0.005	0.5	437	34
Grissom Ditch	050	76	8/26/2003	280	235	25.5	< 0.005	0.3	368	< 0.1
Grissom Ditch	050	78	6/17/2003	185	31	17.1	< 0.005	0.2	363	< 0.1
Grissom Ditch	050	78	8/26/2003	286	83	28.5	< 0.005	0.4	403	< 0.1
Hartzel Ditch	050	80	6/17/2003	190	44	11	< 0.005	0.2	436	< 0.1
Hartzel Ditch	050	80	8/26/2003	289	193	23.9	< 0.005	0.4	430	0.8
Limberlost Cr	050	52	6/10/2003	261	39	14.7	< 0.005	0.2	492	< 0.1
Limberlost Cr	050	52	8/20/2003	308	32	14.3	< 0.005	0.3	482	< 0.1
Limberlost Cr	050	58	6/10/2003	241	41	15.5	< 0.005	0.2	441	< 0.1
Limberlost Cr	050	58	8/25/2003	280	29	17.5	< 0.005	0.2	420	< 0.1
Limberlost Cr	050	59	6/10/2003	225	49	27.7	< 0.005	0.2	405	0.4
Limberlost Cr	050	59	8/25/2003	318	37	16.7	< 0.005	0.4	535	0.1
Limberlost Cr	050	60	6/10/2003	267	40	16.4	< 0.005	0.3	498	0.2
Limberlost Cr	050	60	8/25/2003	305	60	34.2	< 0.005	0.2	420	0.3
Limberlost Cr	050	71	6/9/2003	213	46	16.4	< 0.005	0.3	410	< 1
Limberlost Cr	050	71	8/27/2003	244	58	23.2	< 0.005	0.4	348	0.3
Limberlost Cr	050	72	6/11/2003	295	62	65.5	< 0.005	0.3	512	0.5

Stream Name	HUC14	LSITE	Sample Date	Alkalinity (as CaCO3) (mg/L)	Chloride (mg/L)	COD (mg/L)	Cyanide (Total) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Nitrogen, Ammonia (mg/L)
Limberlost Cr	050	72	8/27/2003	320	224	53.2	< 0.005	0.4	586	< 0.1
Unnamed Trib of East Prong	050	68	6/9/2003	217	32	8	< 0.005	0.2	411	< 0.1
Unnamed Trib of West Prong	050	75	6/17/2003	213	39	17.1	< 0.005	0.2	391	< 0.1
West Prong	050	53	6/16/2003	204	42	15.9	< 0.005	0.2	399	< 0.1
West Prong	050	53	8/26/2003	297	37	15.2	< 0.005	0.4	474	0.2
West Prong	050	77	6/9/2003	138	56	17.6	< 0.005	0.2	312	< 0.1
West Prong	050	77	8/26/2003	252	53	41	< 0.005	0.4	373	< 0.1
West Prong Franks Drain	050	11	7/2/2003	210	45	7	< 0.005		363	< 0.1
West Prong Franks Drain	050	11	8/19/2003	300	41	< 5	< 0.005		363	< 0.1
West Prong Franks Drain	050	11	10/20/2003	260	49	13	< 0.005		424	< 0.1
Wilson Creek	050	49	6/10/2003	179	46	13.4	< 0.005	0.2	398	< 0.1
Wilson Creek	050	49	8/25/2003	227	55	15.6	< 0.005	0.8	430	0.2
Wilson Creek	050	50	6/10/2003	181	46	13.4	< 0.005	0.2	403	< 0.1
Wilson Creek	050	50	8/25/2003	213	34	15.6	< 0.005	0.2	372	< 0.1
Wilson Creek	050	57	6/16/2003	167	25	26.5	< 0.005	0.2	377	< 0.1
Wilson Creek	050	57	8/26/2003	363	364	80.9	< 0.005	0.6	397	7.6
Wilson Creek	050	62	6/16/2003	168	24	31	< 0.005	0.2	361	< 0.1
Wilson Creek	050	62	8/26/2003	325	46	17.5	< 0.005	0.7	682	< 0.1
Wilson Creek	050	64	6/11/2003	206	61	14.7	< 0.005	0.3	394	< 0.1
Wilson Creek	050	70	6/9/2003	198	52	18.1	< 0.005	0.3	346	< 0.1
Wilson Creek	050	70	8/27/2003	295	81	56.6	< 0.005	0.3	390	0.4
Young Ditch	050	73	6/17/2003	197	36	22	< 0.005	0.1	350	< 0.1

Stream Name	HUC14	LSITE	Sample Date	Alkalinity (as CaCO3) (mg/L)	Chloride (mg/L)	COD (mg/L)	Cyanide (Total) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Nitrogen, Ammonia (mg/L)
Young Ditch	050	73	8/26/2003	346	44	14.8	< 0.005	0.3	406	< 0.1
Davidson Ditch	060	25	6/10/2003	169	62	14.7	< 0.005	0.2	309	< 0.1
Davidson Ditch	060	25	8/20/2003	193	93	38	< 0.005	0.4	338	0.3
Davidson Ditch	060	38	6/10/2003	139	57	16.4	< 0.005	0.2	284	< 0.1
Davidson Ditch	060	38	8/19/2003	120	42	22.6	< 0.005	0.3	202	< 0.1
Davidson Ditch	060	39	6/10/2003	132	60	15.1	< 0.005	0.2	274	< 0.1
Davidson Ditch	060	39	8/19/2003	164	43	21.4	< 0.005	0.3	250	< 0.1
Limberlost Cr	060	1	9/29/1998	300	22 (Q)	6.1	< 0.005		540	< 0.1
Limberlost Cr	060	9	8/4/1998	270	24	13	< 0.005		450 (Q)	< 0.1
Limberlost Cr	060	15	6/9/2003	216	40	13.4	< 0.005	0.4	434	< 0.1
Limberlost Cr	060	15	8/18/2003	259	26	18.8	< 0.005	0.5	413	< 0.1
Limberlost Cr	060	17	6/9/2003	221	39	13	< 0.005	0.4	475	< 0.1
Limberlost Cr	060	17	8/18/2003	262	26	18	< 0.005	0.5	436	< 0.1
Limberlost Cr	060	21	6/9/2003	218	35	12.6	< 0.005	0.4	436	< 0.1
Limberlost Cr	060	21	8/18/2003	264	24	18	< 0.005	0.5	435	< 0.1
Limberlost Cr	060	24	6/10/2003	229	36	13.9	< 0.005	0.5	501	< 0.1
Limberlost Cr	060	24	8/18/2003	262	24	15.8	< 0.005	0.5	436	< 0.1
Limberlost Cr	060	26	6/10/2003	230	37	13	< 0.005	0.4	492	< 0.1
Limberlost Cr	060	26	8/19/2003	271	23	15.4	< 0.005	0.6	474	< 0.1
Limberlost Cr	060	36	6/19/2003	199	27	17.1	< 0.005	0.3	422	< 0.1
Limberlost Cr	060	36	8/19/2003	275	22	13.2	< 0.005	0.6	491	< 0.1
Limberlost Cr	060	51	6/10/2003	229	38	13.9	< 0.005	0.4	438	< 0.1
Limberlost Cr	060	51	8/19/2003	275	25	13.9	< 0.005	0.5	480	< 0.1
Limberlost Cr	060	54	6/10/2003	235	41	13.4	< 0.005	0.4	496	< 0.1
Limberlost Cr	060	54	8/19/2003	278	28	13.9	< 0.005	0.5	511	< 0.1
Metzner Ditch	060	33	6/16/2003	161	30	13.1	< 0.005	0.2	326	< 0.1
Metzner Ditch	060	33	8/19/2003	261	41	30.8	< 0.005	0.2	444	< 0.1

Stream Name	HUC14	LSITE	Sample Date	Alkalinity (as CaCO3) (mg/L)	Chloride (mg/L)	COD (mg/L)	Cyanide (Total) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Nitrogen, Ammonia (mg/L)
Metzner Ditch	060	34	6/11/2003	190	148	21.4	< 0.005	0.2	374	< 0.1
Metzner Ditch	060	34	8/19/2003	187	47	22.2	< 0.005	0.3	242	< 0.1
Montgomery Ditch	060	23	6/9/2003	191	52	20.6	< 0.005	0.5	582	< 0.1
Montgomery Ditch	060	23	8/20/2003	324	108	21.4	< 0.005	1	1100	< 0.1
Montgomery Ditch	060	27	6/10/2003	216	102	37.8	< 0.005	0.2	406	< 0.1
Montgomery Ditch	060	27	8/20/2003	246	50	42.1	< 0.005	0.3	332	0.1
Oakley Ditch	060	45	6/11/2003	212	110	12.6	< 0.005	0.2	427	< 0.1
Oakley Ditch	060	45	8/19/2003	240	332	25.6	< 0.005	0.4	430	0.9
Pape Haffner Ditch	060	40	6/11/2003	284	25	19.3	< 0.005	0.2	371	< 0.1
Pape Haffner Ditch	060	40	8/19/2003	286	19	14.7	< 0.005	0.2	351	< 0.1
Pape Haffner Ditch	060	46	6/16/2003	200	29	40	< 0.005	0.2	361	0.2
Pape Haffner Ditch	060	46	8/19/2003	425	218	52.6	< 0.005	0.7	580	4.4
Perry Ditch	060	20	6/9/2003	212	72	44.1	< 0.005	0.4	388	< 0.1
Perry Ditch	060	20	8/20/2003	233	100	38.7	< 0.005	0.8	391	< 0.1
Perry Ditch	060	28	6/11/2003	215	97	17.6	< 0.005	0.3	396	< 0.1
Perry Ditch	060	28	8/18/2003	270	233	42.1	< 0.005 (H)	0.5	401	< 0.1
Perry Ditch	060	30	6/16/2003	219	31	12.2	< 0.005	0.2	357	< 0.1
Perry Ditch	060	30	8/19/2003	294	52	18	< 0.005	0.3	373	< 0.1 (HJ)
Perry Ditch	060	31	6/11/2003	265	55	18.5	< 0.005	0.2	342	< 0.1

Stream Name	HUC14	LSITE	Sample Date	Alkalinity (as CaCO3) (mg/L)	Chloride (mg/L)	COD (mg/L)	Cyanide (Total) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Nitrogen, Ammonia (mg/L)
Perry Ditch	060	31	8/19/2003	258	140	25.6	< 0.005	0.3	339	< 0.1
Perry Ditch	060	32	6/16/2003	223	34	15.5	< 0.005	0.2	362	< 0.1
Perry Ditch	060	32	8/19/2003	240	156	54.5	< 0.005	0.4	331	0.7
Pontius Ditch	060	16	6/19/2003	193	152	23.1	< 0.005	0.2	379	0.4
Pontius Ditch	060	16	8/20/2003	179	102	30.1	< 0.005	0.2	285	0.3
Slentzer Perry Ditch	060	41	6/10/2003	221	30	16	< 0.005	0.3	340	< 0.1
Slentzer Perry Ditch	060	41	8/19/2003	272	30	20.7	< 0.005	0.3	364	< 0.1
Slentzer Perry Ditch	060	42	6/10/2003	218	36	20.6	< 0.005	0.2	328	< 0.1
Slentzer Perry Ditch	060	42	8/19/2003	266	29	19.2	< 0.005	0.2	358	< 0.1
Unnamed Trib of Limberlost Cr	060	47	6/16/2003	241	15	10.2	< 0.005	1	494	0.1
Unnamed Trib of Limberlost Cr	060	47	8/19/2003	261	8.8	5.3	< 0.005	1.4	515	0.2
Unnamed Trib of Pape Haffner D	060	43	6/16/2003	201	46	17.5	< 0.005	0.2	543	< 0.1
Unnamed Trib of Pape Haffner D	060	43	8/19/2003	254	31	17.3	< 0.005	0.3	557	< 0.1
Wheeller Ditch	060	29	6/16/2003	179	25	18.8	< 0.005	0.2	333	0.1
Wheeller Ditch	060	29	8/19/2003	239	76	23.3	< 0.005	0.3	349	0.1

Table 3. Limberlost Water Quality Data-continued.

Stream Name	HUC14	LSITE	Sample Date	pH (SU)	Sulfate (mg/L)	TDS (mg/L)	TKN (mg/L)	TOC (mg/L)	TS (mg/L)
East Prong	050	55	6/16/2003	8.5	56			4.4	541
East Prong	050	55	8/26/2003	8	79			8.5	1130
East Prong	050	65	6/11/2003	8.4	70			3	497
East Prong	050	65	8/26/2003	8	53			5.6	471
Franks Ditch	050	44	6/10/2003	8.2	105			3.3	567
Franks Ditch	050	44	8/20/2003	8	88			5.8	501
Franks Drain	050	48	6/10/2003	8.3	103			3.2	580
Franks Drain	050	48	8/20/2003	8.2	115			4.9	542
Grissom Ditch	050	76	6/11/2003	7.7	101			34.7 (QJ)	1780
Grissom Ditch	050	76	8/26/2003	8.1	54			7.5	834
Grissom Ditch	050	78	6/17/2003	7.8	42			5	510
Grissom Ditch	050	78	8/26/2003	7.7	103			9.1	660
Hartzel Ditch	050	80	6/17/2003	8.1	77			3.4	649
Hartzel Ditch	050	80	8/26/2003	7.9	121			8.1	880
Limberlost Cr	050	52	6/10/2003	7.8	131			3.7	677
Limberlost Cr	050	52	8/20/2003	7.8	121			5.3	628
Limberlost Cr	050	58	6/10/2003	8	111			3.3	646
Limberlost Cr	050	58	8/25/2003	8.4	110			5.7	583
Limberlost Cr	050	59	6/10/2003	7.9	109			5.8	633
Limberlost Cr	050	59	8/25/2003	7.7	180			5.6	728
Limberlost Cr	050	60	6/10/2003	7.9	135			4.1	691
Limberlost Cr	050	60	8/25/2003	8.3	118			10.1	670
Limberlost Cr	050	71	6/9/2003	8.7	88			4.6	777
Limberlost Cr	050	71	8/27/2003	7.9	82			7.8	542
Limberlost Cr	050	72	6/11/2003	8	132			17.7	975

Stream Name	HUC14	LSITE	Sample Date	pH (SU)	Sulfate (mg/L)	TDS (mg/L)	TKN (mg/L)	TOC (mg/L)	TS (mg/L)
Limberlost Cr	050	72	8/27/2003	8.4	141			10.4	1090
Unnamed Trib of East Prong	050	68	6/9/2003	7.6	88			1.6	583
Unnamed Trib of West Prong	050	75	6/17/2003	7.9	72			3.7	590
West Prong	050	53	6/16/2003	8	77			3.9	591
West Prong	050	53	8/26/2003	7.7	129			4.6	644
West Prong	050	77	6/9/2003	8.7	58			3.8	479
West Prong	050	77	8/26/2003	8.3	83			8.6	594
West Prong Franks Drain	050	11	7/2/2003		95	540	1.1	4.7	650
West Prong Franks Drain	050	11	8/19/2003		100	570	0.66	5.2	730
West Prong Franks Drain	050	11	10/20/2003		92	480	0.73	4.8	500
Wilson Creek	050	49	6/10/2003	8.7	107			4.1	605
Wilson Creek	050	49	8/25/2003	7.8	241			4.8	739
Wilson Creek	050	50	6/10/2003	8.1	122			3.6	614
Wilson Creek	050	50	8/25/2003	8.2	126			4.6	518
Wilson Creek	050	57	6/16/2003	8.1	45			4.9	611
Wilson Creek	050	57	8/26/2003	8	280			22.3	1480
Wilson Creek	050	62	6/16/2003	8.2	49			4.9	591
Wilson Creek	050	62	8/26/2003	7.9	322			6.2	939
Wilson Creek	050	64	6/11/2003	8.1	90			3.4	594
Wilson Creek	050	70	6/9/2003	8.6	76			4.4	546
Wilson Creek	050	70	8/27/2003	7.9	60			9.4	642
Young Ditch	050	73	6/17/2003	7.9	71			4.3	527

Stream Name	HUC14	LSITE	Sample Date	pH (SU)	Sulfate (mg/L)	TDS (mg/L)	TKN (mg/L)	TOC (mg/L)	TS (mg/L)
Young Ditch	050	73	8/26/2003	7.6	39			4.2	556
Davidson Ditch	060	25	6/10/2003	8.1	56			3.6	479
Davidson Ditch	060	25	8/20/2003	8	74			7.5	647
Davidson Ditch	060	38	6/10/2003	8.9	64			3.9	447
Davidson Ditch	060	38	8/19/2003	8.9	61			8	330
Davidson Ditch	060	39	6/10/2003	8.9	55			3.8	449
Davidson Ditch	060	39	8/19/2003	8.6	54			7.6	369
Limberlost Cr	060	1	9/29/1998		230 (Q)	820	0.67	5	990
Limberlost Cr	060	9	8/4/1998		190	640	0.65	3.4	710
Limberlost Cr	060	15	6/9/2003	8.3	146			3.4	677
Limberlost Cr	060	15	8/18/2003	8.3	154			6	602
Limberlost Cr	060	17	6/9/2003	8.2	156			3.4	679
Limberlost Cr	060	17	8/18/2003	8.2	174			5.7	633
Limberlost Cr	060	21	6/9/2003	8.4	155			3.4	672
Limberlost Cr	060	21	8/18/2003	8.2	161			5.5	665
Limberlost Cr	060	24	6/10/2003	8	158			3.2	706
Limberlost Cr	060	24	8/18/2003	8.3	167			5.2	642
Limberlost Cr	060	26	6/10/2003	8.1	182			3.3	701
Limberlost Cr	060	26	8/19/2003	8.1	190			4.9	650
Limberlost Cr	060	36	6/19/2003	8	92			5.1	631
Limberlost Cr	060	36	8/19/2003	8.1	193			4.5	675
Limberlost Cr	060	51	6/10/2003	8.1	168			3.1	684
Limberlost Cr	060	51	8/19/2003	8.1	170			4.7	646
Limberlost Cr	060	54	6/10/2003	8.1	151			3	699
Limberlost Cr	060	54	8/19/2003	7.8	176			4.7	679
Metzner Ditch	060	33	6/16/2003	8	49			4.1	456
Metzner Ditch	060	33	8/19/2003	7.9	137			9.5	700

Stream Name	HUC14	LSITE	Sample Date	pH (SU)	Sulfate (mg/L)	TDS (mg/L)	TKN (mg/L)	TOC (mg/L)	TS (mg/L)
Metzner Ditch	060	34	6/11/2003	8.2	66			3.8	694
Metzner Ditch	060	34	8/19/2003	8.3	40			7	405
Montgomery Ditch	060	23	6/9/2003	8.2	268 (Q)			3.5	992
Montgomery Ditch	060	23	8/20/2003	7.7	817			4.9	1850
Montgomery Ditch	060	27	6/10/2003	8.2	63			4.5	744
Montgomery Ditch	060	27	8/20/2003	7.7	38			12.2	532
Oakley Ditch	060	45	6/11/2003	8	118			3	737
Oakley Ditch	060	45	8/19/2003	8	128			8	1070
Pape Haffner Ditch	060	40	6/11/2003	8.2	76			5.1	495
Pape Haffner Ditch	060	40	8/19/2003	8	50			6	428
Pape Haffner Ditch	060	46	6/16/2003	7.8	70			5.2	695
Pape Haffner Ditch	060	46	8/19/2003	7.8	242			11.9	1210
Perry Ditch	060	20	6/9/2003	8.2	115			4	630
Perry Ditch	060	20	8/20/2003	8	173			10.6	722
Perry Ditch	060	28	6/11/2003	8	112			4.6	652
Perry Ditch	060	28	8/18/2003	8.3	124			13.1	931
Perry Ditch	060	30	6/16/2003	7.9	37			3.7	463
Perry Ditch	060	30	8/19/2003	8.2	47			10.1	530
Perry Ditch	060	31	6/11/2003	8	49			5.4	526
Perry Ditch	060	31	8/19/2003	8.3	40			8.2	633

Stream Name	HUC14	LSITE	Sample Date	pH (SU)	Sulfate (mg/L)	TDS (mg/L)	TKN (mg/L)	TOC (mg/L)	TS (mg/L)
Perry Ditch	060	32	6/16/2003	7.9	38			4.1	499
Perry Ditch	060	32	8/19/2003	8.5	81			14.8	692
Pontius Ditch	060	16	6/19/2003	8	66			4.9	731
Pontius Ditch	060	16	8/20/2003	7.8	34			8.3	523
Slentzer Perry Ditch	060	41	6/10/2003	8.1	58			3.5	478
Slentzer Perry Ditch	060	41	8/19/2003	7.8	50			6.2	519
Slentzer Perry Ditch	060	42	6/10/2003	8.1	53			4	488
Slentzer Perry Ditch	060	42	8/19/2003	7.6	35			5.9	521
Unnamed Trib of Limberlost Cr	060	47	6/16/2003	8	178			2.9	698
Unnamed Trib of Limberlost Cr	060	47	8/19/2003	8.1	301			1.8	726
Unnamed Trib of Pape Haffner D	060	43	6/16/2003	7.9	174			4.5	797
Unnamed Trib of Pape Haffner D	060	43	8/19/2003	7.8	255			5.2	806
Wheeller Ditch	060	29	6/16/2003	8.2	59 (Q)			5.4	473
Wheeller Ditch	060	29	8/19/2003	7.9	79			7.1	549

TOTAL MAXIMUM DAILY LOAD PROGRAM
OFFICE OF WATER QUALITY

Comment Form
Draft Limberlost Creek Watershed TMDL

Geneva Public Library
307 East Line Street
Geneva, Indiana 46740

March 15, 2007 at 7:00 p.m.

Please Note: Only written comments will be incorporated and responded to in the final TMDL. **Written comments must be postmarked by close of business (5:00 p.m.) on April 9, 2007.** All written comments may be forwarded via regular mail, email, or fax to:

Limberlost Creek TMDL
Ernest L. Johnson III
MC65-42 TMDL IGCN 1255
100 North Senate Avenue
Indianapolis, Indiana 46204-2251

Email: ejohnson@idem.in.gov

Fax: 317/232-8406

(Please Print)

NAME: Jay H Gould REPRESENTING: Farm Service Agency

ADDRESS (include city, state, zip): 975 S 11th
Decatur IN 46733

PHONE: (260) 724 4124 ext 2 EMAIL: jay.gould@in.usda.gov

COMMENTS:

If TMDL analysis shows present sediment levels, shall we find and implement practices to lesson sediment's presence (i.e. protecting streambanks that are exposed, eroding, caving over)? What do we do with TMDL data and knowledge?

Thanks!
Jay

CONTINUE ON BACK IF NEEDED OR USE ADDITIONAL SHEETS

Ernest L. Johnson

Indiana Department of Environmental Management
Office of Water Quality

Hello, my name is Andrew McLaughlin and I am an avid outdoorsman that has lived and worked around Jay and Adams Counties all of my life. Just today I read an article in the newspaper, The Decatur Daily Democrat, I believe. There was a front page story about the Limberlost Watershed, and how IDEM was not pleased with the quality of progress that this Ecologic Project has made.

Over the past few years I have become increasingly interested with the Wabash River and it's impact on our area. I have personally traveled this river from the Indiana/Ohio state line to Wells County by canoe, and have seen some things that might peak your interest.

I believe that the problem with water quality does not lie in the laps of the "Confined Feeding Operations". The problem that I see as I travel through the tight corridors of this ancient land is the downed trees and garbage. That is right, plain old junk! If a river is clogged and cannot flow, it becomes stagnant and water quality drops. I recall one point in my journey that I had to portage my canoe One Hundred and Fifty paces down stream to get around a log jam that had been compacted with garbage. There have been so many times that I have been tempted to grab my boat and a chainsaw and do the dirty work myself.

I have spoken with the local DNR Officer, Duane Ford, about this and he advised me NOT TO DO THIS, as the state frowns on the "diversion of waterways". The way I see it, I am not diverting the waterway, it is more like I am clearing a way for the water to flow. Perhaps with the States Approval we could have an annual river cleanup day, although a Cleanup Week would be more appropriate and beneficial.

Another point that I must address, is the use of Field Tiles. I am not talking about the much needed drainage tiles that dry up that "wet spot" in the field, rather than the "criss-crossing" of every square tilable inch of land on our countryside with the yellow, blue or black plastic tubes. When an area is tiled like that, the water runs down to the streams much too quickly. Thus, creating more frequent "Flash Floods". This water that runs from the fields so quickly, doesn't have time to "leach" down into the Earth and naturally clean it's self before entering the watertable and the streams. It is no wonder that the Farmer gets blamed for all of this polluting. Allthough the Farmer is the one that tiles the field, then sprays liquid manure on top of the ground right before it rains, so that it "soaks in good". Well it doesn't actually "soak in", it heads straight down the tube to the river. But maybe something should be done about the tiling of fields.

With all of this extra unfiltered water running to the river from the field tiles, and getting backed up by garbage and log jams. It is easy for me to see why there is a problem with water quality in our Rivers.

Andrew McLaughlin