Smalley Lake Diagnostic Study

NOBLE AND WHITLEY COUNTIES, INDIANA

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SMALLEY LAKE DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

Smalley Lake is a 69-acre (28-ha) natural lake located in the headwaters of the Tippecanoe River watershed, east of North Webster, Indiana. Smalley Lake's watershed encompasses 17,076 acres (6,913 ha or 26.7 square miles) and covers portions of Noble and Whitley Counties. Most of the watershed (80%) is utilized for agricultural purposes (row crops, hay, and pasture). Natural features (wetlands, forests, and lakes) cover nearly 20% of the watershed, while residential and commercial land uses account for less than one percent of the watershed's total acreage. Morley soils are the most common soil type in the Smalley Lake watershed.

Smalley Lake possesses two inlet streams: the Tippecanoe River and an unnamed northern inlet. The northern inlet exhibited poor water chemistry conditions. A low dissolved oxygen concentration and high *E. coli* and nitrate-nitrogen concentrations characterized this stream at base flow or "normal" conditions. Water chemistry conditions were slightly better in the Tippecanoe River; however both inlet streams possessed impaired biotic communities and physical habitat. Despite having better water chemistry conditions, the Tippecanoe River delivered more pollutants to Smalley Lake than the northern inlet. When inlet pollutant loads were normalized by dividing by subwatershed size, the Tippecanoe River still delivered more pollutants (except nitrate-nitrogen) to Smalley Lake per acre of subwatershed. Upstream and downstream sediment loading data indicate Smalley Lake serves as a sediment trap.

Smalley Lake is best classified as a eutrophic to hypereutrophic lake. Smalley Lake has poorer water clarity and higher nutrient concentrations than most Indiana lakes. The lake is considered hypereutrophic when evaluated with the Indiana Trophic State Index (TSI) or Carlson's TSI. The lake's biological community is characteristic of eutrophic conditions. Bluegill represent more than 70% of the total fish community and Eurasian water milfoil, Sago pondweed, and coontail dominate the lake's plant community. Historical data suggest that the lake's productivity may be increasing (i.e. water quality may be worsening).

Watershed processes exert a greater influence over Smalley Lake's water quality than in-lake processes. The lake possesses an extremely large watershed area to lake area ratio (248:1) that is more typical of reservoirs than glacial lakes. The lake also has a very short hydraulic residence time of 25 days, meaning that every 25 days, the entire volume of water in Smalley Lake is flushed and replaced with new water from its inlets. The phosphorus model showed that external phosphorus loading accounts for roughly 92% of the total phosphorus load.

The unique characteristics of Smalley Lake and its watershed highlight the need to prioritize watershed management techniques over in-lake management techniques to improve Smalley Lake's water quality. Watershed management efforts should focus on restoring the riparian corridor along the Tippecanoe River or, at a minimum, installing herbaceous filter strips along the stream; restoring wetlands in the Tippecanoe River subwatershed, particularly those identified in the study; restricting livestock access to inlet streams; increasing the use of no-till conservation tillage and the Conservation Reserve Program in the watershed; monitoring and improving erosion control on residential and commercial development sites; planting vegetative filters around field risers; and implementing individual property owner management techniques.

ACKNOWLEDGMENTS

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SMALLEY LAKE DIAGNOSTIC STUDY
NOBLE AND WHITLEY COUNTIES, INDIANA

1.0 INTRODUCTION

Smalley Lake lies in the upper portion of the Tippecanoe River watershed east of North Webster, Indiana (Figure 1). Specifically, the lake is located in Sections 3-10 in Township 32 North, Range 9 East; Sections 20-22 and 27-36 in Township 33 North, Range 9 East; Sections 1-2, 12-13, and 18 in Township 32 North, Range 8 East; and Sections 9-11, 13-15, 22-25, and 35-36 in Township 33 North, Range 8 East. The Smalley Lake watershed stretches out to the east and south of the lake encompassing 17,076 acres (6,913 ha or 26.7 square miles) and covering portions of two counties (Figure 2). Water discharges through the lake's outlet in the northwest corner to the Tippecanoe River. The Tippecanoe River transports water from Smalley Lake through a series of lakes, ultimately reaching the Wabash River northeast of Lafayette, Indiana.

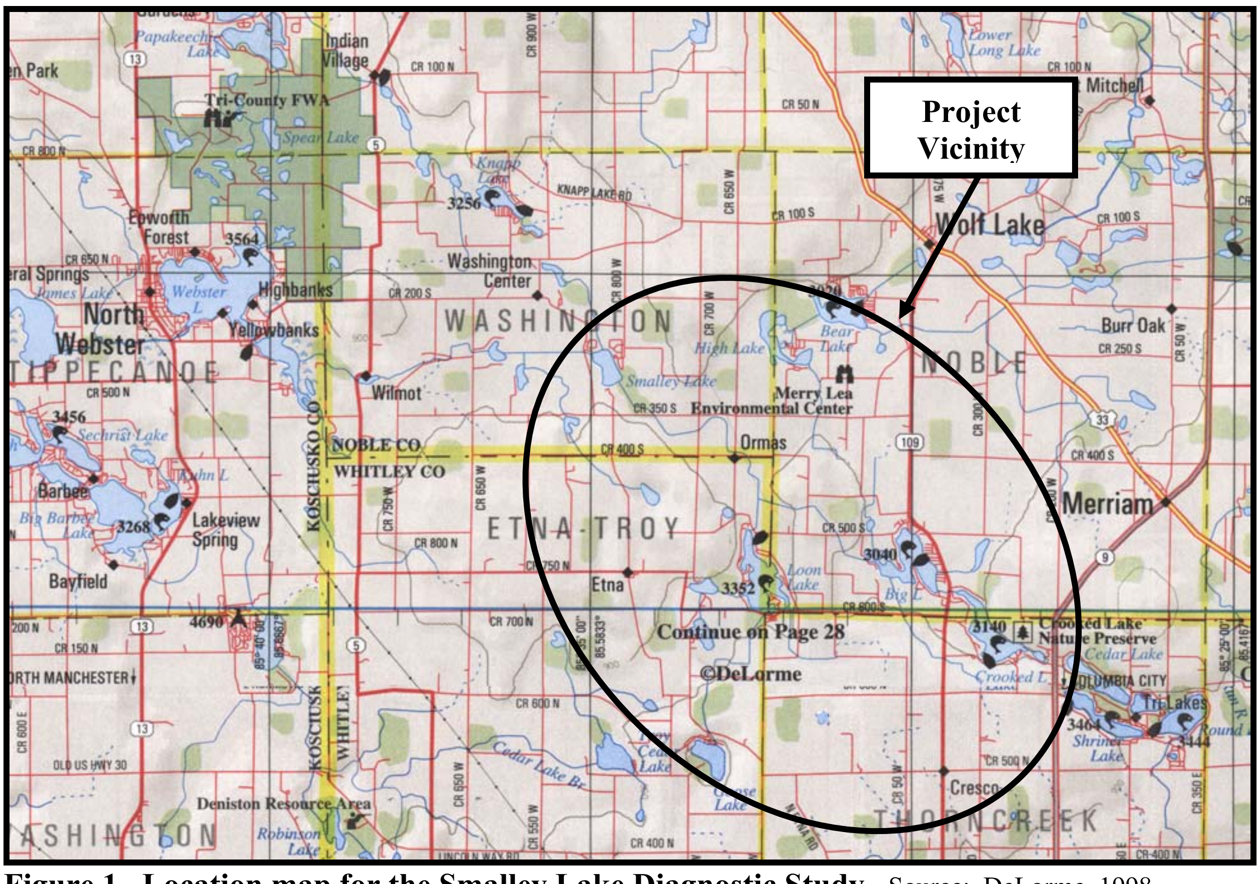

Figure 1. Location map for the Smalley Lake Diagnostic Study. Source: DeLorme, 1998.

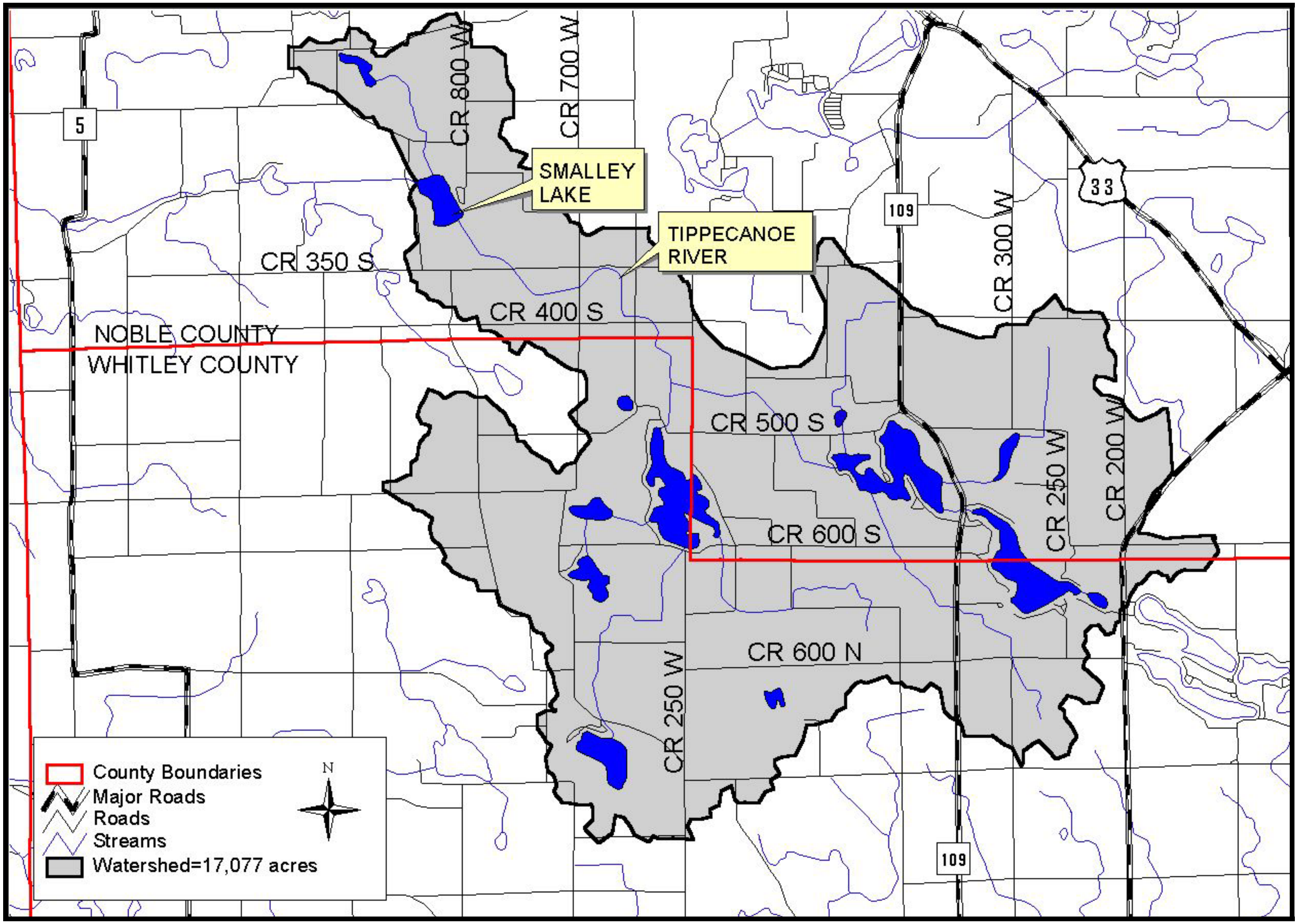

Figure 2. The Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1”=7,000’.

The need for the Smalley Lake Diagnostic Study grew out of concerns that arose during the development of the Upper Tippecanoe River Watershed Management Plan (TELWF, 2002). While reviewing historical watershed data for the Upper Tippecanoe River watershed, watershed stakeholders noted that Smalley Lake exhibits some of the poorest water quality of all the lakes in the watershed. Data collected as part of the Indiana Clean Lakes Program (CLP) showed that in a recent sampling the lake possessed mean total phosphorus concentrations in excess of ten times the threshold at which nuisance algae blooms can be expected (CLP files, 2003). Similarly, Smalley Lake Indiana Trophic State Index scores from the last decade suggest the lake is hypereutrophic, or overly productive, in nature. Hypereutrophic lakes suffer from repeated nuisance algae blooms, poor water clarity, and skewed fish communities, all of which can hamper enjoyment of the lake.

In addition to these concerns, watershed stakeholders also noted that compared to some other areas of the Upper Tippecanoe River watershed, few researchers or groups had examined the condition of the Smalley Lake watershed to diagnose the causes and address the problems listed above. The Indiana Department of Natural Resources (IDNR) conducted a diagnostic study on Big Lake in 1990 (IDNR, 1990). Later, Crisman (1993) examined Crooked Lake and its watershed. Big and Crooked Lakes lie in the southeast corner of the Smalley Lake watershed and their watershed covers approximately 6,000 acres or 35% of the Smalley Lake watershed. This leaves approximately 65% of the Smalley Lake watershed unexamined for potential water quality problems. F.X. Browne and Associates, Inc. (1992) completed a diagnostic study on Loon and Goose Lakes in 1992. While the Loon Lake watershed encompasses 7,000 acres or 41% of the Smalley Lake watershed, the diagnostic study resulted in only one non-specific recommendation for watershed treatment (TELWF, 2002). (It is likely the budget for the Loon and Goose Lakes study did not allow for a more complete watershed investigation.) Additionally, stakeholders could not find any data on the water quality of streams entering Smalley Lake.

The identified water quality concerns for Smalley Lake coupled with the lack of watershed data for the Smalley Lake watershed prompted Upper Tippecanoe River watershed stakeholders to list the Smalley Lake watershed as a priority area and recommend conducting a diagnostic study to gain information of the lake's tributaries. Consequently, the Tippecanoe Environmental Lake and Watershed Foundation (TELWF) applied for and received funding from the IDNR Lake and River Enhancement Program (LARE) to complete the diagnostic study. The purpose of the diagnostic study was to describe the conditions and trends in Smalley Lake and its watershed, identify potential problems, and make prioritized recommendations addressing these problems. The study consisted of a review of historical studies, interviews with area residents and state/local regulatory agencies, the collection of current water quality data, pollutant modeling, and field investigations. In order to obtain a broad understanding of the water quality in Smalley Lake and that entering the lake, the diagnostic study included an examination of the lake and stream water chemistry and their biotic communities (macroinvertebrates, plankton, macrophytes) which tend to reflect the long-term trends in water quality. The lake and inlet streams' habitat was also assessed to help distinguish between water quality and habitat effects on the existing biotic communities. This report documents the results of the study.

2.0 WATERSHED CHARACTERISTICS

2.1 Physical Characteristics

Figure 3 presents a topographical relief map of the 17,076-acre (6,913-ha) Smalley Lake watershed. The varied topography of the Smalley Lake watershed reflects the geological history of the watershed. The highest areas of the watershed lie in the watershed's headwaters, which is part of the interlobate region where the Packerton Moraine meets the Mississinewa and Salamonie Moraines. Elevations in this area along the southeastern edge of the watershed reach over 1000 feet above mean sea level. Fragments of the Packerton Moraine extend along the western edge of the watershed where the elevation reaches 970 feet above mean sea level. Glacial drift material covers the flatter central and north central portion of the Smalley Lake watershed. The flattest part of the watershed lies north of Big Lake. Here the elevation ranges from 900 to 910 feet above sea level. Smalley Lake, elevation 883 feet above mean sea level, is the lowest point in the watershed.

Two main drainages transport runoff water from the watershed to Smalley Lake. These drainages are the Tippecanoe River, which enters Smalley Lake from the south, and an unnamed northern inlet, which drains into the lake from the north. The area of land that drains to each of these inlets are Smalley Lake's subwatersheds. Figure 4 shows the approximate subwatersheds for each of the tributaries to Smalley Lake. The Tippecanoe River subwatershed is approximately 15,578 acres (6,304 ha) in size, while the northern inlet subwatershed is approximately 1,126 acres (456 ha) in size (Table 1). A small portion of land (approximately 372 acres or 150 ha) drains directly to Smalley Lake without first entering one of the two inlets.

Table 1. Watershed and subwatershed sizes for the Smalley Lake watershed.

Subwatershed	Area (acres)	Area (hectares)	Percent of Watershed
Tippecanoe River	15,578	6,304	91.2%
Unnamed Northern Inlet	1,126	456	6.65%
Area adjacent to Smalley Lake	372	150	2.2%
Total Watershed	17,076	6,910	100%
Watershed to Lake Area Ratio	248:1		

Table 1 also provides the watershed area to lake area ratio for Smalley Lake. Watershed size and watershed to lake area ratios can affect the chemical and biological characteristics of a lake. For example, lakes with large watersheds have the potential to receive greater quantities of pollutants (sediments, nutrients, pesticides, etc.) from runoff than lakes with smaller watersheds. For lakes with large watershed to lake ratios, watershed activities can potentially exert a greater influence on the health of the lake than lakes possessing small watershed to lake ratios. Conversely, for lakes with small watershed to lake ratios, shoreline activities and internal lake processes may have a greater influence on the lake's health than lakes with large watershed to lake ratios.

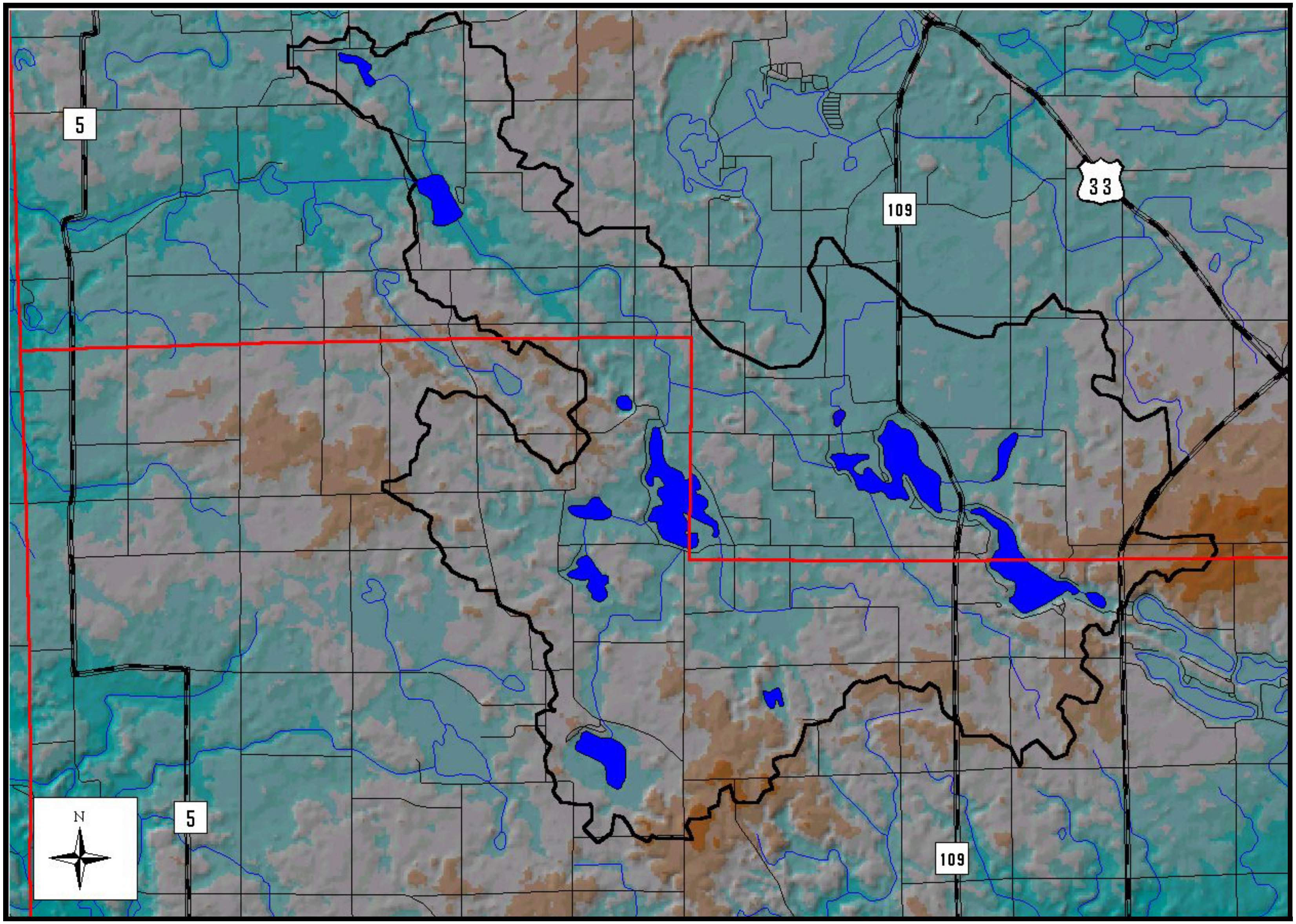

Figure 3. Topographical map of the Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1"=7,000'.

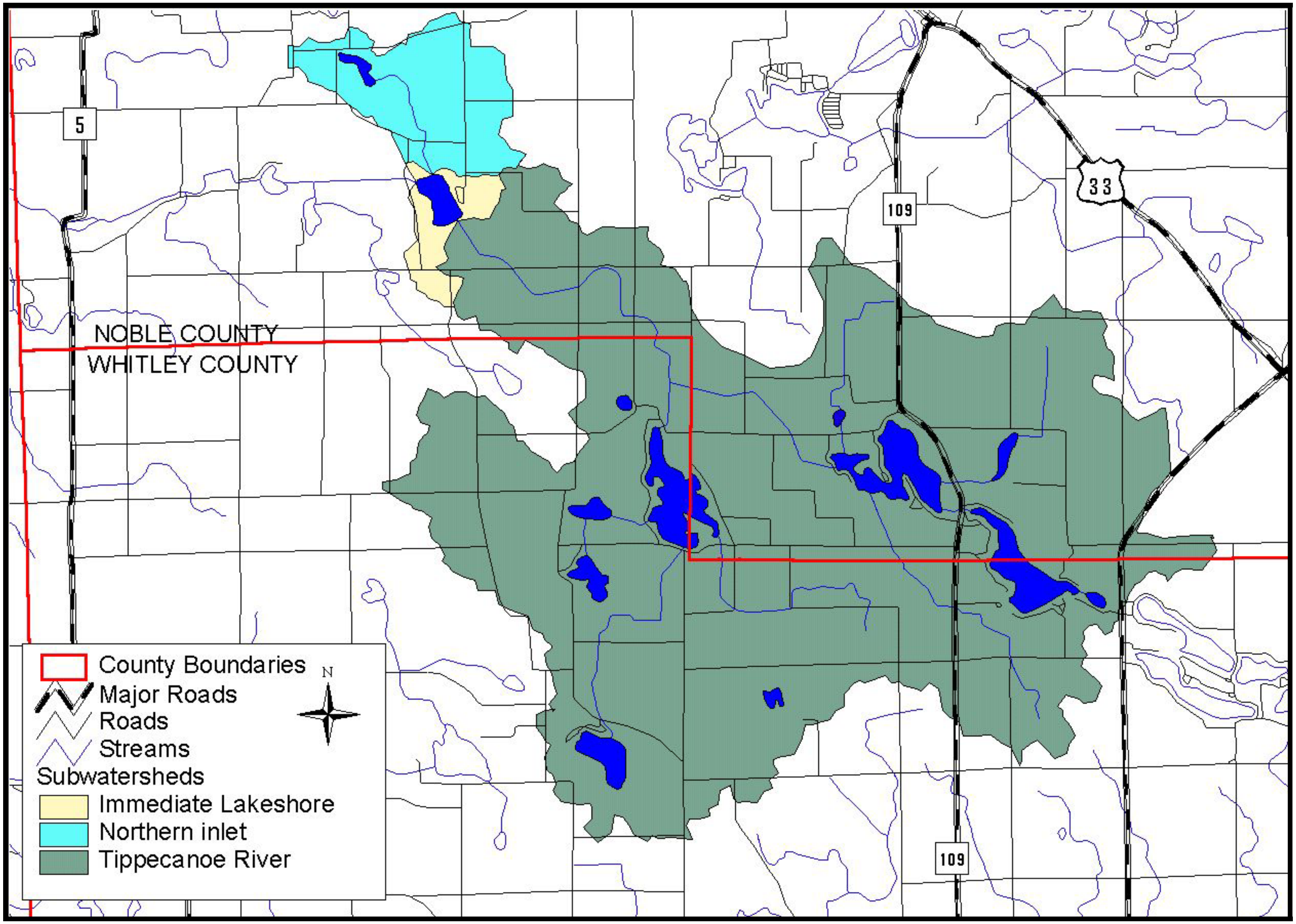

Figure 4. Smalley Lake subwatersheds.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1”=7,000’.

Smalley Lake possesses a watershed area to lake area ratio of approximately 248:1. This is an extremely large watershed area to lake area ratio. In other words, Smalley Lake has an extremely large watershed relative to the size of the lake. This watershed area to lake area ratio is well above the typical ratio for glacial lakes. Many glacial lakes have watershed area to lake area ratios of less than 50:1 and watershed area to lake area ratios on the order of 10:1 are fairly common. Smalley Lake's watershed area to lake area ratio is more typical of reservoirs, where the watershed area to reservoir area ratio typically ranges between 100:1 and 300:1 (Vant, 1987). As a result of Smalley Lake's high watershed area to lake area ratio, watershed activities can potentially exert a greater influence on the health of the lake than shoreline activities and in-lake processes.

2.2 Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. The National Climatic Data Center summarizes Indiana weather well in its 1976 Climatology of the United States document no. 60: "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds in Indiana are generally from the southwest but are more persistent and blow from a northerly direction during the winter months.

Smalley Lake Watershed Climate

The climate of the Smalley Lake watershed is characterized as having four well-defined seasons of the year. Winter temperatures average around 26º F (-3.3º C), while summers are warm, with temperatures averaging 70º F (21.1º C). The growing season typically begins in early April and ends in September. Yearly annual rainfall averages 38.52 inches (97.8 cm). Winter snowfall averages of about 30 inches (76.2 cm). During summers, relative humidity varies from about 60 percent in mid-afternoon to near 80 percent at dawn. Prevailing winds typically blow from the southwest except during the winter when westerly and northwesterly winds predominate. In 2003, almost 45 inches (114 cm) of precipitation (Table 2) was recorded at Columbia City, Indiana in Whitley County. When compared with 30-year average for the area, the 2003 annual rainfall exceeded the average by more than six inches (15 cm).

Table 2. Monthly rainfall data (in inches) for year 2003 as compared to average monthly rainfall. All data was recorded at Columbia City in Whitley County. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 at Columbia City (Purdue Applied Meteorology Group, 2002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2003	0.57	1.04	2.33	2.49	6.78	2.72	8.79	8.06	4.28	2.21	2.82	2.65	**44.74**
Average	2.12	1.80	2.90	3.67	3.70	4.44	3.82	3.58	3.52	2.80	3.31	2.86	**38.52**

2.3 Geology

The advance and retreat of the glaciers in the last ice age shaped much of the landscape found in Indiana today. As the glaciers moved, they laid thick till material over the northern two thirds of the state. Ground moraine left by the glaciers covers much of the central portion of the state. In the northern portion of the state, ground moraines, end moraines, lake plains, and outwash plains create a more geologically diverse landscape compared to the central portion of the state. End moraines, formed by the layering of till material when the rate of glacial retreat equaled the rate of glacial advance, add topographical relief to the landscape. Distinct glacial lobes, such as the Michigan Lobe, Saginaw Lobe, and the Erie Lobe, left several large, distinct end moraines, including the Valparaiso Moraine, the Maxinkuckee Moraine, and the Packerton Moraine, scattered throughout the northern portion of the state. Glacial drift and ground moraines cover flatter, lower elevation terrain in northern Indiana. Major rivers in northern Indiana cut through sand and gravel outwash plains. These outwash plains formed as the glacial meltwaters flowed from retreating glaciers, depositing sand and gravel along the meltwater edges. Lake plains, characterized by silt and clay deposition, are present where lakes existed during the glacial age.

Many of the above noted glacial geological features that are common in northern Indiana are found within the Smalley Lake watershed. The watershed's landscape is the result of movement by both the Saginaw glacial lobe from the northeast and the Erie glacial lobe from the east. Movement and stagnation of the Saginaw Lobe resulted in the deposition of the Packerton Moraine bordering the eastern/southeastern headwaters of the Smalley Lake watershed. (Figure 3 shows the greater relief of this morainal region along the eastern/southeastern edge of the watershed.) Fragments of the Packerton Moraine are also scattered across the western and southern edges of the watershed. Glacial drift material from the Saginaw Lobe covers flatter portions of the Smalley Lake watershed.

Later movement and stagnation of the Erie Lobe from the east deposited the Mississinewa and Salamonie Moraines near and south of the Packerton Moraine. The Packerton Moraine prevented movement of the Erie Lobe west across the Smalley Lake watershed and pushed the Erie Lobe southeasterly toward the center of the state. The headwaters of the Smalley Lake watershed lie in the interlobate region where the Packerton Moraine blends together with the Mississinewa and Salamonie Moraines. This overlapping of end moraines resulted in a complex mixture of tills. The sedimentary sequences in this interlobate region are said to be "unsurpassed in their variety and complexity" (IPFW, unpublished).

The movement of the two glacial lobes and the glacial materials they left behind are responsible for the diversity of landforms found in the Smalley Lake watershed today. The landscape's diversity is characteristic of the physiographic region in which the watershed lies, the Steuben Morainal Lake Area (Schneider, 1966). The headwaters of the watershed, where the Packerton, Mississinewa, and Salamonie Moraines merge, consists of knob and kettle physiography. Fragments of the Packerton Moraine to the west of the interlobate region became knob outcroppings composed of ice-contact sand and gravel deposits (kames). These kames dot the western and southern edges of the watershed. (Note the higher elevations in Figure 3 along the western edge and a few along the northern edge of the Smalley Lake watershed.) Glacial till also covers a portion of the Smalley Lake watershed. The flat area north of Big Lake is the largest expanse of land in the watershed covered by glacial till. Areas of outwash plains also exist in the Smalley Lake watershed.

This complex surficial geology covers a less complex bedrock foundation. Antrim shale lies under most of the Smalley Lake watershed. This bedrock shale is from the Devonian-Mississippian Period. Older Muscatatuck bedrock from the Devonian Period underlies a small portion of the southern and eastern edges of the watershed (Gutschick, 1966).

2.4 Soils

The Smalley Lake watershed's geological history described in the previous section determined the soil types found in the watershed and is reflected in the six major soil associations that cover the Smalley Lake watershed (Figure 5). The mixed till material associated with the Packerton, Mississinewa, and Salamonie Moraines consists largely of finer silt and clay particles. As a result, silty clay loam to clay loam soils developed on these terrains. Because either the moraines themselves or fragments of the moraines cover the headwaters of the Smalley Lake watershed as well as the western portion of the watershed, silt loam to clay loam soils cover most of these areas of the watershed. Many of these finer textured soils are Morley soils. As shown in Figure 5, Morley soils are the dominant component in three of the six soil associations covering the Smalley Lake watershed.

The surficial geology also shaped the soils found in other areas of the Smalley Lake watershed. The Haskins-Toledo association covers the area north of Big Lake. In this area, glacial drift material blankets the landscape. Soils that developed from the glacial drift have very fine (silty clay loam to silty clay) textured surface layers. Both Haskins and Toledo soils exhibit finely textured surface layers associated with glacial drift. Sandy outwash deposits also lie within the Smalley Lake watershed. These deposits developed into the sandy soils associated with the Fox-Oshtemo association. Finally, muck deposits occur in lower elevations of the Smalley Lake watershed. These deposits developed into the muck soils of the Houghton-Edwards-Adrian association.

Before detailing the major soil association covering the Smalley Lake watershed, it may be useful to examine the concept of soil associations. Major soil associations are determined at the county level. Soil scientists review the soils, relief, and drainage patterns on the county landscape to identify distinct proportional groupings of soil units. The review process typically results in the identification of 8 to 15 distinct patterns of soil units. These patterns are the major soil associations in the county. Each soil association typically consists of two or three soil units that dominate the area covered by the soil association, and several soil units that occupy only a small portion of the soil association's landscape. Soil associations are named for their dominant components. For example, the Fox-Oshtemo association consists primarily of Fox sandy loam and Oshtemo loamy sand.

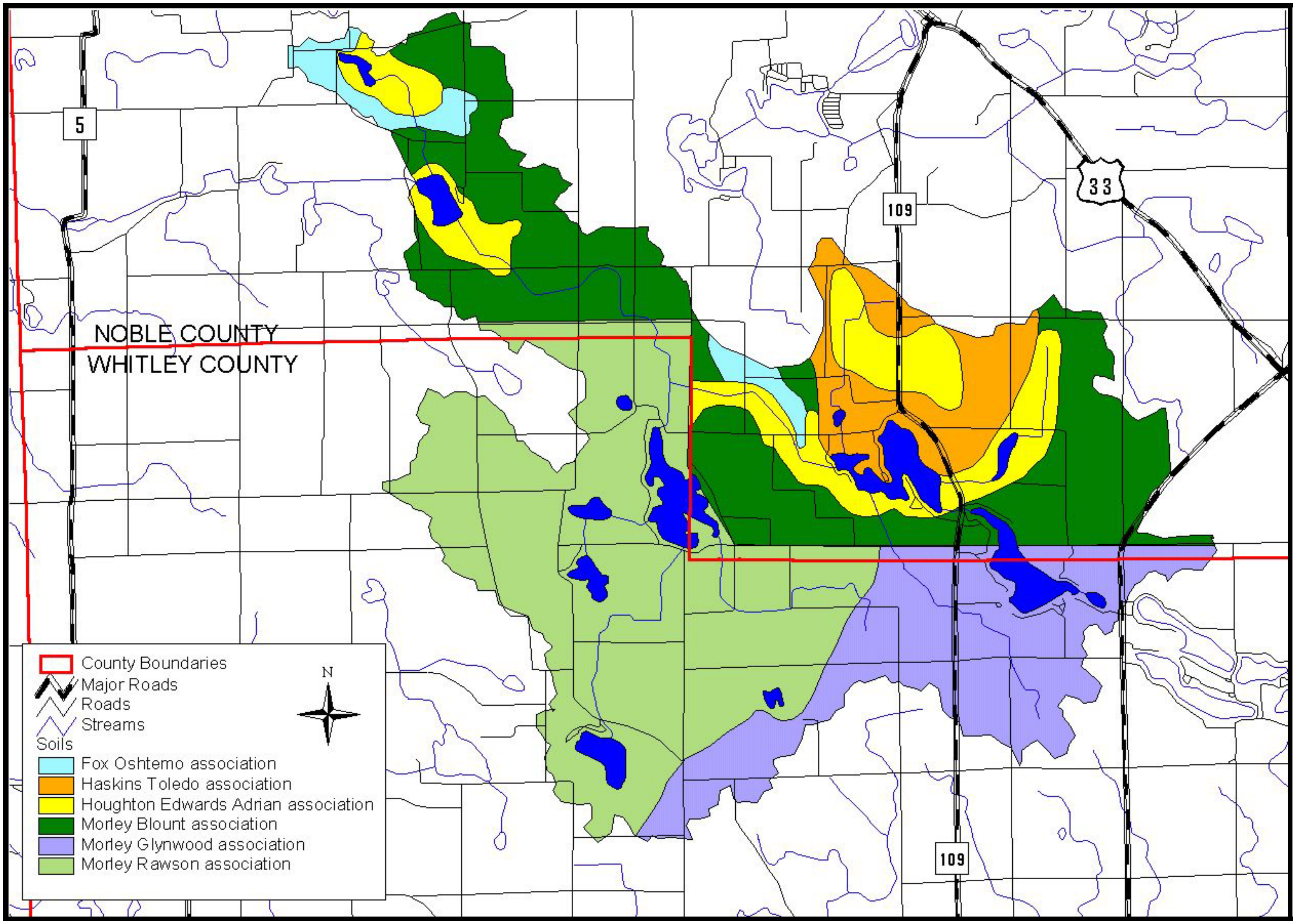

Figure 5. The major soil associations covering the Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1"=7,000'.

Because soil scientists developed soil association maps at different times, soil associations in one county are not always consistent with soil associations in an adjacent county. Ruesch (1990) points to three reasons for the differences observed in soil association maps published at different times: 1. changes in the concepts of soil series occur; 2. variations in the extent of the soils occur; and 3. variations in the slope range allowed in the association occur. Differences between county soil association maps can be the result of one or more of these reasons.

The Noble County and Whitley County soil association maps were published at different times. The Noble County Soil Survey (McCarter, 1977) was issued in 1977, while the Whitley County Soil Survey (Ruesch, 1990) was published thirteen years later. Consequently, soil associations in these counties do not agree with one another. Because the Smalley Lake watershed encompasses part of both counties, the soil associations covering the watershed end abruptly at the county line (Figure 5).

Despite the fact that several of the major soil associations of the Smalley Lake watershed end abruptly at the Noble County/Whitley County line, adjacent soil associations are somewhat similar in composition. In Noble County, the Morley-Blount soil association lies along most of the county line. The Morley-Glynwood and Morley-Rawson soil associations lie directly south of the Morley-Blount soil association on the Whitley County side of the watershed. Morley soils dominate all three of these soil associations, accounting for 45-51% of each association. The other major component of each of these soil associations accounts for no more than 13% of the association. In essence, the dominance of Morley soils spreads across the two counties.

Six major soil associations cover the Smalley Lake watershed (Figure 5). Four of these soil associations, Morley-Blount, Houghton-Edwards-Adrian, Fox-Oshtemo, and Haskins-Toledo, lie within the Noble County portion of the Smalley Lake watershed. The Morley-Blount association covers a large portion of the Smalley Lake watershed in Noble County. This association is the most common soil association found in the Noble County, covering approximately 35% of the county landscape. The other three soil associations are less common in the Smalley Lake watershed and less common in Noble County. Fox-Oshtemo, Houghton-Edwards-Adrian, and Haskins-Toledo soil associations cover 15%, 10%, and 2% of the county, respectively (McCarter, 1977).

The Morley-Blount association covers a large portion of the Smalley Lake watershed in Noble County. Soils in this association reflect of geological heterogeneity that is characteristic of morainal depositional areas. Soils in the Morley-Blount association range from well drained to somewhat poorly drained and are found on nearly level to moderately sloping landscapes. Soils in this soil association typically cover fine textured (clay loam) to moderately fine textured (silt loam) subsoil. Morley and Blount soils comprise approximately 60% of the soil association. Morley soils lie on knolls and along drainageways, while Blount soils occupy lower elevation flats and drainages. Minor soil units in the association include Pewamo silty clay loam, Washtenaw silt loam, Rawson loam, Milford silty clay loam, Haskins loam, and Shoals silt loam. Erosion is a noted problem on Morley soils, and, in general, the soils in this association are severely limited in their use as a septic tank absorption field.

Soils in the Houghton-Edwards-Arian association cover the areas around Smalley, Gilbert, and Big Lakes and follow a portion of the Tippecanoe River and its tributaries. This soil association also exists in a depressional area in the northeast corner of the watershed. Very poorly drained, nearly level muck soils dominate the Houghton-Edwards-Adrian association. These soils developed from partially decayed organic matter than accumulated in depressional areas of the county. In general, Houghton soils account for roughly 60% of the total soils in the association; Edwards soils account for 12%, while Adrian soils make up 7% of the association. Minor components of the association include Walkill silt loam, Palms muck, Gilford sandy loam, and Sebewa loam. Houghton soils tend to be very deep, while Edwards and Adrian soils are deep to moderately deep. Edwards soils overlay marl deposits; Adrian soils cover sandy and gravelly outwash. When drained, soils in this association may be utilized for agriculture; however, undrained soils in the Houghton-Edwards-Adrian association often hold water and serve best as wetland habitat. Soils in this association typically have severe limitations for use as a septic system absorption field.

The Fox-Oshtemo soil association covers only a small portion of the Smalley Lake watershed. The soil association is found surrounding the Houghton-Edwards-Adrian soil association around Gilbert Lake in the northwest corner of the watershed and just north of the Tippecanoe River downstream of Big Lake. This soil association consists largely of Fox soils (60%) and Oshtemo soils (15%). Both soils possess sandy loam, clay loam, sandy clay loam, or loamy sand textures and overlay sand and gravelly sand subsoil layers. Both soils are also common on outwash plains and upland knolls on the landscape. Minor components of this soil association include Boyer loamy sand, Casco sandy clay loam, Homer loam, Riddles sandy loam, and Sebewa loam soils. Erosion can be a concern with this soil association in sloping areas. In contrast to the other soil associations covering the Noble County portion of the Smalley Lake watershed, however, Fox-Oshtemo soils are only slightly limited in their ability to serve as a septic tank absorption field.

The Haskins-Toledo soil association is relatively uncommon in Noble County covering only 2% of the county. This soil association is found in the northeast portion of the Smalley Lake watershed adjacent to and north of Big Lake. Somewhat poor to very poor drainage capacity characterizes this soil association. Soils in this association are typically found on flats and in depressional areas. Haskins soils comprise 50% of the soil association, while Toledo soils comprise about 25% of the association. Haskins soils are on flats and in drainageways in uplands and on outwash plains. Surface layers of Haskins soils are loamy and finer textured (silty clay loam and silty clay) below the surface layer. Toledo soils are tighter than Haskins soils reducing the drainage capacity of Toledo soils. Toledo soils consist of a silty clay loam surface layer over silty clay subsurface and substratum. Minor components in the Haskins-Toledo soil association include Fulton silt loam, Rawson sandy loam and loam, and Milford silty clay loam soils. The poor drainage capacity of Haskins-Toledo soils severely limits this soil association's ability to serve as a septic tank absorption field.

Two major soil associations, Morley-Rawson and Morley-Glynwood, cover the Whitley County portion of the Smalley Lake watershed. Soils in the southwestern portion of the Smalley Lake watershed belong to the Morley-Rawson association, while the southeastern portion of the watershed lies in the Morley-Glynwood association. Combined, these two soil associations cover nearly 40% of the county (Ruesch, 1990).

The Morley-Rawson soil association covers the southwestern portion of the Smalley Lake watershed. Like the soils in the Morley-Blount soil association in the Noble County portion of the Smalley Lake watershed, soils in the Morley-Rawson soil association reflect of geological heterogeneity of the landscape. Ruesch (1990) notes that "the association is on hills and ridges and in ravines and depressions." These soils developed in glacial till and loamy outwash over glacial till. Fine textured silty clay loam and clay loam glacial till underlies much of this association. Morley soils comprise the dominant portion (45%) of the soil association. Morley soils are well drained and located on gentle to steep slopes. Surface layers of Morley soils are loamy to clay loam in texture, while the subsoil has a clayey and clay loam texture. Rawson soils account for 13% of the Morley-Rawson soil association. They are similar in texture to Morley soils but have more sand in them than Morley soils. Minor soil units in the Morley-Rawson soil association include Blount silt loam, Coesse silty clay loam, Glynwood loam and clay loam, Haskins loam, Houghton muck, Muskego muck, Pewamo silty clay loam, and Seward loamy fine sand soils. Generally, the minor components of the soil association are less well drained than the major components. Erosion is a concern in the Morley-Rawson soil association, and slope, permeability, and wetness severely limit the use of soils in this association for septic tank absorption fields.

The Morley-Glynwood soil association covers the southeastern portion of the Smalley Lake watershed. This soil association is very similar in composition to the Morley-Rawson soil association. Like the Morley-Rawson soil association, the Morley-Glynwood soil association is found on a variety of landscape features common to glacial till plains and moraines including hills, ridges, ravines, and depressions. Soils in the Morley-Glynwood soil association developed in glacial till. Morley soils are the dominant component of the Morley-Glynwood soil association accounting for just over 51% of the total acreage. Glynwood soils comprise about 9% of the soil association. Glynwood soils are moderately well drained soils found on gentle to moderate slopes. The surface layer of Glynwood soils is similar to Morley soils. The subsoil of Glynwood soils consists largely of clay. Minor soil units in the Morley-Glynwood soil association include Blount silt loam, Hennepin loam, Houghton muck, Martisco muck, Milford silty clay loam, Pewamo silty clay loam, Rawson sandy loam, and Seward loamy fine sand soils. Like the Morley-Rawson soil association, erosion is a concern and soils in the Morley-Glynwood soil association are severely limited in their ability to serve as septic tank absorption fields.

Soils in the watershed, and in particular their ability to erode or sustain certain land use practices, can impact the water quality of lakes and streams in the watershed. The dominance of Morley soils across the Smalley Lake watershed suggests much of the watershed is prone to erosion; common erosion control methods should be implemented when the land is used for agriculture or during residential development to protect waterbodies in the Smalley Lake watershed. Similarly, very poorly drained soils in the Houghton-Edwards-Adrian association cover the areas adjacent to many of the watershed's lakes. These areas are also the ones that are most likely to be developed for residential use and therefore utilize septic systems (and the soil) to treat residential waste. The coupling of high density residential land use with soils that are poorly suited for treating septic tank effluent is of concern for water quality in the Smalley Lake watershed. More detailed discussion of highly erodible soils and soils used to treat septic tank effluent in the Smalley Lake watershed follows below.

2.4.1 Highly Erodible Soils

Soils that erode from the landscape are transported to waterways where they degrade water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals, like some herbicides and pesticides, can kill aquatic life and damage water quality.

Highly erodible and potentially highly erodible are classifications used by the Natural Resources Conservation Service (NRCS) to describe the potential of certain soil units to erode from the landscape. The NRCS examines common soil characteristics such as slope and soil texture when classifying soils. The NRCS maintains a list of highly erodible soil units for each county. Table 3 lists the soil units in the Smalley Lake watershed that the NRCS considers to be highly erodible. Table 3 can be cross referenced with the county soil surveys to locate highly erodible soils on the Smalley Lake watershed landscape.

Highly erodible and potentially highly erodible soil units cover much of the Smalley Lake watershed. Mapping work completed as part of Purdue University's Upper Tippecanoe River Hydrologic Unit Area Project shows that the majority of the highly erodible and potentially highly erodible soils lie in the river's headwaters. These soils are particular dominant in the northwestern portion of the Tippecanoe River's headwaters, which corresponds with the Smalley Lake watershed area.

The geology of the Smalley Lake watershed makes the area particularly susceptible to erosion. The watershed's headwaters lie within a glacial interlobate region where the Packerton Moraine blends together with the Mississinewa and Salamonie Moraines. This creates a landscape that is diverse in topography and geological composition. Fragments of the Packerton Moraine scattered across the lower portion of the watershed add topographical relief to the landscape. The relatively steep slopes that exist across the Smalley Lake watershed (compared to flatter areas in the Upper Tippecanoe River watershed) create conditions ideal for erosion. The glacial drift material covering the landscape is also easily eroded since it is primarily composed of fine textured material such as clay and clay loams. This geological history increases the erosion potential of the Smalley Lake watershed.

Table 3. Highly erodible and potential highly erodible soils units in the Smalley Lake watershed.

County	Soil Unit	Status*	Soil Name	Soil Description
Noble	BlB2	PHES	Blount silt loam	2-4% slopes, eroded
Noble	BoB-BoC	PHES	Boyer loamy sand	2-12% slopes
Noble	BoD2	HES	Boyer loamy sand	12-18% slopes, eroded
Noble	CcC3	HES	Casco sandy clay loam	8-15% slopes, severely eroded
Noble	ChC	PHES	Chelsea fine sand	2-6% slopes
Noble	FoB	PHES	Fox sandy loam	2-6% slopes
Noble	FoC2	PHES	Fox sandy loam	6-12% slopes, eroded
Noble	FsD2-FsE2	HES	Fox-Casco sandy loam	18-25% slopes, eroded
Noble	MfB2	PHES	Miami loam	2-6% slopes, eroded
Noble	MfD2-MfE2	HES	Miami loam	12-18% slopes, eroded
Noble	MgC3-MgD3	HES	Miami clay loam	6-18% slopes, severely eroded
Noble	MhB2	PHES	Miami loam, gravelly substratum	2-6% slopes, eroded
Noble	MrB2-MrC2	PHES	Morley silt loam	2-12% slopes, eroded
Noble	MrB2-MrD2	HES	Morley silt loam	12-18% slopes, eroded
Noble	MsC3-MsD3	HES	Morley silty clay loam	6-18% slopes, severely eroded
Noble	MtE	HES	Morley soils	18-25% slopes
Noble	MuC2	PHES	Morley, Miami, Rawson loams	6-12% slopes, eroded
Noble	OsB, OsC	PHES	Oshtemo loamy sand	2-12% slopes
Noble	RaB	PHES	Rawson sandy loam	2-6% slopes
Noble	RaC2	PHES	Rawson sandy loam	6-12% slopes, eroded
Noble	RdB2	PHES	Rawson, Morley, and Miami loams	2-6% slopes, eroded
Noble	RsB	PHES	Riddles sandy loam	2-6% slopes
Noble	RsC2-RsD2	HES	Riddles sandy loam	2-12% slopes, eroded
Whitley	BmB2	PHES	Blount silt loam	1-4% slopes, eroded
Whitley	BvC	PHES	Boyer loamy sand	2-6% slopes
Whitley	BvD	HES	Boyer loamy sand	6-12% slopes
Whitley	BwA-BwC	PHES	Boyer sandy loam	0-12% slopes
Whitley	Fu	PHES	Fulton silty clay loam	
Whitley	GsB2	PHES	Glynwood loam	3-6% slopes, eroded
Whitley	GsB3	HES	Glynwood clay loam	3-8% slopes, severely eroded
Whitley	HbA	HES	Haskins loam	0-3% slopes
Whitley	KaA	PHES	Kalamazoo sandy loam	0-2% slopes
Whitley	MbB-MbC	PHES	Martinsville loam	1-15% slopes
Whitley	MmB2-MmC2	PHES	Miami sandy loam	2-12% slopes
Whitley	MvB2	PHES	Morley loam	3-6% slopes, eroded
Whitley	MxC3	PHES	Morley clay loam	5-12% slopes, severely eroded
Whitley	RcB-RcC	PHES	Rawson sandy loam	2-12% slopes
Whitley	RhB-RhC	PHES	Riddles sandy loam	1-12% slopes
Whitley	SfC	PHES	Seward loamy fine sand	6-15% slopes
Whitley	SpC	PHES	Spinks sand	6-15% slopes
Whitley	WmC	PHES	Wawasee sandy loam	6-15% slopes
Whitley	Wt	PHES	Whitaker loam	

* PHES=Potentially highly erodible soil; HES=Highly erodible soil
Source: 1988 USDA/SCS Indiana Technical Guide Section II-C for Noble County; 1988 USDA/SCS Indiana Technical Guide Section II-C for Whitley County.

2.4.2 Soils Used for Septic Tank Absorption Fields

Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in many areas of Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment around Smalley Lake and other lakes in the Smalley Lake watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination. The soil's ability to sequester and degrade pollutants in septic tank effluent will ultimately determine how well surface and groundwater is protected.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area; the chemical properties of the surfaces; soil conditions like temperature, moisture, and oxygen content; and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing the larger pores in the profile. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb bacteria and viruses, but retention is not necessarily permanent. During storm flows, bacteria and viruses may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

Taking into account the various factors described above, NRCS has ranked each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields in moderately or severely limited soils generally requires special design, planning, and/or maintenance to overcome the limitations and ensure proper function.

While all septic system use in the Smalley Lake watershed has the potential to impact the water quality of Smalley Lake, the ability of the soil immediately adjacent to Smalley Lake to treat septic effluent has a more direct effect on Smalley Lake's water quality than the ability of the soil in other areas of the watershed to treat septic effluent does. Therefore the following discussion focuses on the soils adjacent to Smalley Lake.

Figure 6 shows the soil units surrounding Smalley Lake, while Table 4 summarizes the soils' suitability for use as septic tank absorption fields. Following Table 4 and Figure 6 is a short description of the soils listed in the table.

Table 4. Soil types adjacent to Smalley Lake and their suitability to serve as a septic tank absorption field.

Symbol	Name	Depth to High Water Table	Suitability for Septic Tank Absorption Field
Ed, Em	Edwards muck	0-1 ft	Severe: high water table, subject to ponding
MrC2	Morley silt loam	3-6 ft	Severe: slope, slow permeability, seepage at the base of slopes
MsC3, MsD3	Morley silty clay loam	3-6 ft	Severe: slow permeability, slope, seepage at the base of slopes
RaB	Rawson sandy loam	3-6 ft	Severe: slow to very slow permeability
RbB	Rawson loam	3-6 ft	Severe: slow to very slow permeability
Wa	Wallkill silt loam	0-1 ft	Severe: seasonal high water table, ponding
Ws	Washtenaw silt loam	0-1 ft	Severe: seasonal high water table, subject to ponding, percs slowly

Source: McCarter, 1977.

Figure 6. Soil series bordering Smalley Lake.
Source: McCarter, 1977. Scale: 1”=1,320’

Edwards muck soils (Ed, Em) are poorly drained, organic soils found in depressional areas and on outwash plains. Typically, these soils are located adjacent to lakes and streams. Shallow water generally covers them for some portion of the year. McCarter (1977) characterizes these soils as optimal for wildlife habitat but poor for all other uses. These soils are absolutely unsuited for sanitary facilities due to ponding and permeability issues. Because these soils generally occupy some of the lowest points on the landscape, pumping systems are necessary for adequate drainage.

Morley silt loams (MrC2) are found on gently to strongly sloping hillsides of uplands. Fluid movement through the soil type is moderately slow. The slow permeability and wetness issues generally inhibit complete waste treatment. The slow permeability of Morley soils is a result of soil formation and aging processes. When Morley silt loams are located along steep slopes, slope can also pose problems for proper septic field function. It is important to note that Morley silt loams border the eastern shoreline of Smalley Lake where most of the development around Smalley Lake has occurred.

Morley silty clay loams (MsC3, MsD3) are moderately to strongly sloping, well drained, and easily erodible. Potential limitations for sanitary facilities include: slow permeability, wetness, and seepage of effluent at the base of slopes. Special engineering techniques may be necessary to overcome limitations.

The Rawson (RaB, RaC2) soil series is found on ridge tops, knolls, and slopes. Permeability decreases with depth. Enlarged absorption fields are usually required to overcome slow permeability and wetness limitations.

Wallkill silt loam (Wa) soils formed in wetlands, and because they typically occupy depressional areas, shallow water generally covers them at some time during the year. The water table is typically near the soil surface in winter and spring months. Proper septic system function in Wallkill silt loam soils is severely limited because the soil tends to remain wet and does not readily absorb liquid waste.

Washtenaw silt loams (Wh) are limited for on-site sanitary facilities for many of the same reasons already discussed. The soil tends to occupy low-lying areas and tends to be ponded with runoff following rain events. Additionally, slow permeability may limit the proper treatment of liquid waste.

As shown in Table 4, all of the soils surrounding Smalley Lake are severely limited in their use as a septic tank absorption field. Currently, most of the residences exist along the eastern shoreline where soils are mapped in Morley silty clay loam and Rawson loam. Septic fields placed in these soils typically require larger leach fields to overcome the slow permeability of these soils. Unfortunately, enlarging the existing septic leach fields or creating new leach fields if sufficient room exists may be too costly. At a minimum, residents in existing homes should take steps to properly care for their septic systems such as pumping their septic tanks annually, avoiding the disposal of household chemicals that may kill soil bacteria, and implementing water conservation measure to alleviate strain on the system.

New homes are being built in the northeast corner of the lake. Soil units in this area include Morley silty clay loam, Rawson loam, and Rawson sandy loam. The septic fields servicing these new homes should be enlarged to overcome the slow permeability associated with these soils. Additionally, residents in the new homes should follow the same proper care guidelines noted above for residents of existing homes. Residential development should be prohibited along the western and southern shorelines where Edwards muck is mapped. This soil unit is unsuitable for use as a septic tank absorption field.

2.5 Land Use

The study watershed is located in the central portion of the Northern Lakes Natural Region (Homoya et al., 1985). The Northern Lakes Natural Region occupies the north central and northeastern area of the state and is bordered by the Eel River on the southeast and the western side of the Maxinkuckee Moraine on the west. Prior to European settlement, the region was a mixture of numerous natural community types including bog, fen, marsh, prairie, sedge meadow, swamp, seep spring, lake and deciduous forest (Homoya et al., 1985). The dry to dry-mesic uplands were likely forested with red oak, white oak, black oak, shagbark hickory, and pignut hickory. More mesic areas probably harbored beech, sugar maple, black maple, and tulip poplar with sycamore, American elm, red elm, green ash, silver maple, red maple, cottonwood, hackberry, and honey locust dominating the floodplain forests.

Land use across the Smalley Lake watershed has changed over the past two centuries. Table 5 and Figure 7 present current land use information for the Smalley Lake watershed. Land use data from the U.S. Geological Survey (USGS) forms the basis of Figure 7. In the Indiana Land Cover Data Set, the USGS defines high intensity residential areas as areas with high densities of multi-family residences (apartment complex, condominiums, etc.). Hardscape covers approximately 80-100% of the landscape in the high intensity residential land use category. Low intensity residential areas consist largely of single family homes; hardscape covers only 30-80% of the landscape.

Table 5. Detailed land use in the Smalley Lake watershed.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed
Row crop agriculture	11,067.8	4,480.9	64.8%
Pasture/hay	2,450.8	992.2	14.4%
Deciduous forest	1,802.9	729.9	10.6%
Open water	1,034.0	418.6	6.1%
Woody wetlands	410.8	166.3	2.4%
Emergent herbaceous wetlands	133.0	53.8	0.8%
Low intensity residential	119.6	48.4	0.7%
Evergreen forest	35.2	14.3	0.2%
High intensity commercial	14.0	5.7	0.1%
High intensity residential	6.4	2.6	<0.1%
Mixed forest	1.9	0.8	<0.1%
Total	**17,076.3**	**6,913.5**	**100.0%**

Agricultural land use dominates the Smalley Lake watershed. Row crops cover nearly 65% of the watershed while pastures or hay vegetate another 15%. Most of the agricultural land in the Smalley Lake watershed is used for growing grain corn and soybeans. County wide tillage transect data for Noble and Whitley Counties provides an estimate for the portion of cropland in conversation tillage for the Smalley Lake watershed. Producers in Whitley County utilized no-till methods on 22% and some form of reduced tillage methods on 43% of corn fields. In Noble County, corn producers utilized no-till methods on 35% and some form of reduced tillage methods on 22% of corn fields. Usage of no-till methods on corn fields in these two counties was below the statewide median percentage of acreage in no-till. In contrast, soybean producers in Whitley County utilized no-till methods on nearly 80% and some form of reduced tillage methods on 15% of the soybean fields in production. Whitley County ranked 8th in the state for use of conservation tillage on soybean fields. Soybean tillage transects in Noble County found similar percentages for that county (Purdue University and IDNR, no date).

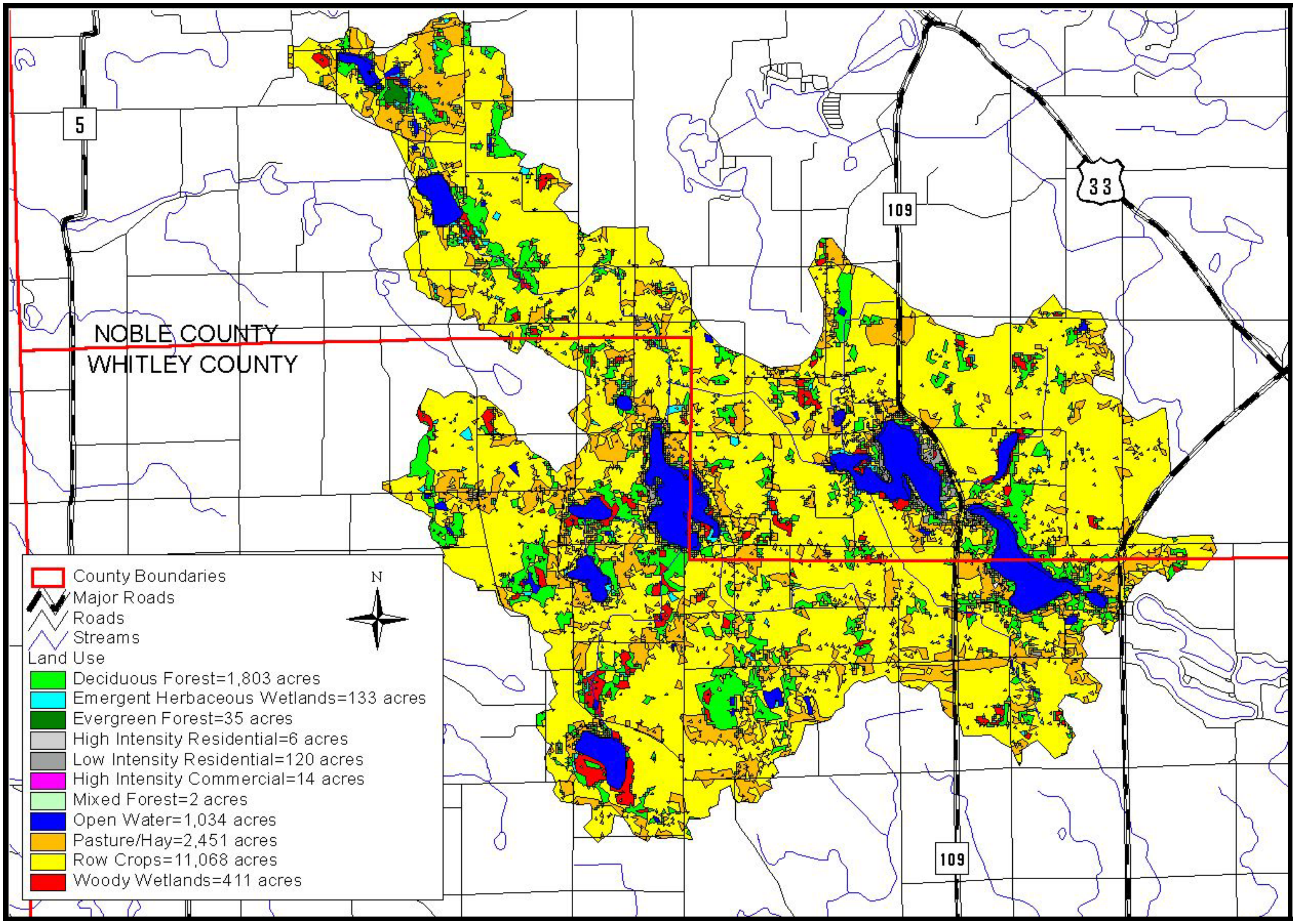

Figure 7. Land use in the Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1”=7,000’.

Land uses other than agricultural occupy only 20% of the watershed. Natural landscapes including forested areas and wetlands account for approximately 14% of the watershed. Most of the natural areas are contained in forested tracts adjacent to Loon Lake, in the Crooked Lake Nature Preserve on the northeastern shore of Crooked Lake, and along the Tippecanoe River southeast of Smalley Lake. Additional independent forested tracts are scattered throughout the southern and southeastern portion of the watershed, while one contiguous forested-wetland complex encompasses Goose Lake in the southern part of the watershed (Figure 7). Open water in the form of Smalley, Crooked, Big, Loon, and Goose Lakes accounts for another 6% of the watershed. A negligible area (<1%) of the Smalley Lake watershed is utilized for residential and commercial uses.

Land use in the Smalley Lake watershed is similar to land use across the region. The Smalley Lake watershed supports a slightly higher percentage of land in agricultural use (80%) compared to the Upper Tippecanoe River watershed (76%), Noble County (69%), and Whitley County (77%) (TELWF, 2002 and U.S. Census of Agriculture, 1999). The Upper Tippecanoe River watershed is the area of land draining to the Lake Oswego outlet. In contrast, wetlands cover a smaller percent of the Smalley Lake watershed (3.2%) than the Upper Tippecanoe River watershed (5%). The percentage of forested land in the Smalley Lake watershed is nearly equivalent to the percentage of forested land in the Upper Tippecanoe River watershed.

2.6 Wetlands

Because wetlands perform a variety of functions in a healthy ecosystem, they deserve special attention when examining watersheds. Functioning wetlands filter sediments and nutrients in runoff, store water for future release, provide an opportunity for groundwater recharge or discharge, and serve as nesting habitat for waterfowl and spawning sites for fish. By performing these roles, healthy, functioning wetlands often improve the water quality and biological health of streams and lakes located downstream of the wetlands.

In general, wetlands, including lake systems, cover roughly 10% of the Smalley Lake watershed. The USGS Land Cover Data Set suggests that wetlands cover approximately 3.2% of the Smalley Lake watershed and open water covers an additional 6.1% of the watershed (Table 5). The United States Fish and Wildlife Service's National Wetland Inventory Map (Figure 8) shows that wetlands cover approximately 13% of the Smalley Lake watershed. (Table 6 presents the acreage of wetlands by type according to the National Wetland Inventory.) The differences in reported wetland acreage in the Smalley Lake watershed reflect the differences in project goals and methodology used by the different agencies to collect land use data.

Table 6. Acreage and classification of wetland habitat in the Smalley Lake watershed.

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed
Lake	863.0	349.4	5.1%
Emergent	632.7	256.1	3.7%
Forested	510.0	206.5	3.0%
Pond	110.9	44.9	0.6%
Shrubland	73.4	29.7	0.4%
Submergent	4.3	1.7	<0.1%
Total	**2,194.1**	**888.3**	**12.9%**

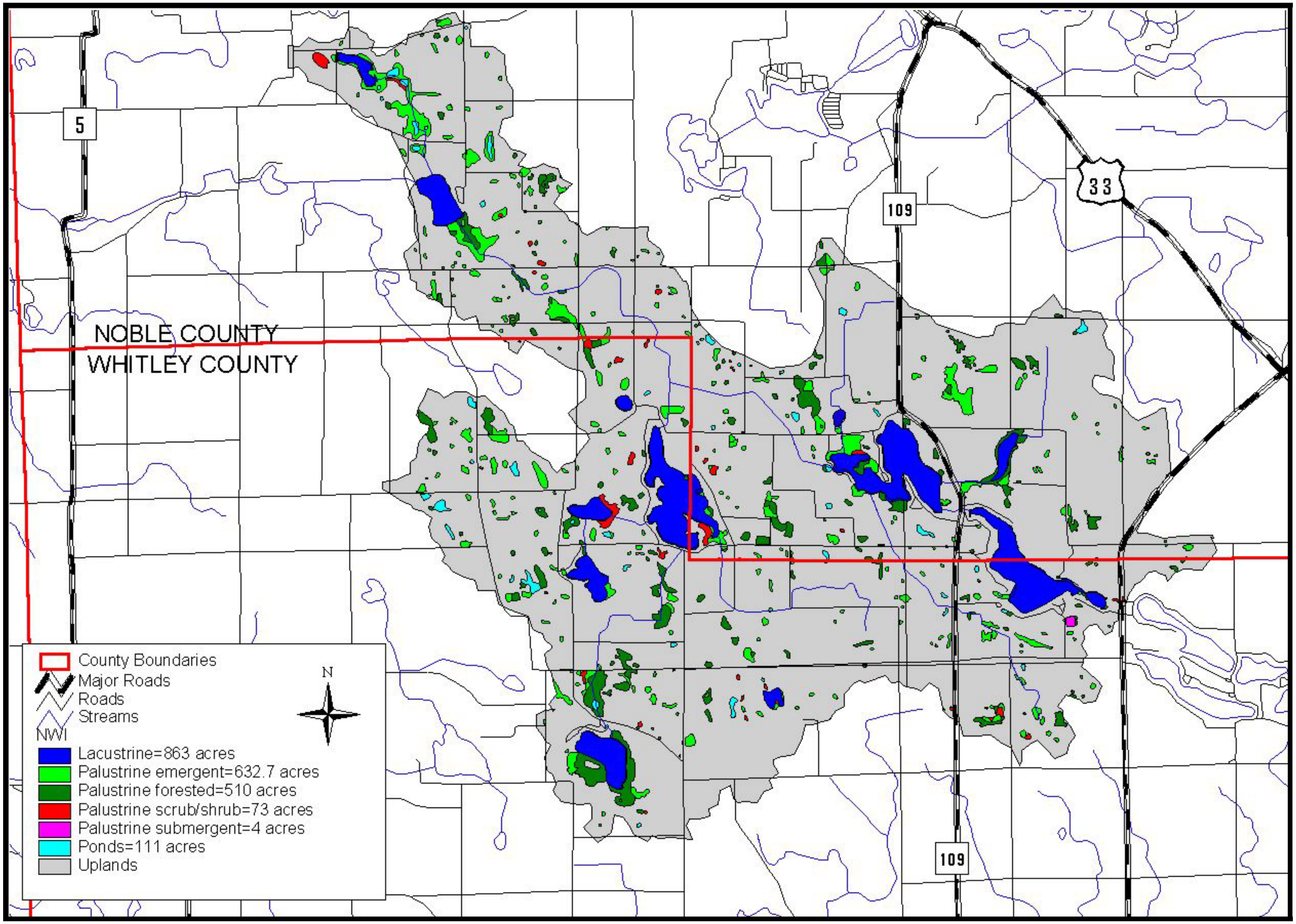

Figure 8. Wetlands in the Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1"=7,000'.

The IDNR estimates that approximately 85% of the state's wetlands have been filled (Indiana Wetland Conservation Plan, 1996). The greatest loss has occurred in the northern counties of the state such as Noble and Whitley Counties. The last glacial retreat in these northern counties left level landscapes dotted with wetland and lake complexes. Development of the land in these counties for agricultural purposes altered much of the natural hydrology, eliminating many of the wetlands. The 1978 Census of Agriculture found that drainage is artificially enhanced on 35% and 45% of the land in Noble and Whitley Counties, respectively (cited in Hudak, 1995). Shoreline development around lakes has also significantly reduced wetland acreage.

2.7 Natural Communities and ETR Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species; high quality natural communities; and natural areas in Indiana. The Indiana Department of Natural Resources developed the database to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the IDNR. Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed in a specific location.

Appendix B presents the results from the database search for the Smalley Lake watershed. (For additional reference, Appendix C provides a listing of endangered, threatened, and rare species documented in Noble and Whitley Counties.) The database records the presence of significant natural areas within the Smalley Lake watershed. Three of these areas lie in the southeastern portion of the watershed within the Crooked Lake Nature Preserve, one is located within the Merry Lea Nature Preserve east of Smalley Lake, and two are located north of Big Lake. The Crooked Lake Nature Preserve supports three of these significant natural areas including a lake, a dry-mesic upland forest, and an upland mesic forest. The Merry Lea Nature Preserve also supports dry-mesic upland forest habitat. The two remaining significant areas, a forested fen and a bog, lie within the wetland complex on the north side of Big Lake.

The habitat within the watershed supports, or at least historically supported, one state endangered animal species, the blanding's turtle (*Emydoidea blandingii*), one species of special concern, the cisco (*Coregonus artedi*), and one species of special interest, the great blue heron (*Ardea herodias*). The database locates the blanding's turtle within the Crooked Lake Nature Preserve, the cisco within Crooked Lake, and the great blue heron southwest of New Lake. The database indicates that sightings of all three species occurred fairly recently, 1992, 1997, and 1993, respectively; cisco were also noted in Crooked Lake in 1945.

The database also documents the occurrence of eleven state endangered plant species in the watershed. Three of these species, creeping sedge (*Carex chordorrhiza*), mud sedge (*Carex limosa*), and Fries' pondweed (*Potamogeton friesii*), were observed in 1917 west of Goose Lake. The database documents wild calla (*Calla palustris*) and Illinois hawthorn (*Crataegus prona*) along State Road 109 southeast of Big Lake. Both of these state endangered plant listings are quite old occurring in 1900 and 1935, respectively. The database also lists five state endangered plant species within the Crooked Lake Nature Preserve along the south side of Crooked Lake. Some of the plant observations are quite old like Fries' pondweed (*Potamogeton friesii*, 1962), and straight-leaf pondweed (*Potamogeton strictifolius*, 1962), while other observations occurred more recently like whitestem pondweed (*Potamogeton praelongus*, 1985), horsetail spikerush (*Eleocharis equisetoides*, 1982), and lesser bladderwort (*Utricularia minor*, 1982). The remaining two species were observed in the northeastern portion of the watershed; observation of American scheuchzeria (*Scheuchzeria palustris*) occurred in 1938 on the northwest side of Gilbert Lake near the intersection of County Road 950 West and Gilbert Lake Road, while bristly sarsaparilla (*Aralia hispida*) was observed in 1980 within the boundaries of the Merry Lea Nature Preserve southwest of Bear Lake. The database contains ten additional plant records including six state threatened species and four state rare species. Most of the species sightings are old like slender cotton-grass (*Eriophorum gracile*, 1917), Atlantic sedge (*Carex atlantica atlantica*, 1917), bog rosemary (*Andromeda glaucophylla*, 1920), shining ladies' tresses (*Spiranthes lucida*, 1924 and 1929), small cranberry (*Vaccinium oxycoccos*, 1935), small purplefringe orchid (*Platanthera psycodes*, 1935), horned bladderwort (*Utricularia cornuta*, 1938), marsh arrow-grass (*Triglochin palustris*, 1938), and slim spike three awn grass (*Aristida intermedia*, 1945) while only one sighting, flatleaf pondweed (*Potamogeton robbinsii*, 1962), occurred more recently.

3.0 STREAM ASSESSMENT

3.1 Stream Assessment Methods

3.1.1 Water Chemistry

Water samples were collected and analyzed for various parameters from three streams in the Smalley Lake watershed (Table 7 and Figure 9). The LARE sampling protocol requires assessing the water quality of each designated stream site once during base flow and once during storm flow. This is because water quality characteristics change markedly between these two flow regimes. A storm flow sample will be influenced by runoff from the landscape and usually contains higher concentrations of soil and soil-associated nutrients. A base flow sample represents the 'usual' water characteristics of the stream. Storm flow samples were collected on May 1, 2003, following 1-2 inches (2.5-5 cm) of rain. (The National Weather Service office in North Webster, Indiana reported 2.16 inches of rain on April 30, 2003.) Base flow samples were collected on August 6, 2003 following a period of little precipitation.

Table 7. Location of stream sampling sites.

Site #	Stream Name	Sampling Location	Latitude	Longitude
1	Tippecanoe River inlet	County Road 350 South	N41º18'8.8"	W85º34'0.6"
2	Northern inlet	County Road 250 South	N41º19'9.5"	W85º34'53.0"
3	Smalley Lake outlet	County Road 850 West	N41º18'52.4"	W85º35'6.5"

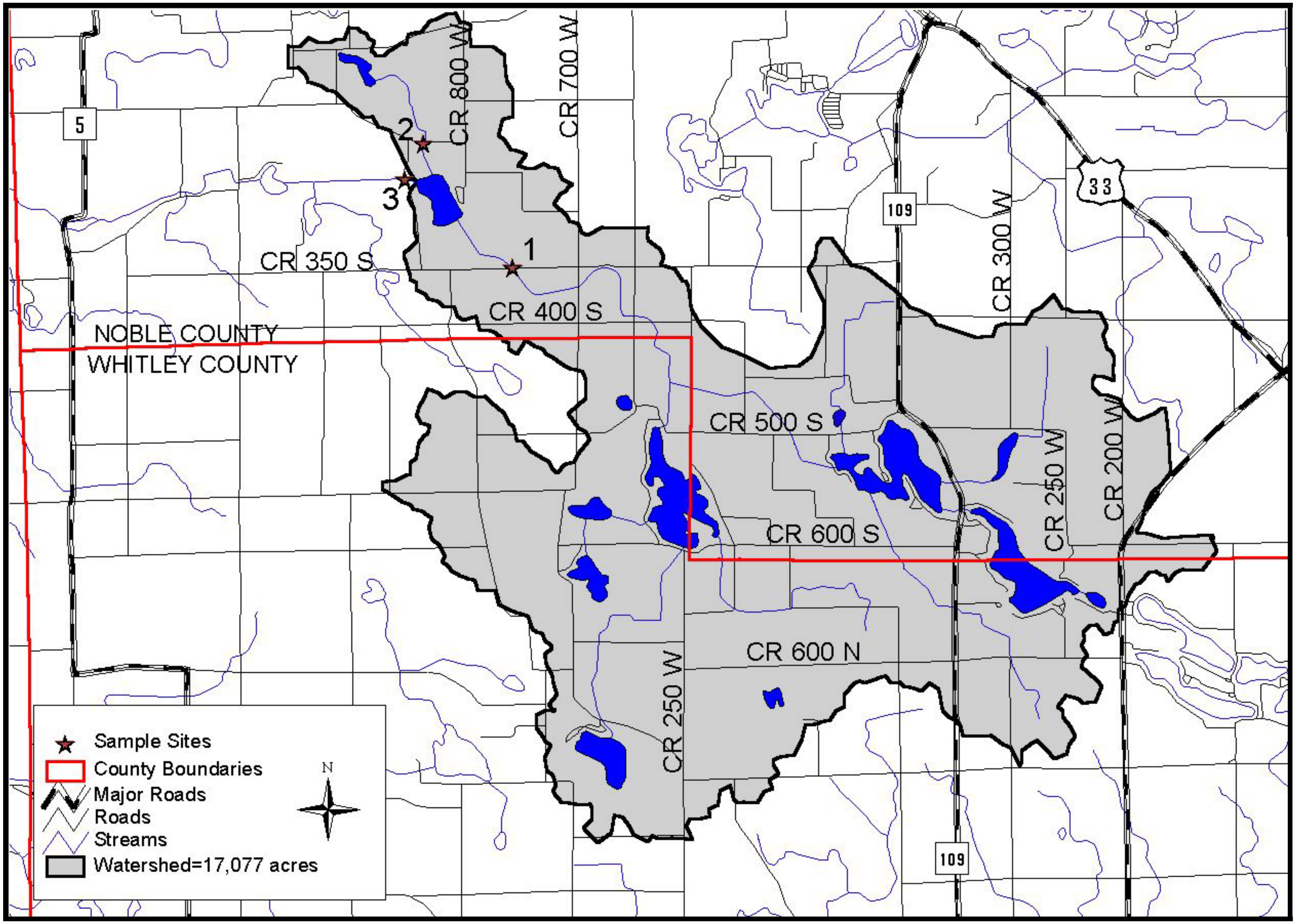

Figure 9. Location of Smalley Lake stream sampling sites.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1”=7,000’.

Stream water chemistry samples were analyzed for pH, alkalinity, conductivity, total phosphorus, soluble reactive phosphorus, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, organic nitrogen, total suspended solids, turbidity, and *E. coli* bacteria. Conductivity, temperature, and dissolved oxygen were measured *in situ* at each stream site with an YSI Model 85 meter. Stream water velocity was measured using a Marsh-McBirney Flo-Mate current meter. The cross-sectional area of the stream channel at each site was measured and discharge calculated by multiplying water velocity by the cross-sectional areas.

All water samples were placed in the appropriate bottle (with preservative if needed) and stored in an ice chest until analysis at Indiana University School of Public and Environmental Affair's (SPEA) laboratory in Bloomington. Soluble reactive phosphorus samples were filtered in the field through a Whatman GF-C filter. The *E. coli* bacteria samples were taken to EIS Analytical Laboratory in South Bend, Indiana for analysis. All sampling techniques and laboratory analytical methods were performed in accordance with procedures in *Standard Methods for the Examination of Water and* Wastewater, 20th Edition (APHA, 1998).

The following is a brief description of the parameters analyzed during the stream sampling efforts:

Temperature. Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. For example, water temperature affects the amount of oxygen dissolved in the water column. Likewise, life associated with the aquatic environment in any location has its species composition and activity regulated by water temperature. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana streams. For example, temperatures during the month of May should not exceed 80 ^{o}F (23.7 ^{o}C) by more than 3 ^{o}F (1.7 ^{o}C). Temperatures during the summer months should not exceed 90 ^{o}F (32.2 ^{o}C).

Dissolved Oxygen (D.O). D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 mg/L of D.O. Coldwater fish such as trout generally require higher concentrations of D.O. than warmwater fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. D.O. enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O. Conversely, dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low discharge, conductivity is higher than during high discharge runoff because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity measurements.

Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 μmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 μmhos per mg/L yields a specific conductance range of approximately 1000 to 1360 μmhos. This report presents conductivity measurements at each site in μmhos.

pH. The pH of water describes the concentration of acidic ions (specifically H+) present in water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6 to 9 pH units for the protection of aquatic life. pH concentrations in excess of 9 are considered acceptable when the concentration occurs as daily fluctuations associated with photosynthetic activity.

Alkalinity. Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Nutrients. Limnologists measure nutrients to predict the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a lake or stream. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake or stream. Complete elimination of algae and/or rooted plants is neither desirable nor even possible and should, therefore, never be the goal in managing a lake or stream. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake or stream. Limnologists commonly measure nutrient concentrations in aquatic ecosystem evaluations to determine the potential for such nuisance growth.

Like terrestrial plants, algae and rooted aquatic plants rely primarily on phosphorus and nitrogen for growth. Aquatic plants receive these nutrients from fertilizers, human and animal waste, atmospheric deposition in rainwater, and yard waste or other organic material that reaches the lake or stream. Nitrogen can also diffuse from the air into the water. This nitrogen is then "fixed" by certain algae species into a usable, "edible" form of nitrogen. Because of this readily available source of nitrogen (the air), phosphorus is usually the "limiting nutrient" in aquatic ecosystems. This means that it is actually the amount of phosphorus that controls plant growth in a lake or stream.

Phosphorus and nitrogen have several forms in water. The two common phosphorus forms are **soluble reactive phosphorus (SRP)** and **total phosphorus (TP)**. SRP is the dissolved form of phosphorus. It is the form that is "usable" by algae. Algae cannot directly digest and use particulate phosphorus. Total phosphorus is a measure of both dissolved and particulate forms of phosphorus. The most commonly measured nitrogen forms are **nitrate-nitrogen (NO_3)**,

ammonium-nitrogen (NH_4^+), and **total Kjeldahl nitrogen (TKN)**. Nitrate is a dissolved form of nitrogen that is commonly found in the upper layers of a lake or anywhere that oxygen is readily available. Because oxygen should be readily available in stream systems, nitrate-nitrogen is often the dominant dissolved form of nitrogen in stream systems. In contrast, ammonium-nitrogen is generally found where oxygen is lacking. Ammonium is a byproduct of decomposition generated by bacteria as they decompose organic material. Like SRP, ammonium is a dissolved form of nitrogen and the one utilized by algae for growth. The TKN measurement parallels the TP measurement to some extent. TKN is a measure of the **total organic nitrogen** (particulate) and ammonium-nitrogen in the water sample.

While the United States Environmental Protection Agency (USEPA) has established some nutrient standards for drinking water safety, it has not established similar nutrient standards for protecting the biological integrity of a stream. (The USEPA, in conjunction with the States, is currently working on developing these standards.) The USEPA has issued recommendations for numeric nutrient criteria for streams (USEPA, 2003b). While these are not part of the Indiana Administrative Code, they serve as potential target conditions for which watershed managers might aim. The Ohio EPA has also made recommendations for numeric nutrient criteria in streams based on research on Ohio streams (Ohio EPA, 1999). These, too, serve as potential target conditions for those who manage Indiana streams. Other researchers have suggested thresholds for several nutrients in aquatic ecosystems as well (Dodd et al., 1998). Lastly, the Indiana Administrative Code (IAC) requires that all waters of the state have a nitrate concentration of less than 10 mg/L, which is the drinking water standard for the state.

Researchers have recommended various thresholds and criteria for nutrients in streams. The USEPA's recommended targets for nutrient levels in streams are fairly low. The agency recommends a target total phosphorus concentration of 0.033 mg/L in streams (USEPA, 2000b). Dodd et al. (1998) suggest the dividing line between moderately (mesotrophic) and highly (eutrophic) productive streams is a total phosphorus concentration of 0.07 mg/L. The Ohio EPA recommended a total phosphorus concentration of 0.1 mg/L in wadeable streams to protect the streams' aquatic biotic integrity (Ohio EPA, 1999). (This criterion is for streams classified as Warmwater Habitat, or WWH, meaning the stream is capable of supporting a healthy, diverse warmwater fauna. The Tippecanoe River inlet (Site 1) and the Smalley Lake outlet (Site 3) would likely fit this definition. Streams that cannot support a healthy, diverse community of warmwater fauna due to "irretrievable, extensive, man-induced modification" are classified as Modified Warmwater Habitat (MWH) streams. The northern inlet (Site 2) would fit this definition.)

The USEPA also sets aggressive nitrogen criteria recommended for streams compared to the Ohio EPA. The USEPA's recommended criteria for nitrate-nitrogen and total Kjeldahl nitrogen for streams in Aggregate Nutrient Ecoregion VII are 0.30 mg/L and 0.24 mg/L, respectively (USEPA, 2000b). In contrast, the Ohio EPA suggests using a nitrate-nitrogen criterion of 1.0 mg/L in WWH wadeable streams (comparable to the Tippecanoe River inlet and the Smalley Lake outlet, Sites 1 and 3, respectively) and MWH headwater streams (comparable to the northern inlet, Site 2) to protect aquatic life. Dodd et al. (1998) suggests the dividing line between moderately and highly productive streams using nitrate-nitrogen concentrations is approximately 1.5 mg/L.

It is important to remember that none of the threshold or recommended concentrations listed above are state standards for water quality. They are presented here to provide a frame of reference for the concentrations found in the Smalley Lake watershed streams. The IAC sets only nitrate-nitrogen and ammonia-nitrogen standards for waterbodies in Indiana. The Indiana Administrative Code requires that all waters of the state have a nitrate-nitrogen concentration of less than 10 mg/L, which is the drinking water standard for the state. The IAC standard for ammonia-nitrogen depends upon the water's pH and temperature, since both can affect ammonia-nitrogen's toxicity. None of the Smalley Lake watershed streams violated the state standard for either nitrate-nitrogen or ammonia-nitrogen.

Turbidity. Turbidity (measured in Nephelometric Turbidity Units) is a measure of particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978). As part of their effort to make numeric nutrient criteria recommendations, the USEPA set 9.9 NTUs as a target for turbidity in stream ecosystems (USEPA, 2000b).

Total Suspended Solids (TSS). A TSS measurement quantifies all particles suspended and dissolved in water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in water. In general, the concentration of suspended solids is greater in streams during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. The sediment in water originates from many sources, but a large portion of sediment entering streams comes from active construction sites or other disturbed areas such as unvegetated stream banks and poorly managed farm fields.

Suspended solids impact streams and lakes in a variety of ways. When suspended in the water column, solids can clog the gills of fish and invertebrates. As the sediment settles to the creek or lake bottom, it covers spawning and resting habitat for aquatic fauna, reducing the animals' reproductive success. Suspended sediments also impair the aesthetic and recreational value of a waterbody. Few people are enthusiastic about having a picnic near a muddy creek or lake. Pollutants attached to sediment also degrade water quality. In general, TSS concentrations greater than 80 mg/L have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria.** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 colonies/100 ml in any one sample within a 30-day period or a geometric mean of 125 colonies per 100 ml for five samples collected in any 30-day period. In general, fecal coliform bacteria have a life expectancy of less than 24 hours.

3.1.2 Macroinvertebrates

Macroinvertebrate samples from each of the three designated stream sites in the Smalley Lake watershed were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition can reflect water quality; research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995)

Macroinvertebrates were collected during base flow conditions on August 6, 2003 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes; a third researcher aided in the collection for 10 minutes, for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al., 1984, Ferraro and Cole, 1995, Marchant, 1995, Bowman and Bailey, 1997, Waite et al., 2000).

The benthic community at each sample site was evaluated using two biological indices: the Hilsenhoff Family Level Biotic Index (FBI) (Hilsenhoff, 1988) and IDEM's macroinvertebrate Index of Biotic Integrity (mIBI) (IDEM, unpublished). The FBI uses the macroinvertebrate community to assess the level of organic pollution in a stream. (IDEM uses the abbreviation HBI to refer to the FBI.) The FBI is based on the premise that different families of aquatic insects possess different tolerance levels to organic pollution. Hilsenhoff assigned each aquatic insect family a tolerance value from 1 to 9; those families with lower tolerances to organic pollution were assigned lower values, while families that were more tolerant to organic pollution were assigned higher values. The FBI is calculated by multiplying the number of organisms from each family collected at a given site by the family tolerance value, summing these products, and dividing by the total number of organisms in the sample:

$$FBI = \frac{\sum x_i t_i}{n}$$

where x_i is the number of species in a given family, t_i is the tolerance values of that family, and n is the total number of organisms in the sample. Benthic communities dominated by organisms that are tolerant of organic pollution will exhibit higher FBI scores compared to benthic communities dominated by intolerant organisms. Table 8 relates the FBI score obtained using the equation above to a stream's water quality and degree of organic pollution.

Table 8. Water quality correlation to family level Hilsenhoff Biotic Index score.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

IDEM's mIBI is a multi-metric index designed to provide a complete assessment of a creek's biological integrity. Karr and Dudley (1981) define biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region". It is likely that this definition of biological integrity is what IDEM means by biological integrity as well. The mIBI consists of ten metrics (Table 9) which measure the species richness, evenness, composition, and density of the benthic community at a given site. The metrics include family-level HBI (Hilsenhoff's FBI), number of taxa, number of individuals, percent dominant taxa, EPT Index, EPT count, EPT count to total number of individuals, EPT count to chironomid count, chironomid count, and total number of individuals to number of squares sorted. (EPT stands for the Ephemeroptera, Plecoptera, and Trichoptera orders.) A classification score of 0, 2, 4, 6, or 8 is assigned to specific ranges for metric values. For example, if the benthic community being assessed supports nine different families, that community would receive a classification score of 2 for the "Number of Taxa" metric. The mIBI is calculated by averaging the classification scores for the ten metrics. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired; scores of 4-6 indicate the site is slightly impaired; and scores of 6-8 indicate that the site is non-impaired.

IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected in Indiana. Because the values for some of the metrics can vary depending upon the collection and subsampling methodologies used to survey a stream, it is important to adhere to the collection and subsampling protocol IDEM used when it developed the mIBI. Since the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999) was utilized in this survey to ensure adequate representation of all macroinvertebrate taxa, the protocol dependent metrics of the mIBI (number of individuals and number of individuals to number of squares sorted) were not included in the metric classification score averaging. Eliminating the protocol dependent metrics allows the mIBI scores at sites surveyed using different survey protocols to be compared to mIBI scores at sites sampled using the IDEM recommended protocol.

Table 9. Benthic macroinvertebrate scoring criteria used by IDEM in the evaluation of pool-riffle streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
	CLASSIFICATION SCORE				
	0	2	4	6	8
Family Level HBI	≥5.63	5.62- 5.06	5.05-4.55	4.54-4.09	≤4.08
Number of taxa	≤7	8-10	11-14	15-17	≥18
Number of individuals	≤79	129-80	212-130	349-213	≥350
Percent dominant taxa	≥61.6	61.5-43.9	43.8-31.2	31.1-22.2	<22.1
EPT index	≤2	3	4-5	6-7	≥8
EPT count	≤19	20-42	43-91	92-194	≥195
EPT count to total number of individuals	≤0.13	0.14-0.29	0.30-0.46	0.47-0.68	≥0.69
EPT count to chironomid count	≤0.88	0.89-2.55	2.56-5.70	5.71-11.65	≥11.66
Chironomid count	≥147	146-55	54-20	19-7	≤6
Total number of individuals to number of squares sorted	≤29	30-71	72-171	172-409	≥410

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Non-impaired

Although the Indiana Administrative Code does not include mIBI scores as numeric criteria for establishing whether streams meet their aquatic life use designation, IDEM hints that it may be using mIBI scores to make this determination. (Under state law, all waters of the state, except for those noted as Limited Use in the Indiana Administrative Code, must be capable of supporting recreational and aquatic life uses.) In the 2000 305 (b) report, IDEM suggests that those waterbodies with mIBI scores less than 2 are considered non-supporting for aquatic life use. Similarly, waterbodies with mIBI scores between 2 and 4 are considered to be partially supporting for aquatic life use. Under federal law, waters that do not meet their designated uses must be placed on the 303 (d) list and remediation/restoration plans (Total Maximum Daily Load plans) must be developed for these waters.

3.1.3 Habitat

The physical habitat at the three study stream sites was evaluated using the Qualitative Habitat Evaluation Index (QHEI) The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin 1989, 1995). The QHEI is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat (Ohio EPA, 1989). While the Ohio EPA originally developed the QHEI to evaluate fish habitat in streams, IDEM and other agencies routinely utilize the QHEI as a measure of general "habitat" health. The QHEI is composed of six metrics including substrate composition, in-stream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle-run quality, and map gradient. Each metric is scored individually then summed to provide the total QHEI score. The QHEI score generally ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Because the rock (gravel, cobble, boulder) that comprise a stream's substrate do not fit together perfectly like pieces in a jigsaw puzzle, small pores and crevices exist between the rock in the stream's substrate. Many stream organisms can colonize these pores and crevices, or microhabitats. In streams that carry high silt loads, the pores and crevices between substrate rock become clogged over time. This clogging, or "embedding", of the stream's substrate eliminates habitat for the stream's biota. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, refers to the type(s) and quantity of habitat provided within the stream itself. Examples of in-stream cover include woody logs and debris, aquatic and overhanging vegetation, and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity, and other factors that represent the stability and direct modification of the site comprise this metric score.

A stream's buffer, which includes the riparian zone and the floodplain zone, is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. Riparian zones govern the quality of goods and services provided by riverine ecosystems (Ohio EPA, 1999). Riparian zone (the area immediately adjacent to the stream), floodplain zone (the area beyond the riparian zone that may influence the stream though runoff), and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of erosion in the stream, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian zone consists only of forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation has higher runoff potential than woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989). Streams with grass or other herbaceous vegetation growing in the riparian zone receive low QHEI scores for this metric.

Metric 5 of the QHEI evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and, in turn, can increase habitat quality. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradient streams will have negative effects on habitat quality. Moderate gradient streams receive the highest score, 10, for this metric. The gradient ranges for scoring take into account the varying influence of gradient with stream size.

The QHEI evaluates the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation (IDEM, 2000).

3.2 Stream Assessment Results and Discussion

3.2.1 Water Chemistry

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling of the inlet and outlet streams of Smalley Lake (Site 1 = Tippecanoe River inlet, Site 2 = northern inlet, and Site 3 = Smalley Lake outlet) are presented in Table 10. Stream cross-sections, determined while measuring discharge, are shown in Figure 10. (Silt and muck filled the northern inlet's (Site 2) channel, making exact determination of the channel's shape impossible.) The box shaped profile shown for the Tippecanoe River inlet (Site 1) is characteristic of channelized streams. Stream discharges measured during base and storm flow conditions are shown in Figure 11. The northern inlet's (Site 2) discharge was not measured during base flow because the flow was negligible. Storm flow discharge was higher for all sites compared to base flow, but this difference was small.

Table 10. Physical characteristics of the Smalley Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow).

Site	Date	Timing	Flow (cfs)	Temp (°C)	D.O. (mg/L)	D.O. Sat. (%)	Cond. (µmhos)	TSS (mg/L)	Turbidity (NTU)
1	5/1/03	Storm	11.79	19.3	11.0	119.0	n/a	6.4	4.9
	8/6/03	Base	11.16	25.3	8.0	97.3	520	22.0	4.6
2	5/1/03	Storm	0.45	21.1	>20.0	n/a	n/a	11.8	5.1
	8/6/03	Base	0.00	23.8	2.7	31.0	500	20.4	17
3	5/1/03	Storm	14.81	17.1	11.8	123.0	n/a	4.7	3.1
	8/6/03	Base	14.18	26.7	11.8	147.6	393	6.0	2.9

n/a = not available/not sampled

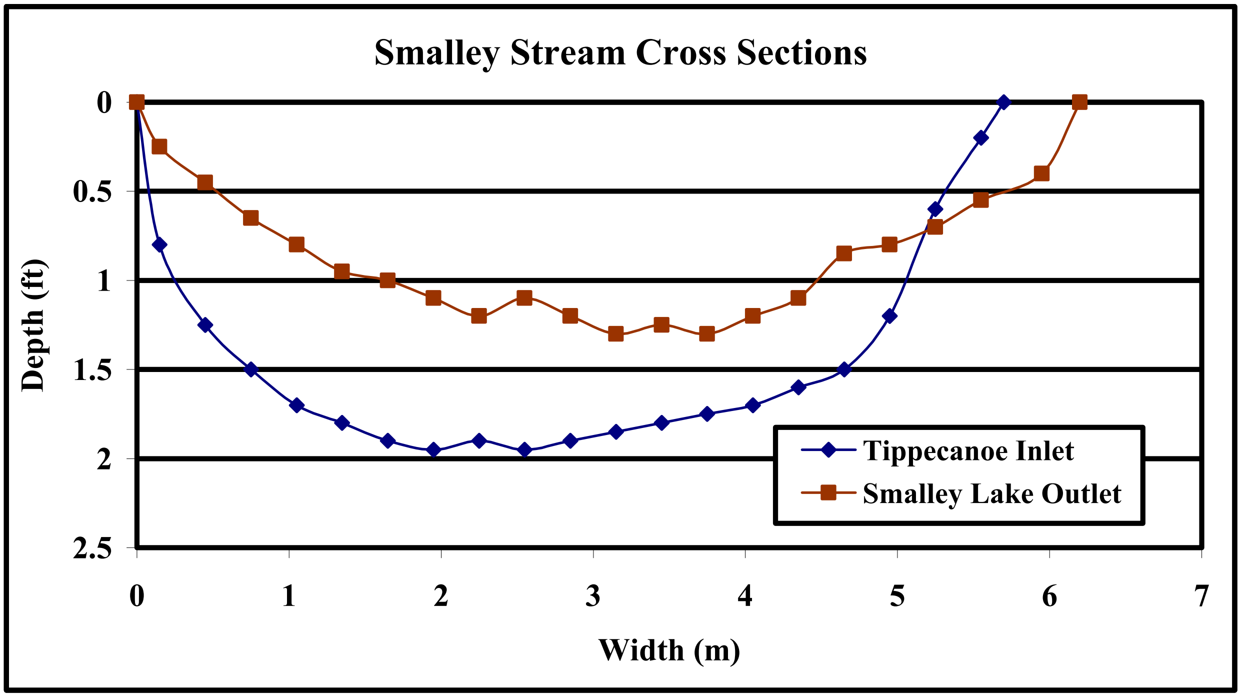

Figure 10. Physical dimensions at the sampling locations at Tippecanoe River inlet and Smalley Lake outlet.

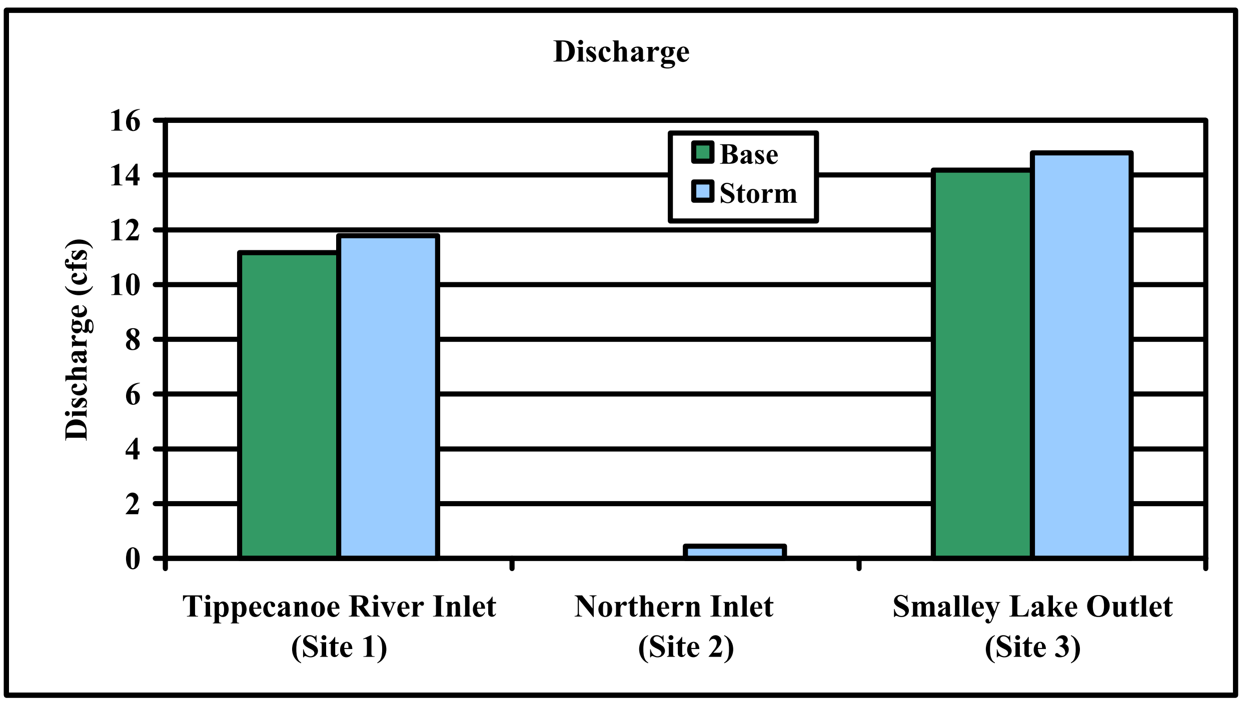

Figure 11. Discharge measurements during base flow and storm flow sampling of Smalley Lake watershed streams. Site 2 base flow was negligible and impossible to measure.

Early May storm flow temperatures were cool, ranging from 17.1 ºC (62.8 ºF) at the Smalley Lake outlet (Site 3) to 21.2 ºC (70.2 ºF) at the northern inlet (Site 2). Early August base flow temperatures ranged from 23.8 ºC (74.8 ºF) to 26.7 ºC (80.1 ºF), reflecting the warmer air temperatures. None of the temperatures observed in the study streams violated the state water quality standards.

Dissolved oxygen concentrations ranged from a low of 2.7 mg/L to exceeding 20 mg/L. These extremes were both measured in the northern inlet (Site 2). The extremely high dissolved oxygen concentration is likely the result of photosynthetic activity in the stream. As plants, both rooted plants and algae, photosynthesize, they release oxygen into the water column, increasing the dissolved oxygen concentration. A dense stand of coontail exists at sampling site on the northern inlet. Additionally, the relatively high total suspended solid concentration and turbidity suggest free floating algae may also be present. Furthermore, this site possessed the highest pH. Because carbon dioxide, a weak acid, is consumed during photosynthesis, pH typically rises. This evidence suggests that photosynthesizing plants likely played a role in the observed high dissolved oxygen concentration.

In contrast to the high dissolved oxygen concentration observed in the northern inlet (Site 2) during storm flow, this site exhibited the lowest dissolved oxygen concentration during the August base flow sampling event. The low oxygen level was likely the result of intense decomposition occurring at the site. Excessive organic detritus was present at this site. In addition, cattle on the adjacent property had unrestricted access to the stream, making the presence of cattle waste products in the stream inevitable. As the organic detritus and cattle wastes decay, oxygen is removed from the water column. Further evidence that decomposition processes were occurring in the stream at the time of sampling was the relatively high ammonia concentration at this site during base flow. The northern inlet (Site 2) possessed the highest ammonia concentration, a by-product of decomposition, of the three sampling sites during the base flow sampling event. The higher water temperature during the base flow sampling compared to the storm flow sampling likelihood facilitated the decomposition process.

With the exception of the results at the Smalley Lake outlet during base flow, the Tippecanoe River inlet (Site 1) and the Smalley Lake outlet (Site 3) exhibited dissolved oxygen concentrations within normal ranges for Indiana streams. The dissolved oxygen concentration at the Smalley Lake outlet (Site 3) was elevated during the base flow sampling event. This relatively high concentration of dissolved oxygen suggests the presence of photosynthesizing algae in the stream. In-lake sampling indicated that Smalley Lake possessed a dense population of algae. Because the Smalley Lake outlet sampling site is located immediately downstream of the lake, it is possible that free floating algae simply drifted out of the lake into the slow flowing outlet stream. These photosynthesizing algae were responsible for the observed high dissolved oxygen concentration at this location.

Turbidity was higher during storm flow than at base flow at the Tippecanoe River inlet (Site 1) and the Smalley Lake outlet (Site 3). Storms tend to wash soil and other particulates from the land into streams, resulting in higher turbidity and TSS concentrations. In contrast, the northern inlet (Site 2) exhibited a high base flow turbidity concentration of 17 NTUs. This turbidity level is relatively high for Indiana streams and exceeds the target level recommended by the USEPA (USEPA, 2000). This high turbidity was most likely related to direct disturbance of cattle congregating within the stream channel at the time of sampling. These cattle had unrestricted access to the stream immediately upstream of the sampling location. The other sites were clearer with turbidities ranging from 2.9 to 5.1 NTUs.

Total suspended solid concentrations usually increase with increased stream flow because of instream scouring and inputs from overland flow from surrounding lands. The inlet and outlet streams actually had higher TSS concentrations during base flow. Local land use activities could result in isolated increases in erosion such as direct cattle usage of the northern inlet (Site 2) during base flow measurement, leading to increased TSS concentration.

Chemical and Bacterial Characteristics

The chemical and bacterial characteristics are shown in Table 11. In a recent study of 85 relatively undeveloped basins across the United States, the USGS reported the following median concentrations: ammonia (0.020 mg/L), nitrate (0.087 mg/L), total nitrogen (0.26 mg/L), soluble reactive phosphorus (0.010 mg/L), and total phosphorus (0.022 mg/L) (Clark et al., 2000). Nutrient concentrations, excluding soluble reactive phosphorus, in the Smalley Lake streams all exceeded these median concentrations, some parameters by an order of magnitude.

Table 11. Chemical and bacterial characteristics of the Smalley Lake watershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow).

Site	Date	Timing	pH	Alk. (mg/L)	NH_3-N (mg/L)	NO_3^--N (mg/L)	TKN (mg/L)	TP (mg/L)	SRP (mg/L)	*E. coli* (#/100 mL)
1	5/1/03	Storm	8.5	129	0.102	0.928	1.665	0.089	0.016	280
	8/6/03	Base	7.7	165	0.075	0.797	1.139	0.027	0.010*	490
2	5/1/03	Storm	8.7	238	0.075	3.556	1.342	0.058	0.010*	390
	8/6/03	Base	7.2	261	0.191	1.807	4.09	0.131	0.079	2,700
3	5/1/03	Storm	8.5	192	0.052	1.017	1.293	0.034	0.010*	9
	8/6/03	Base	8.5	156	0.064	0.735	1.343	0.084	0.010*	340

* Method Detection Limit

Alkalinity concentrations were typical of moderately buffered streams, evidence of the presence of carbonates and other alkalinity-producing materials in the watershed's bedrock. Alkalinity ranged from 129 to 261 mg/L. pH values were also slightly alkaline ranging from a low of 7.2 (northern inlet - Site 2 at base flow) to 8.7 (northern inlet - Site 2 at storm flow). The lower base flow pH value observed in the northern inlet (Site 2) could have resulted from the decaying organic matter potentially adding acidic compounds as well as bovine uric acid inputs. The study streams' pH values; however, were within the acceptable range to protect aquatic life.

Nitrate concentrations in the study streams were average to slightly elevated for Indiana streams (Figure 12). Nitrate concentrations ranged from 0.735 mg/L at the Smalley Lake outlet (Site 3) to 3.556 mg/L at the northern inlet (Site 2). The northern inlet exhibited the highest nitrate concentration under both base and storm flow conditions. The base flow concentration of 1.807 mg/L exceeds the Ohio EPA recommended nitrate concentration for headwater streams of 1.0 mg/L (Ohio EPA, 1999). The storm flow concentration of nitrate at this location is within the range shown by the Ohio EPA to impair aquatic biotic integrity. The high nitrate concentration at this location is likely the result of cattle wastes in the stream. (Nitrates are typically associated animal, including human, waste.) The nitrate-nitrogen concentration at all sites exceeded the USEPA recommended target criterion of 0.3 mg/L for nitrate in streams. None of the streams exceeded the IAC standard of 10 mg/L.

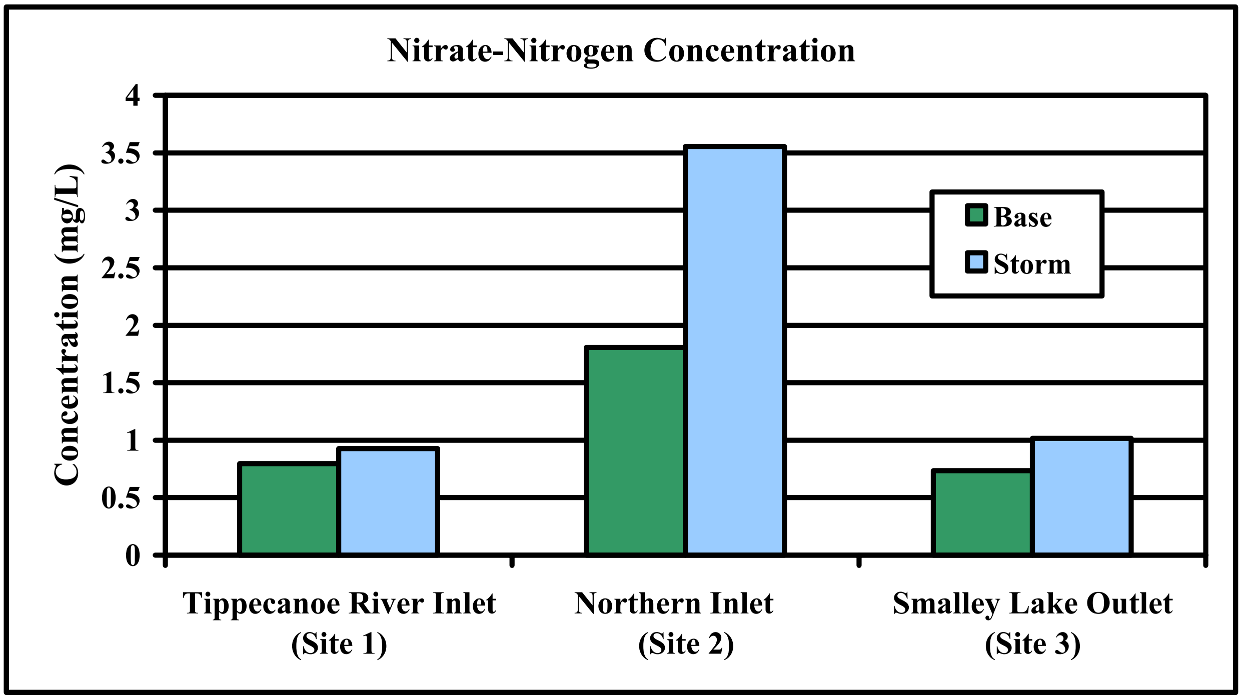

Figure 12. Nitrate-nitrogen concentrations for Smalley Lake watershed streams.

Ammonia concentrations ranged from 0.052 mg/L in the Smalley Lake outlet (Site 3) during storm flow to 0.191 mg/L in the northern inlet (Site 2) at base flow (Figure 13). Small streams are typically well oxygenated because of the turbulent flow; therefore, ammonia is usually oxidized to nitrate. However, both inlet streams, Sites 1 and 2, had relatively high concentrations of ammonia, 0.102 mg/L (storm) and 0.191 mg/L (base), respectively. This likely resulted from both sites containing decaying organic material within the stream itself or in the riparian zone. Decaying organic material was observed in the northern inlet during sampling. Decomposing cattle waste was undoubtedly present at the location as well.

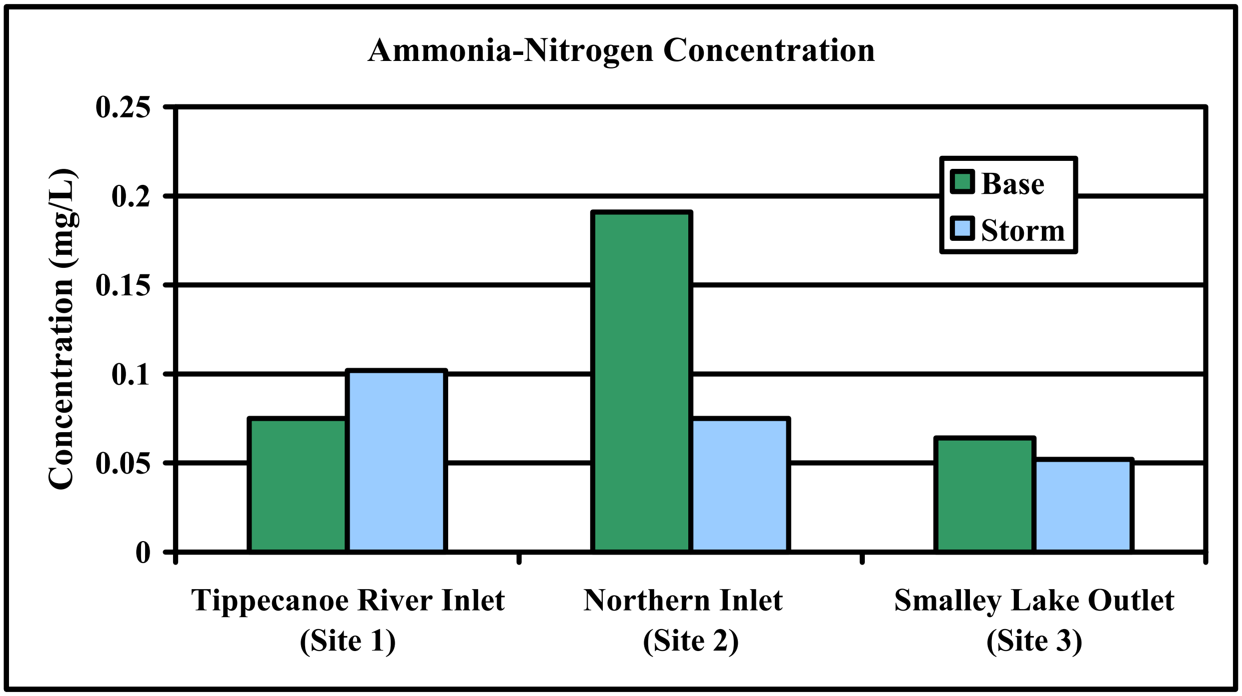

Figure 13. Ammonia-nitrogen concentrations for Smalley Lake watershed streams.

Like nitrate concentrations, total Kjeldahl nitrogen levels in the Smalley Lake inlet and outlet streams were average to elevated for Indiana streams (Figure 14). TKN concentrations ranged from 1.139 mg/L at the Tippecanoe inlet (Site 1) during base flow to 4.09 mg/L at the northern inlet (Site 2) during base flow. Typically storm flow concentrations of TKN exceed base flow concentrations since runoff liberates significant organic material stored within the stream and in riparian areas adjacent to the stream. This relationship did not occur in the northern inlet (Site 2), likely due to cattle disturbing the stream's muck substrate during the base flow sampling event. At the Smalley Lake outlet (Site 3), settling of particulate matter in Smalley Lake likely played a role in lowering both the base and storm flow TKN concentrations compared to the inlet concentrations.

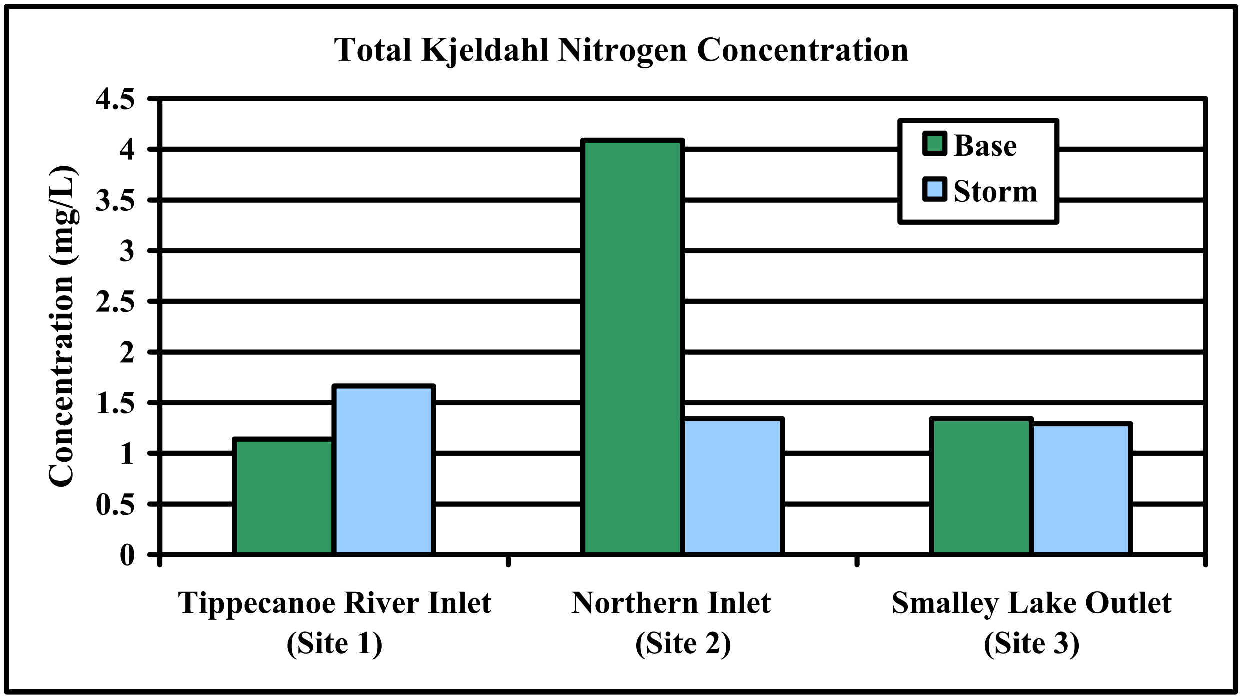

Figure 14. Total Kjeldahl nitrogen concentrations for Smalley Lake watershed streams.

Total phosphorus concentrations in the Smalley Lake watershed streams were average for Indiana streams. Total phosphorus values ranged from 0.027 mg/L at the Tippecanoe River inlet (Site 1 – base flow) to 0.131 mg/L at the northern inlet (Site 2 – base flow) (Figure 15). Total phosphorus (TP) concentrations typically increase during storm events, since the increased overland flow during storm events results in the erosion of soil and soil-attached nutrients from the landscape. This scenario occurred in the Tippecanoe River inlet (Site 1) where the concentration of TP tripled following the storm event. In the northern inlet (Site 2), disturbance of the ditch's substrate by cattle immediately upstream of the sampling location during the base flow sampling event likely was responsible for the elevated phosphorus concentration (0.131 mg/L) measured there. Base flow TP concentration was also higher than the storm flow TP concentration in the Smalley Lake outlet. Various, summertime in-lake processes including algal growth and phosphorus cycling may have controlled the total phosphorus concentration at this site.

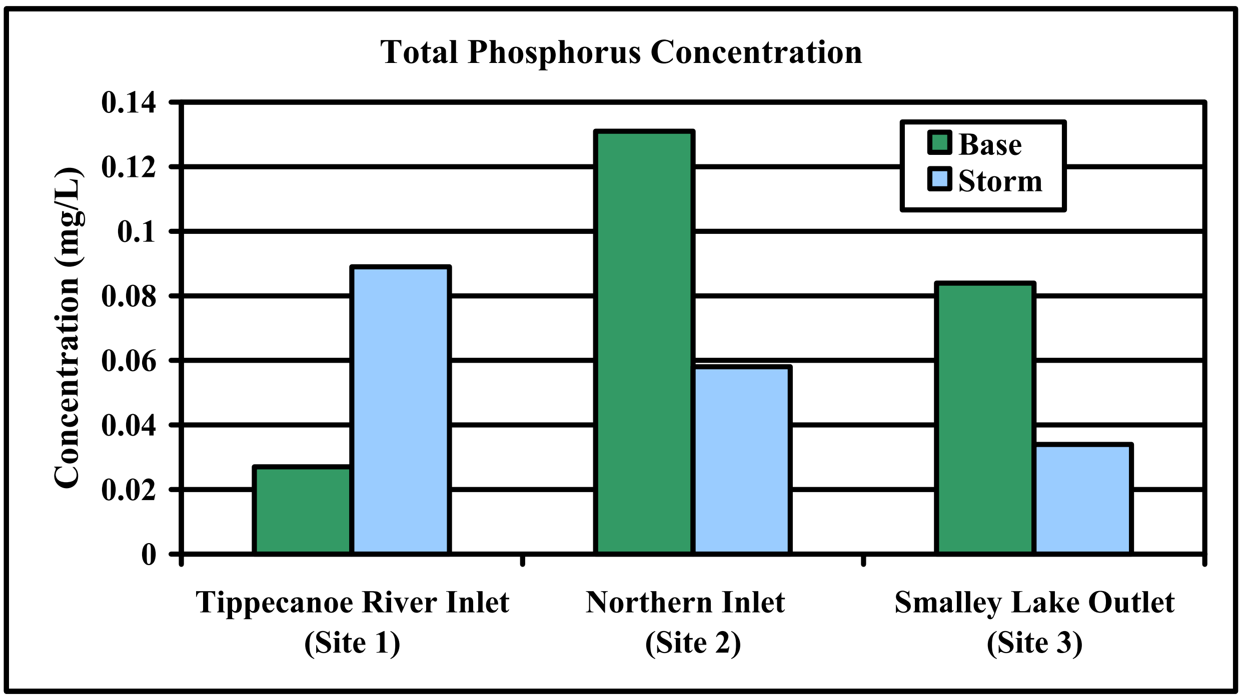

Figure 15. Total phosphorus concentrations for Smalley Lake watershed streams.

Generally, the TP levels in the Tippecanoe River (Sites 1 and 3) were near or below levels observed to protect aquatic life and suggest the river is only moderately productive. The base flow TP concentration in the Tippecanoe River inlet was below the USEPA recommended target criterion of 0.033 mg/L (USEPA, 2000b) and well below the Ohio EPA's recommended TP criterion to protect aquatic life of 0.1 mg/L in wadeable WWH streams (Ohio EPA, 1999). The storm flow concentration at this site was also below the Ohio EPA's TP criterion. Similarly, base and storm flow concentrations in the Smalley Lake outlet were below Ohio EPA's TP criterion. Both sites exhibited TP concentrations that would be associated with only moderate productivity using Dodd et al.'s (1998) criteria. While the TP levels during base and storm flow were slightly higher in the northern inlet (Site 2), they fell below the Ohio EPA's criterion for MWH (Ohio EPA, 1999).

Soluble reactive phosphorus (SRP) concentrations were generally low; most of the SRP concentrations were at or below the method detection limit of 0.010 mg/L (Figure 16). The storm flow SRP concentration in the Tippecanoe River inlet (Site 1) was slightly above (0.016 mg/L) the detection limit. Only the northern inlet (Site 2) exhibited elevated concentrations of SRP. The SRP concentration of 0.079 mg/L during base flow in the northern inlet (Site 2) accounted for more than half of the TP concentration observed at the site. Cattle waste, fertilizer, and release of phosphorus from the ditch's bottom substrate are also possible sources of this SRP in the northern inlet.

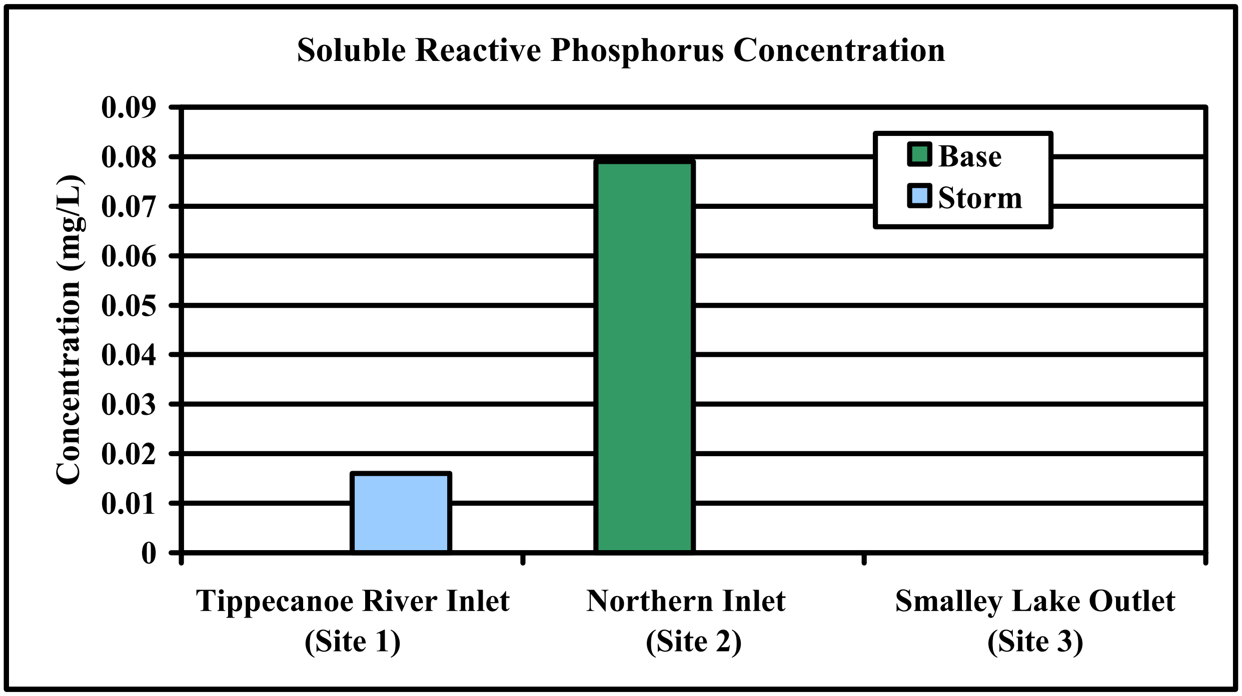

Figure 16. Soluble reactive phosphorus concentrations for Smalley Lake watershed streams.

Total suspended solid concentrations were low to moderate in the Smalley Lake watershed streams (Figure 17). TSS concentrations ranged from a low of 4.7 mg/L observed in the Smalley Lake outlet (Site 3) following a storm event to a high of 22.0 mg/L observed in the Tippecanoe River inlet (Site 1) during base flow conditions. The relatively high concentration (20.4 mg/L) observed in the northern inlet (Site 2) at base flow was likely due to the disturbance of the ditch's substrate by cattle in the ditch at the time of sampling. It is important to note that the TSS concentration in the Smalley Lake outlet is lower than the TSS concentration observed in either of the inlet during both the base and storm flow sampling events. This coupled with the turbidity measurements show that the water leaving Smalley Lake is clearer than the water entering the lake. Although an analysis of TSS loading is necessary to make a definitive conclusion, it is likely that the lake acts as a sediment basin, trapping the sediment load carried by the Tippecanoe River and the northern inlet.

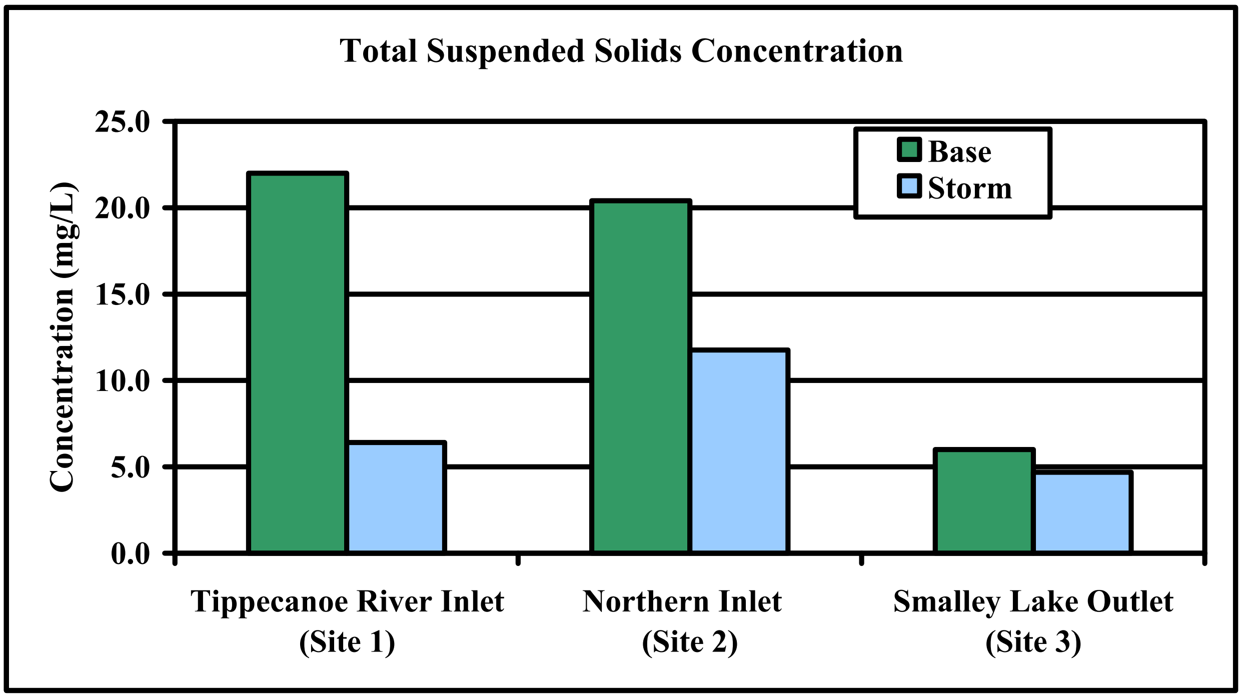

Figure 17. Total suspended solid concentrations for Smalley Lake watershed streams.

While all samples except the storm flow sample collected from the Smalley Lake outlet (Site 3) violated the Indiana state *E. coli* standard of 235 col/100ml, the *E. coli* concentrations were not generally high for Indiana (Figure 18). White (unpublished data) noted that the average *E. coli* concentration in Indiana waters is approximately 650 col/100ml. Most of the Smalley Lake watershed stream's *E. coli* concentrations were under 500 col/100ml. The base flow sample collected from the northern inlet is the exception to this. The *E. coli* concentration at this sampling location was 2700 col/100ml during base flow. The high *E. coli* concentration observed in the northern inlet (Site 2) during base flow likely resulted from livestock waste.

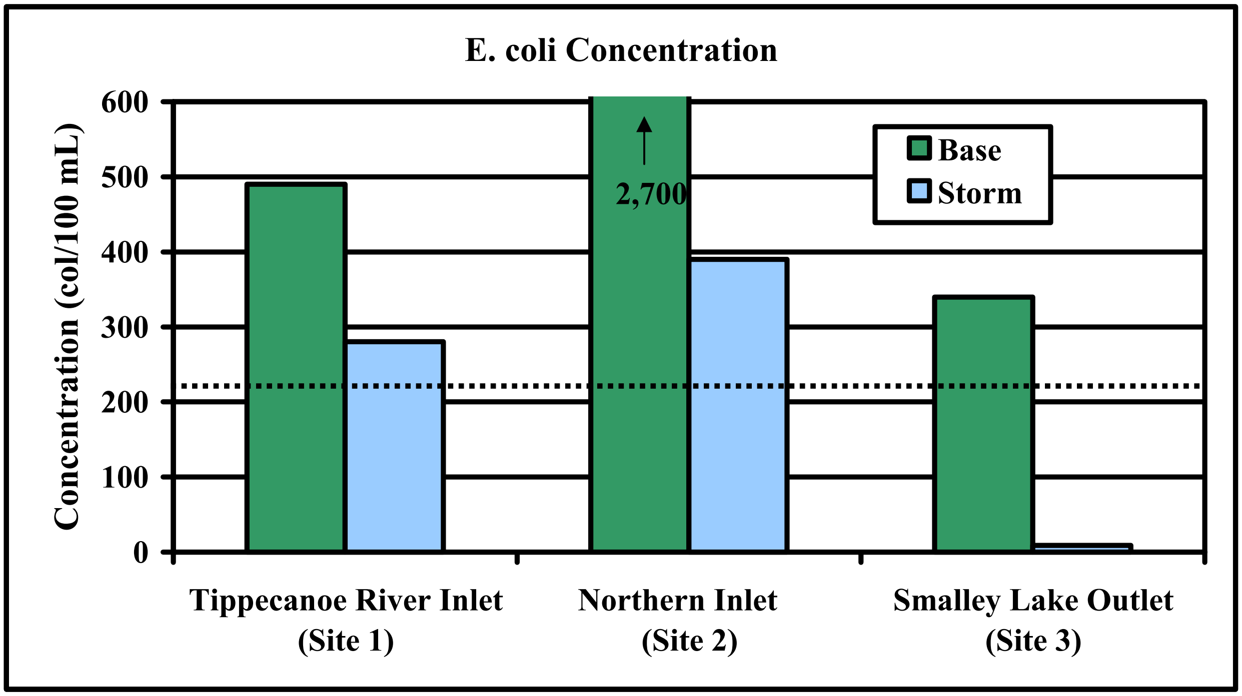

Figure 18. *E. coli* concentrations for Smalley Lake inlet watershed streams. The dashed line represents the Indiana state *E. coli* standards for recreational waterbodies, 235 col/100mL.

Chemical and Sediment Loading

Table 12 lists the chemical and sediment loading data for the Smalley Lake watershed streams. Figures 19-23 present mass loading information graphically.

Table 12. Chemical and sediment load characteristics of the Smalley Lakewatershed streams on 5/1/03 (storm flow) and 8/6/03 (base flow).

Site	Date	Timing	NH_3-N Load (kg/d)	NO_3^--N Load (kg/d)	TKN Load (kg/d)	TP Load (kg/d)	SRP Load (kg/d)	TSS Load (kg/d)
1	5/1/03	Storm	0.10	0.95	1.70	0.09	0.02	6.52
	8/6/03	Base	0.07	0.77	1.10	0.03	bdl	21.21
2	5/1/03	Storm	0.00	0.14	0.05	0.00	bdl	0.45
	8/6/03	Base*	--	--	--	--	--	--
3	5/1/03	Storm	0.07	1.30	1.65	0.04	bdl	5.99
	8/6/03	Base	0.08	0.90	1.65	0.10	bdl	7.35

bdl=Below detection level *The northern inlet contained negligible flow during base flow sampling.

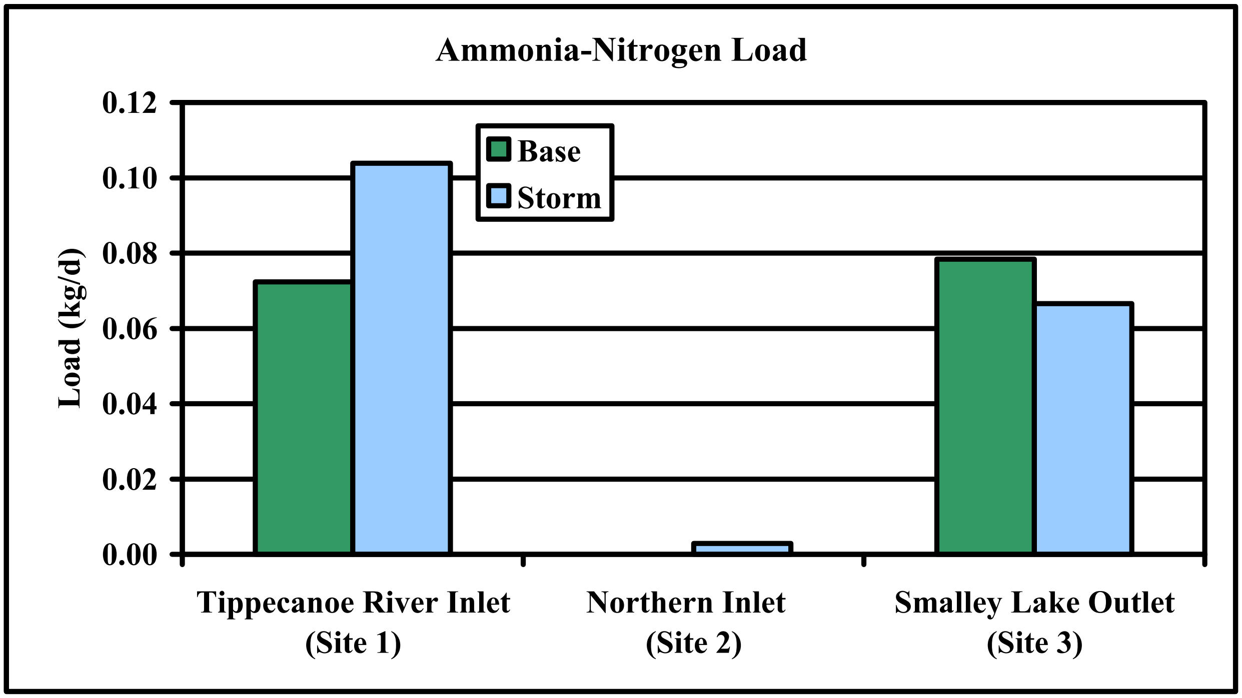

Figure 19. Ammonia-nitrogen load for Smalley Lake watershed streams.

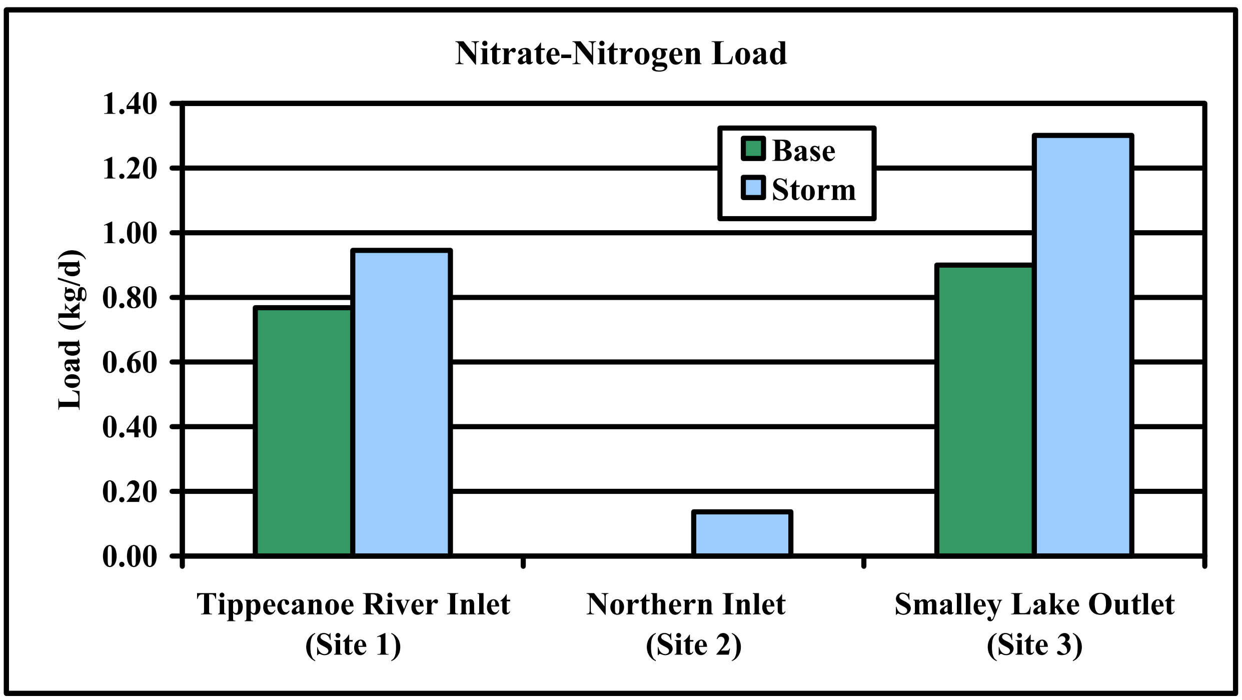

Figure 20. Nitrate-nitrogen load for Smalley Lake watershed streams.

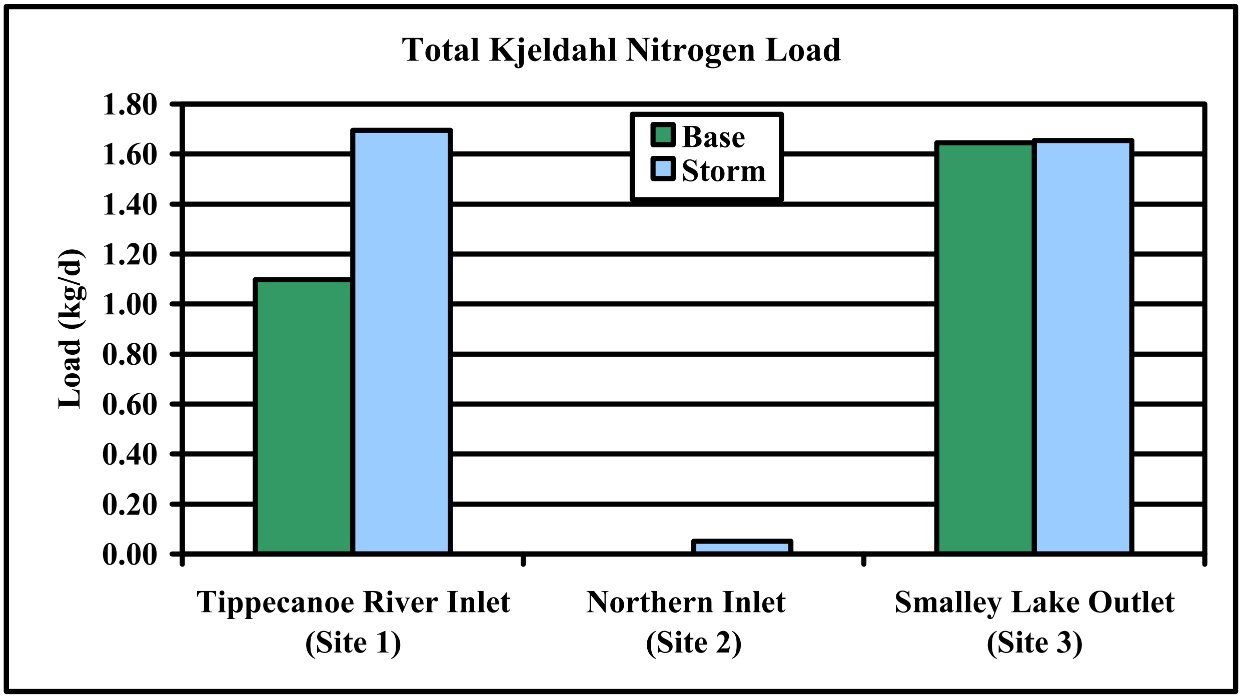

Figure 21. Total Kjeldahl nitrogen load for Smalley Lake watershed streams.

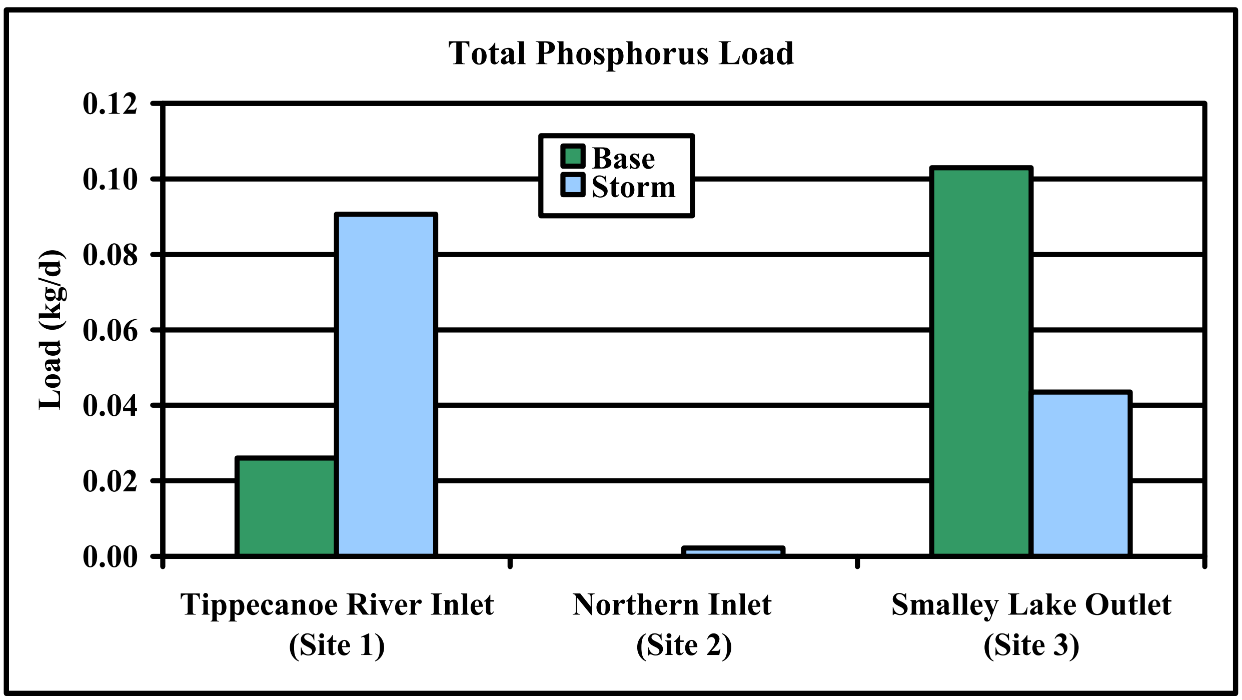

Figure 22. Total phosphorus load for Smalley Lake watershed streams.

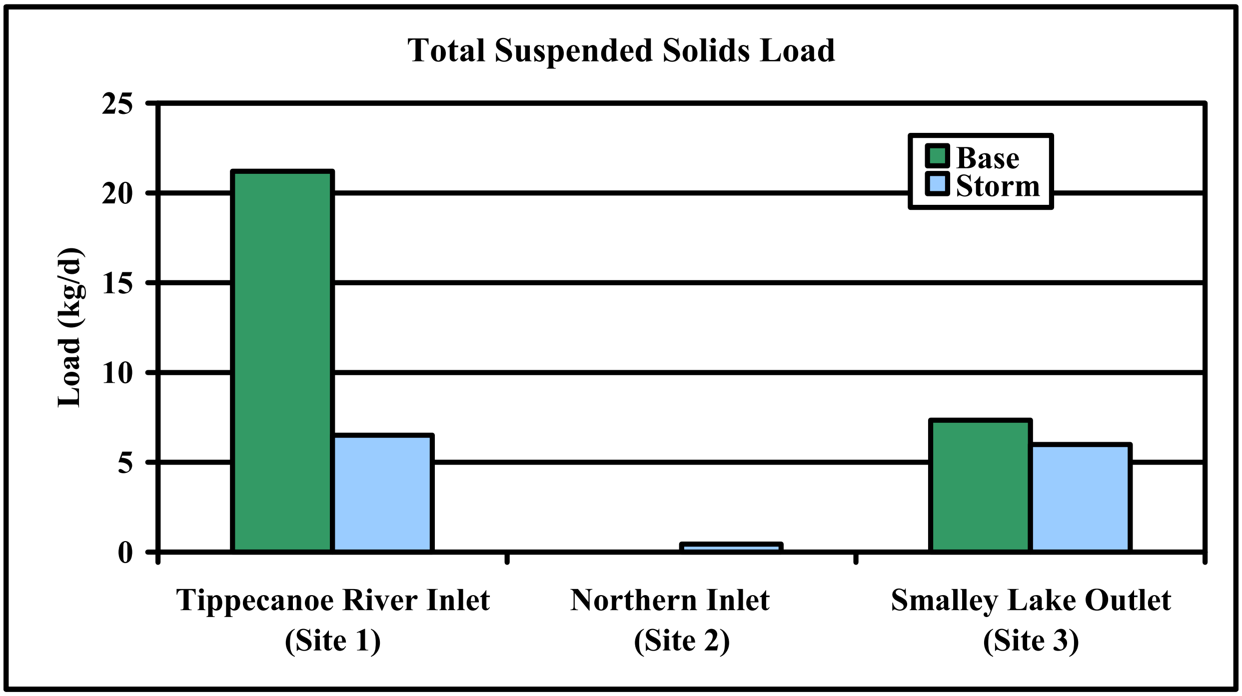

Figure 23. Total suspended solids load for Smalley Lake watershed streams.

The pollutant load data for Smalley Lake's inlet and outlet streams suggest that the lake serves as a sediment trap for particulate pollutants, especially during storm flow. Figure 23 shows that more total suspended solids entered the lake than left the lake under both base and storm flow conditions. Similarly, particulate nutrient loading data indicate that Smalley Lake trapped a portion of the total phosphorus and total Kjeldahl nitrogen entering the lake during storm flow.

The sampling regime did not definitively determine that Smalley Lake traps the sediment or particulate nutrients. It is possible that the sediment and particulate nutrients were sequestered by the riparian zone of the Tippecanoe River prior to entry into the lake or by the expansive wetland at the mouth of the lake. Visual inspection of the riparian zone at sampling Site 1 suggests that it is unlikely that the stream's riparian zone is responsible for the removal of sediment and particulate nutrients from the stream water. The stream in this area suffers from the effects of channelization, decreasing the likelihood that water from the stream can even access the adjacent riparian zone. In contrast, the well vegetated wetland that lies at the juncture of the Tippecanoe River and Smalley Lake likely removes at least a portion of the particulate pollutant load before it reaches Smalley Lake. Well-vegetated wetlands have the capacity to remove approximately 70-85% of the total suspended solids from incoming water (Winer, 2000)

Differences in dissolved pollutant loads entering and exiting the lake are likely the result of common chemical reactions that occur in lake and stream systems. For example, the amount of ammonia leaving Smalley Lake is less than that entering the lake during storm flow. As noted previously, ammonia is converted to nitrate in the presence of oxygen. Because of the relatively cool spring, Smalley Lake was likely experiencing the effects of ***spring turnover*** in early May when the storm flow sampling occurred. During turnover, the lake mixes completely and oxygen is well distributed throughout the water column. Any ammonia in the incoming stream water likely came into immediate contact with oxygen and was converted to nitrate once the stream water entered the lake. This would also explain the increase in the nitrate load leaving the Smalley Lake (Figures 19 and 20).

It is often useful to compared the areal pollutant loading rates of the inlet streams to lakes to help direct watershed management efforts. The areal pollutant loading rate normalizes the pollutant loading rates by subwatershed acreage. By dividing the pollutant loading rate by subwatershed acreage, one obtains a per acre pollutant load. Thus, pollutant loading rates from large subwatersheds are comparable to those from small subwatersheds.

Smalley Lake has two inlets. The Tippecanoe River delivers significantly more pollutants to the lake than the northern inlet. This is expected since the Tippecanoe River drains approximately 91% of the Smalley Lake watershed, while the northern inlet drains slightly less than 7% of the lake's watershed. However, when areal loading rates are examined, one notices that the Tippecanoe River still contributes more pollutants per acre of subwatershed than the northern inlet. The exception to this is nitrate-nitrogen. The northern inlet contributes more nitrate-nitrogen to Smalley Lake per acre of subwatershed than the Tippecanoe River. This suggests that, in general, management efforts should focus primarily on the Tippecanoe River subwatershed rather than the northern inlet subwatershed. However, management efforts to control nitrate-nitrogen in the northern inlet subwatershed, such as installing fencing to restrict cattle's access to the northern inlet, should be pursued.

3.2.2 Macroinvertebrates

Tables 13 through 15 present the results of the macroinvertebrate analysis conducted at each stream site, while Table 16 provides a summary of individual mIBI metric score by sampling site. (Appendix D presents a list of macroinvertebrate families collected at each site.) The individual metrics that make up the mIBI present mixed data on the macroinvertebrate communities at each sampling site. The Tippecanoe River inlet (Site 1) and the northern inlet (Site 2) support similar numbers of taxa (16 and 15 taxa, respectively). However, the taxa themselves differ between the two sites. Individuals from both moderately tolerant (*Heptageniidae* and *Hydropsychidae*) and very tolerant families (*Talitridae*) dominant the macroinvertebrate community in the Tippecanoe River inlet (Site 1), while individuals from only very tolerant families (*Caenidae* and *Coenagrionidae*) dominate the macroinvertebrate community in the northern inlet (Site 2). Members of the *Caenidae* and *Coenagrionidae* are known for their tolerance to silt, which is the dominant substrate type found in the northern inlet (Site 2). The two sites (Sites 1 and 2) also differ in the number individuals from the EPT (*Ephemeroptera, Plecoptera*, and *Trichoptera*) orders present, with the Tippecanoe River inlet (Site 1) possessing more compared to the northern inlet (Site 2). These differences result in different ratings of biological integrity. The mIBI score in Tippecanoe River inlet (Site 1) was 5.0 suggesting the macroinvertebrate community is slightly impaired; the mIBI score in the northern inlet (Site 2) was 3.5 indicating moderate impairment of the macroinvertebrate community.

The Smalley Lake outlet (Site 3) exhibits poorer taxa richness than observed in the Tippecanoe River inlet (Site 1) and the northern inlet (Site 2) and possesses only two EPT families on its taxa list. Individuals from the *Trichoptera* family *Hydropsychidae* dominate the macroinvertebrate community at the Smalley Lake outlet (Site 3). Member of the family *Hydropsychidae* tend to be moderately tolerant of poor water quality. The dominance of this family at the site increased the site's HBI score and metrics with EPT counts. The result is a mIBI score of 5.0 suggesting only slight impairment of the biotic community.

Table 13. Raw metric scores, classification scores, and mIBI score for the Tippecanoe River inlet (Site 1), 8/14/2003.

mIBI Metric	Raw Score	Metric Score
HBI	7.50	0
No. Taxa (family)	16	6
% Dominant Taxa	30.0	6
EPT Index	4	4
EPT Count	46	4
EPT Count/Total Count	0.46	4
EPT Abundance/Chironomid Abundance	23.00	8
Chironomid Count	2.00	8
mIBI Score		5.0

Table 14. Raw metric scores, classification scores, and mIBI score for the northern inlet (Site 2), 8/14/2003.

mIBI Metric	Raw Score	Metric Score
HBI	7.90	0
No. Taxa (family)	15	6
% Dominant Taxa	27.8	6
EPT Index	2	0
EPT Count	26	2
EPT Count/Total Count	0.23	2
EPT Abundance/Chironomid Abundance	4.30	4
Chironomid Count	6.00	8
mIBI Score		3.5

Table 15. Raw metric scores, classification scores, and mIBI score for the Smalley Lake outlet (Site 3), 8/14/2003.

mIBI Metric	Raw Score	Metric Score
HBI	4.40	6
No. Taxa (family)	12	4
% Dominant Taxa	69.4	0
EPT Index	2	0
EPT Count	92	6
EPT Count/Total Count	0.74	8
EPT Abundance/Chironomid Abundance	15.30	8
Chironomid Count	6.00	8
mIBI Score		5.0

Table 16. Summary of classification scores and mIBI scores for the Smalley Lake watershed streams, 8/14/2003.

	Tippecanoe River Inlet (Site 1)	Northern Inlet (Site 2)	Smalley Lake Outlet (Site 3)
HBI	0	0	6
No. Taxa (family)	6	6	4
% Dominant Taxa	6	6	0
EPT Index	4	0	0
EPT Count	4	2	6
EPT Count/Total Count	4	2	8
EPT Abundance/Chironomid Abundance	8	4	8
Chironomid Count	8	8	8
mIBI Score	**5.0**	**3.5**	**5.0**

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

The greater impairment of the northern inlet's (Site 2) biotic community compared to the other sites is consistent with the nutrient concentrations in the water at this site during base flow conditions. This site exhibited higher nutrient concentrations than either the Tippecanoe River inlet (Site 1) or the Smalley Lake outlet (Site 3) during base flow. (Biotic integrity of streams is most closely correlated with base flow water chemistry since the base flow conditions are the normal conditions to which the biota are subjected.) The base flow nitrate-nitrogen concentration at the northern inlet (Site 2) exceeded the Ohio EPA recommended target for the protection of aquatic life. High nitrate-nitrogen levels in this stream may be one cause of the observed biotic impairment.

Data from the biotic community assessment also support the idea that Smalley Lake serves as a sediment trap. (Total suspended solid loading data presented in the previous section suggest this hypothesis may be valid.) The family level HBI results in both the Tippecanoe River inlet (Site 1) and the northern inlet (Site 2) were very high suggesting a high level of organic pollution in those inlet streams. In contrast, the family level HBI score in the Smalley Lake outlet (Site 3) was lower suggesting only moderate levels of organic pollution. The drop in family level HBI scores from the inlets to the outlet suggests some of the organic pollution present in the inlet water may drop out of suspension and settle to the bottom of the lake. Lake assessment data presented later in this report support the presence of organic matter at the lake's bottom. The dominance of moderately tolerant taxa in the Smalley Lake outlet (Site 3) compared to the co-dominance of moderately tolerant and very tolerant taxa in the Tippecanoe River inlet (Site 1) or the dominance of very tolerant taxa the northern inlet (Site 2) lend further evidence to the idea that Smalley Lake serves as a trap for pollutants.

Watershed stakeholders should interpret the macroinvertebrate data with caution though. The mIBI scores, which combine several evaluation metrics in the final score, suggest that there is little difference between the macroinvertebrate community in the Tippecanoe River inlet (Site 1) and the Smalley Lake outlet (Site 3). This supports the idea that there is little difference in water quality between the sites and the lake is not serving as a pollutant trap. In addition, factors other than simply water quality play a role in shaping the macroinvertebrate community in a stream (Karr et al., 1986). Habitat is one such factor. As discussed below, the habitat at the Smalley Lake outlet (Site 3) is better than the habitat at the other sites. This fact may have a greater influence over the quality of the biological community than water quality.

3.2.3 Habitat

In addition to a stream's water quality, habitat quality also influences the quality of the biotic community inhabiting the stream. Thus, it is useful to examine the habitat quality of the streams in the Smalley Lake watershed. Table 17 presents the results of the QHEI calculated at each of the three study sites. (Appendix E presents the QHEI data sheets for each of the three study sites.) The following paragraphs provide a short description of the in-stream and riparian characteristics observed at each of the study sites.

Table 17. QHEI scores for the Smalley Lake watershed streams, 8/14/2003.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Tippecanoe River inlet-Site 1	4	12	6	9	11	0	6	**48**
Northern inlet-Site 2	1	16	7	6	8	0	8	**46**
Smalley Lake outlet-Site 3	14	10	9	5.5	6	5	10	**60**

Site 1. Tippecanoe River inlet. Forested land surrounds the Tippecanoe River reach at Site 1. The riparian buffer along both stream banks is wide reaching in excess of 150 feet (45 m). Vegetation immediately adjacent to the stream is predominately trees and shrubs. Overhanging vegetation, rootwads, deep pools, and woody debris provide a moderate level of in-stream cover. The stream banks are stable with only moderate erosion observed. The stream also appears to be recovering from stream channelization; however sinuosity and channel development are poor. Hardpan and detritus are the main substrate types found in this reach. Limited amounts of cobble, muck/silt, gravel, and artificial stones (rip rap) cover the stream bottom in portions of the reach. Silt cover and the level of substrate embeddedness are extensive.

Site 2. Northern inlet. Open cow pasture and an old field surround the stream at this site. Cows are permitted direct access to the stream and appear to spend much time congregating in the channel, under County Road 250 South. The riparian width on either side of the stream is narrow extending out only 15 to 30 feet (5 to 9 m), where a buffer exists at all. In-stream cover is extensive with abundant aquatic macrophytes, overhanging vegetation, deep pools, and woody debris. Erosion along the banks is limited to where the cows entered the stream. The stream has been channelized in the past; channel sinuosity is low and pool and riffle development is poor. Muck and silt are the dominant substrate types. The level of substrate embeddedness is extensive with a heavy silt cover. This site offers extremely poor habitat for stream biota.

Site 3. Tippecanoe River at Smalley Lake outlet. The land use surrounding the stream site is a mixture of residential land and row crop agriculture. The riparian buffer is narrow reaching a maximum width of 30 feet (9 m) along both banks. Vegetation immediately adjacent to the stream consists of trees and shrubs. In-stream cover at the site is moderate and includes overhanging vegetation, rootwads, and woody debris. The stream banks show little evidence of erosion. The stream reach appears to be recovering from past channelization. The pool and riffle development is poor and the stream channel lacks sinuosity. Gravel and sand are the dominant substrate types; however cobble and muck are also present in limited quantities. The levels of substrate embeddedness and silt cover are low.

The Tippecanoe River inlet (Site 1) and the northern inlet (Site 2) received similar QHEI scores (48 and 46, respectively). Both scores suggest the habitat in these two reaches is impaired, as both scores fell below IDEM's threshold of 51 which marks the level at which stream habitat is considered supportive of aquatic life uses (IDEM, 2002). Both sites suffer from a lack of clean substrate and poor riffle development. Despite the relatively poor scores, both reaches possess some positive characteristics; Tippecanoe River inlet (Site 1) possesses a good riparian corridor, and the northern inlet (Site 2) offers ample in-stream cover for aquatic biota. In contrast to the Tippecanoe River inlet (Site 1) and the northern inlet (Site 2), the Smalley Lake outlet (Site 3) offers stream biota much better habitat. This site possesses better substrate and riffles distinguishing it from the two inlet streams. The QHEI score of 60 at the Smalley Lake outlet (Site 3) is within the range of QHEI scores that the Ohio EPA found to correlate with habitat that is generally conducive to the existence of warmwater faunas (Ohio EPA, 1999).

With respect to the observed biotic integrity, the QHEI results suggest that both water quality and habitat play a role in impairing the biotic integrity at the Tippecanoe River inlet (Site 1) and the northern inlet (Site 2). The low QHEI scores at these sites indicate that the quality of habitat may not be sufficient to support a healthy biotic community regardless of the water quality. In contrast, habitat quality appears to be sufficient to support a healthy biotic community at the Smalley Lake outlet (Site 3), suggesting that water quality impairment may play a larger role in the observed impairment of the biotic community at this site.

3.3 Stream Assessment Summary

The Smalley Lake inlet and outlet streams were assessed to gain a better understanding of the quality of water entering and exiting Smalley Lake. The assessment also provided insight into the magnitude and scale of the pollutant loads entering Smalley Lake. The stream assessment included an evaluation of each stream's biological community and physical habitat in addition to an evaluation of the stream's water chemistry since: 1. the biological community reflects the long-term trend in water quality, whereas the analysis of the stream water chemistry from a grab sample only provides information on the current condition of the stream's water quality; and 2. a stream's biota and physical habitat play a role in processing and sequestering nutrients and other pollutants in stream water (Ohio EPA, 1999). Thus, assessing whether the stream's biological community and/or physical habitat are impaired is important to knowing why a given pollutant load is reaching a lake from an inlet stream.

The results of the Smalley Lake watershed stream assessment indicated that in general the northern inlet (Site 2) possesses poorer water quality and a more impaired biotic community and physical habitat than Smalley Lake's other inlet (Site 1). Water chemistry conditions in the northern inlet (Site 2) were generally poor, particularly during base flow. The inlet exhibited higher nutrient concentration than the Tippecanoe River inlet (Site 1) at base flow. Its nitrate-nitrogen concentration at base flow was above the level recommended by the Ohio EPA (1999) to protect aquatic life. Similarly, *E. coli* and dissolved oxygen concentrations at base flow in the northern inlet (Site 2) violated the Indiana state standard. Finally, the inlet possessed higher turbidity levels during base and storm flow and higher total suspended solids levels during base flow than the Tippecanoe River inlet (Site 1).

The northern inlet (Site 2) also possesses poor habitat quality. The site has an extremely poor riparian buffer, limiting the stream system's ability to sequester sediment and nutrients. Cows have direct access to the northern inlet further impairing the stream's habitat and water quality. The site suffers from a lack of clean substrate and has no riffle habitat. The northern inlet's (Site 2) QHEI score suggests habitat at this site is not capable of supporting a healthy warmwater fauna.

The northern inlet's (Site 2) macroinvertebrate community reflects the site's poor water chemistry and physical habitat conditions. Very tolerant taxa dominate the site's macroinvertebrate community. Given the heavy silt covering in the reach, the dominant taxa in the northern inlet (Site 2) are, not surprisingly, extremely silt tolerant. The reach's family level HBI score suggested that organic pollution levels are severe in the stream. The reach's mIBI score show that the stream's biotic integrity is at least moderately impaired. This impairment likely impacts the biota's ability to process nutrients in the stream, leading to poorer water quality downstream (i.e. in Smalley Lake).

Despite the relatively poor water quality conditions in the northern inlet (Site 2), the Tippecanoe River inlet (Site 1) also presents a concern for the health of Smalley Lake. The Tippecanoe River inlet (Site 1) exhibited higher nutrient and sediment concentrations during storm flow than the northern inlet (Site 2). This fact coupled with the fact that discharge rates are significantly higher at the Tippecanoe River inlet (Site 1) than the northern inlet (Site 2) means that most of the pollutant load entering Smalley Lake comes from the Tippecanoe River inlet (Site 1). This is not surprising since the Tippecanoe River inlet has a much larger watershed than the northern inlet. However, the Tippecanoe River inlet's areal loading rates (loading rate divided by subwatershed acreage) are higher than those for the northern inlet for all pollutants except nitrate-nitrogen. This suggests that management efforts should focus on the Tippecanoe River subwatershed, in general, since management efforts in this subwatershed will (theoretically) have a greater impact on Smalley Lake. Watershed stakeholders should focus efforts to curb nitrate-nitrogen loading on the northern inlet's subwatershed.

In addition to having high pollutant loading rates, the mIBI score and QHEI score at the Tippecanoe River inlet (Site 1) suggest the biological community and physical habitat are both impaired. While this impairment is not as severe as the impairment observed in the northern inlet (Site 2), the impairment may be impacting the ability of the biota and riparian zone to process and remove pollutants from the stream and preventing these pollutants from reaching Smalley Lake. Improvement of the riparian zone, particularly improving the ability of water in the Tippecanoe River channel to flow into the stream's riparian zone, should also be considered as a management priority.

The stream assessment provides some limited data to support the idea that Smalley Lake serves as a sediment trap. More total suspended solids entered the lake than left the lake under both base and storm flow conditions. Similarly, particulate nutrient loading data indicate that Smalley Lake trapped a portion of the total phosphorus and total Kjeldahl nitrogen entering the lake during storm flow. The biological data lend further evidence to the sediment trap hypothesis. The family level HBI results in both the Tippecanoe River inlet (Site 1) and the northern inlet (Site 2) were very high suggesting a high level of organic pollution in those inlet streams. In contrast, the family level HBI score in the Smalley Lake outlet (Site 3) was lower suggesting only moderate levels of organic pollution. The drop in family level HBI scores from the inlets to the outlet suggests some of the organic pollution present in the inlet water may drop out of suspension and settle to the bottom of the lake. The dominance of moderately tolerant taxa in the Smalley Lake outlet (Site 3) compared to the co-dominance of moderately tolerant and very tolerant taxa in the Tippecanoe River inlet (Site 1) or the dominance of very tolerant taxa in the northern inlet (Site 2) lend further evidence to the idea that Smalley Lake serves as a trap for pollutants. It is important to note that the biological data offer only weak support of the Smalley Lake-as-a-sediment-trap hypothesis.

4.0 LAKE ASSESSMENT

4.1 Morphology and Shoreline Development

Smalley Lake is approximately 69 acres (28 ha) in size and has a volume of approximately 1,350 acre-feet (1,628,872 m^3) (Table 18). The lake extends to a depth of 49 feet (15 m) in its northeast corner, directly east of the Tippecanoe River outlet (Figure 24). Figures 25 and 26 present depth-area and depth-volume curves for Smalley Lake based on the IDNR bathymetric map. Smalley Lake possesses a fairly linear relationship between lake depth and lake area. Only a small portion the lake (26%) contains a depth of less than 10 feet (3.1 m), which is generally the considered the lower limit of rooted plant growth. This means that only 26% of Smalley Lake's surface area could potentially support rooted aquatic plants. Almost 57% of the lake's surface area is greater than 20 feet (6.1 m) in depth. Volume increases fairly uniformly with depth in Smalley Lake until approximately 30 feet (9.1 m) where there is a sharp increase in depth per unit volume. The sharp increase in depth per unit volume in the lake's deeper water suggests that very little of Smalley Lake's volume is contained in the lake's deepest water.

Table 18. Morphological characteristics of Smalley Lake.

Smalley Lake	
Surface Area	68.9 acres (27.9 ha)
Volume	1,350 acre-feet (1,628,872 m^3)
Maximum Depth	49 feet (15 m)
Mean Depth	19.6 feet (6.0 m)
Shoreline Length	9,816 feet (2,992 m)
Shoreline Development Ratio	1.6

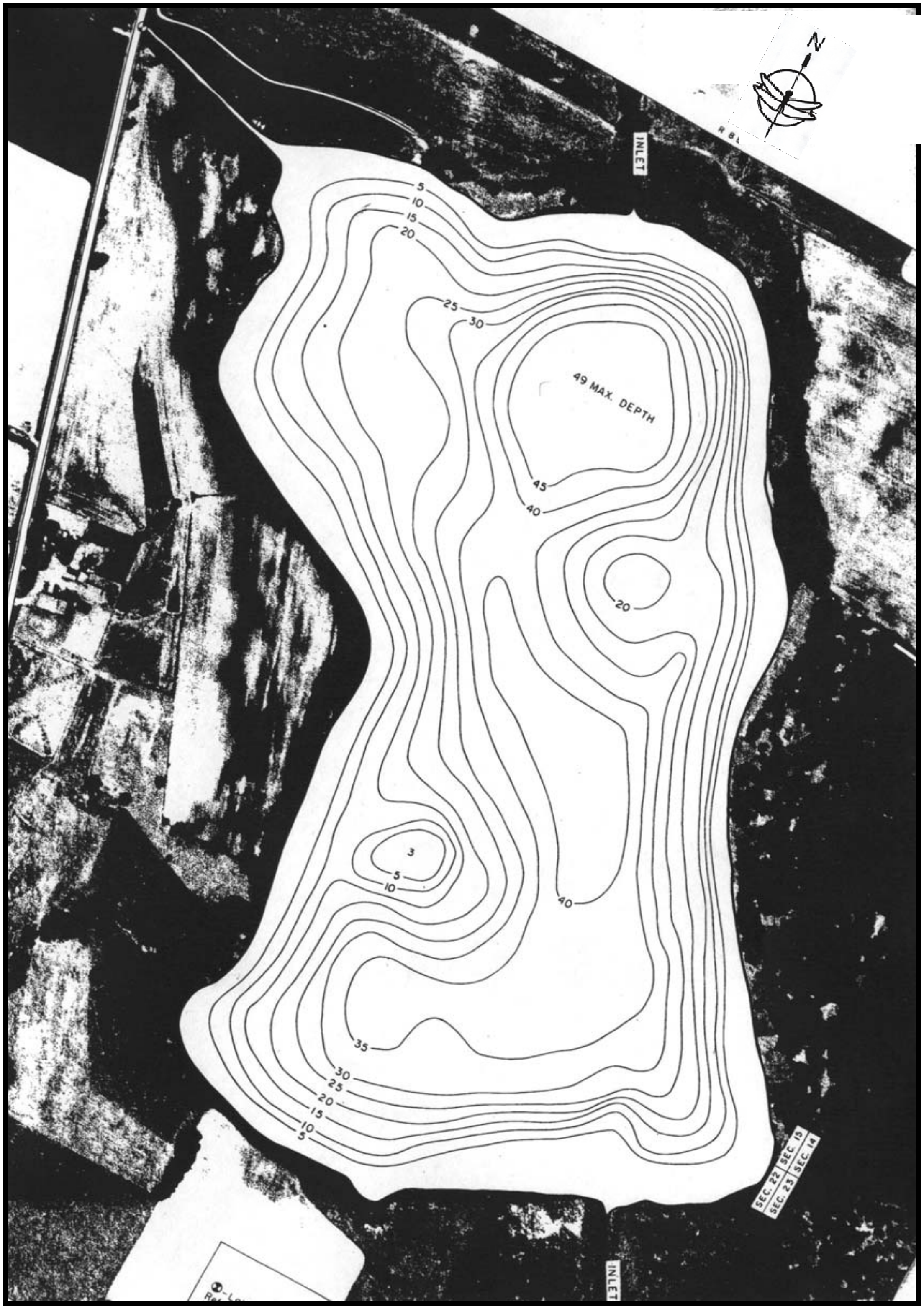

Figure 24. Bathymetric map of Smalley Lake.
Source: IDNR, 1960. Scale: 1”=400’

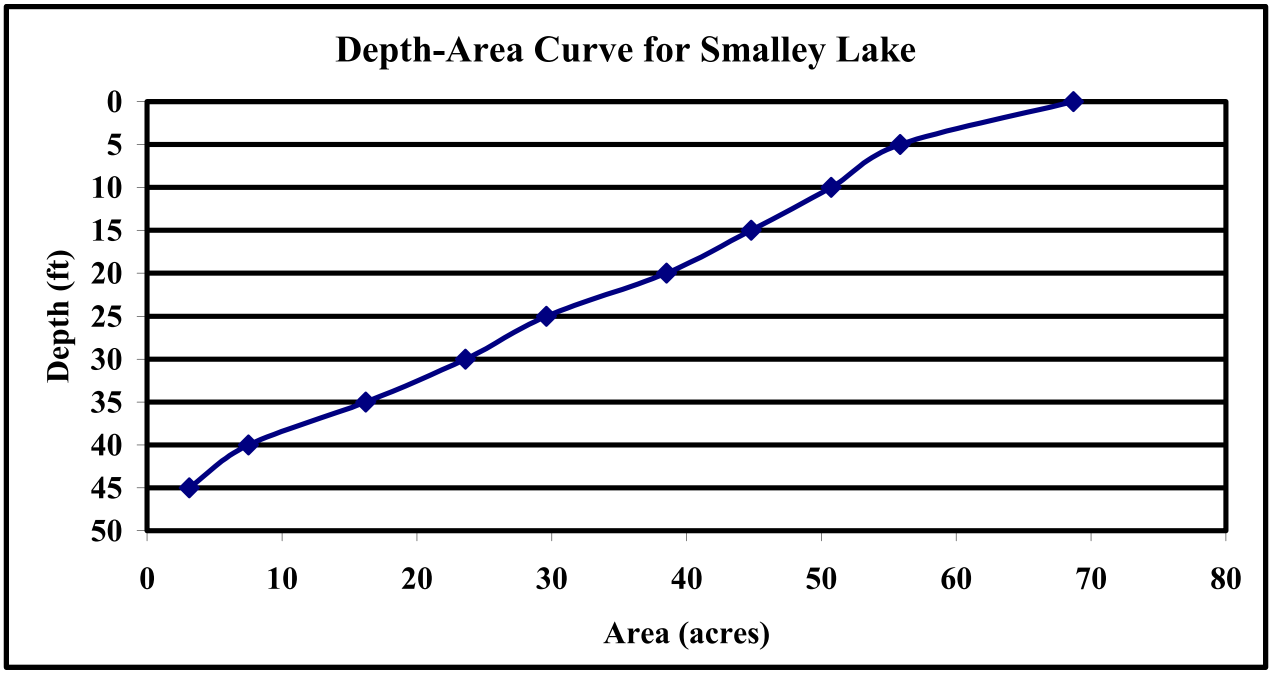

Figure 25. Depth-area curve for Smalley Lake

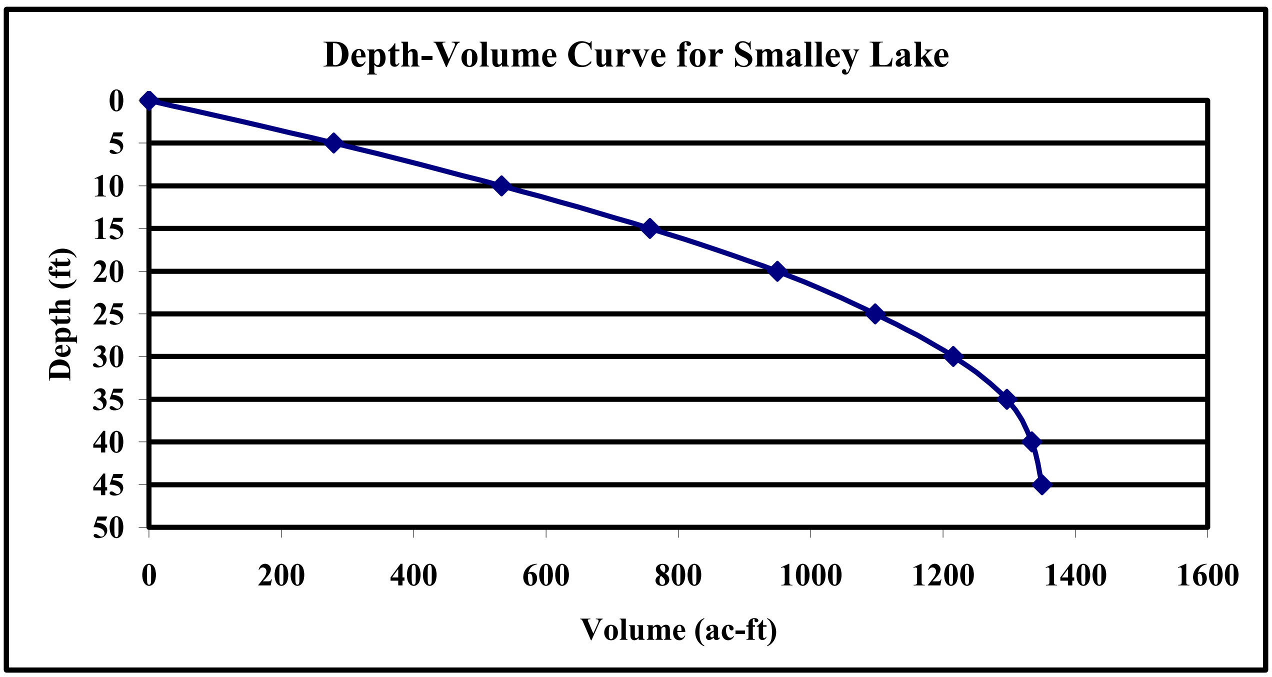

Figure 26. Depth-volume curve for Smalley Lake

The shoreline development ratio is a measure of the development potential of a lake. It is calculated by dividing the shoreline length by the circumference of a circle that has the same area as the lake. A perfectly circular lake with the same area as Smalley Lake (68.9 acres or 27.9 ha) would have a circumference of 6,141 ft (1,872 m). Dividing Smalley Lake's shoreline length (9,816 ft or 2,992 m) by 6,141 feet yields a ratio of 1.6:1. This ratio is fairly low compared to the shoreline development ratios observed on many other developed, northern Indiana lakes. Smalley Lake lacks shoreline channels observed on other popular Indiana lakes such as lakes in the Barbee Chain and Lake Tippecanoe. Shoreline channels increase the lakes' shoreline development ratios and increase potential for the development around the lakes. Given the immense popularity of lakes in northern Indiana this potential is often realized. Greater development around a lake has obvious impacts on the health of the lake system.

Smalley Lake's shoreline is relatively undeveloped compared to other northern Indiana lakes. Development of the lake likely began in the 1950s and 1960s. In 1972, IDNR fisheries biologists estimated that residential development existed along roughly 20% of the lake's shoreline (Taylor, 1973). Residential development continued over the next ten years. By 1982, much of the eastern shoreline was developed and development began to extend along the northern shoreline (Pearson, 1983). By 1992, portions of the northern, southern, and eastern shorelines had been residentially developed (Pearson, 1993). Additionally, IDNR fisheries biologists noted the construction of a subdivision on the north end of the lake.

Currently, Smalley Lake's shoreline development appears to be very similar to levels observed in 1992. In total, approximately 35 homes surround Smalley Lake (Figure 27). Much of the eastern and southeastern shorelines are developed for residential use. Residents along this portion of the lake have removed tree cover to create an unobstructed view of the lake. In place of emergent vegetation, residents have created beaches and installed a limited number of glacial rock and concrete seawalls. The western and southwestern shorelines of the lake remain largely undeveloped. One residence is present along the western shoreline; however, a shrub and tree buffer is present along much of the western shoreline. Smalley Lake's gravel boat ramp seen in Figure 27 in the northwestern corner of the lake was transferred to IDNR Division of Fish and Wildlife control in 1986.

Newer residential development along the northern and northeastern shoreline differs slightly than the older residential development along the eastern and southeastern portions of the Smalley Lake shoreline. One small subdivision exists adjacent to the northwest corner of the lake and one small subdivision exists adjacent to the northeast corner of the lake. Site development continues in these areas, particularly in the northeastern subdivision. These subdivisions are set back from Smalley Lake's shoreline resulting in less alteration of the lake's natural shoreline compared to the eastern and southeastern shorelines. In general, the northern portion of the lake has more natural vegetation patterns with trees and shrubs growing along the lakeshore and gradually transitioning into emergent vegetation along and within Smalley Lake.

The semi-natural shoreline around Smalley Lake has assisted in limiting erosion along the lakeshore. Only one potential area of concern was noted during a shoreline erosion survey of the lake. A homeowner along the southeastern side of the lake appeared to have recently completed some lakeshore landscaping leaving some areas of bare ground. It is likely that once this landscaped area becomes revegetated, this area will no longer pose an erosion concern.

Figure 27. Aerial photograph of Smalley Lake's shoreline.
Source: USGS, 1998. Scale: 1"=800'

4.2 Historical Water Quality Data

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana Stream Pollution Control Board, and the Indiana Clean Lakes Program have conducted various water quality tests on Smalley Lake. Table 19 presents a summary of some selected water quality parameters from these assessments of Smalley Lake.

Based on the parameters in Table 19, Smalley Lake's water quality may have worsened slightly over the past 30 years, but the decrease in quality has not be significant. There has been a slight decrease in water clarity in Smalley Lake over the past 30 years. Secchi disk transparency depths ranged from 1.5 to 2.1 meters in the 1970's and 1980's. In contrast, all Secchi disk transparency depths were below 1.5 meters after 1990. Total phosphorus concentration in Smalley Lake's water column appears to have increased 10-fold, although this is based on only one data point before 1989. The percentage of the water column that contains oxygen has decreased over the past 30 years. In the 1970's to mid 1980's 60-100% of the water column contained oxygen, providing ample habitat for the lake's inhabitants. During the late 1980's to the present day, the percentage of the water column with oxygen decreased to around 30%. (The 1982 and 1988 samples were not included in this analysis since sampling occurred earlier in the summer during these years making a direct comparison invalid.) Finally, the Indiana TSI scores increased slightly from the 1970's to the present time. The 1974 score suggest Smalley Lake is only slightly eutrophic, while the score from the 1989, 1993, and 1998 assessments suggest the lake is eutrophic to hypereutrophic. The results from the present study place the lake squarely in the hypereutrophic category.

Table 19. Summary of historic data for Smalley Lake.

Date	Secchi (m)	Mean TP (mg/L)	Percent Oxic (%)	Plankton Density (#/L)	TSI score (based on means)	Data Source
1972	2.0	-	61%	-	-	Pearson, 1993
1974	2.1	0.05*	100%	-	34***	ISPCB
1982	1.5	-	100%**	-	-	Pearson, 1993
1983	-	-	60%	-	-	Pearson, 1993
1988	2.1	-	100%**	-	-	Pearson, 1993
1989	1.5	0.313	31%	54,349	47	CLP, 1989
1992	1.4	-	-	-	-	Pearson, 1993
1993	1.3	0.584	27%	16,850	40	CLP, 1993
1998	1.3	0.502	31%	19,810	43	CLP, 1998
2003	1.1	0.316	22%	165,183	61	Present Study

* Water column average; all other values are mean of epilimnion and hypolimnion values.
** Sampling conducted in June when better oxygen conditions are expected.
*** Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.

Historical dissolved oxygen profiles from the 1989, 1993, and 1998 assessments of Smalley Lake were available and are displayed in Figure 28. The profiles reiterate the data summarized in Table 19 above. Each profile shows that the bottom two thirds of the lake was anoxic. Both 1993 and 1998 profiles are plus-heterograde, which is characterized by a peak in oxygen concentration at a depth below the water surface. This is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a ***metalimnetic oxygen maxima***, this results when the rate of settling plankton slows in the denser waters of the metalimnion. At this depth, the plankton can take advantage of nutrients diffusing from the nutrient-enriched hypolimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating the peak in oxygen at that level.

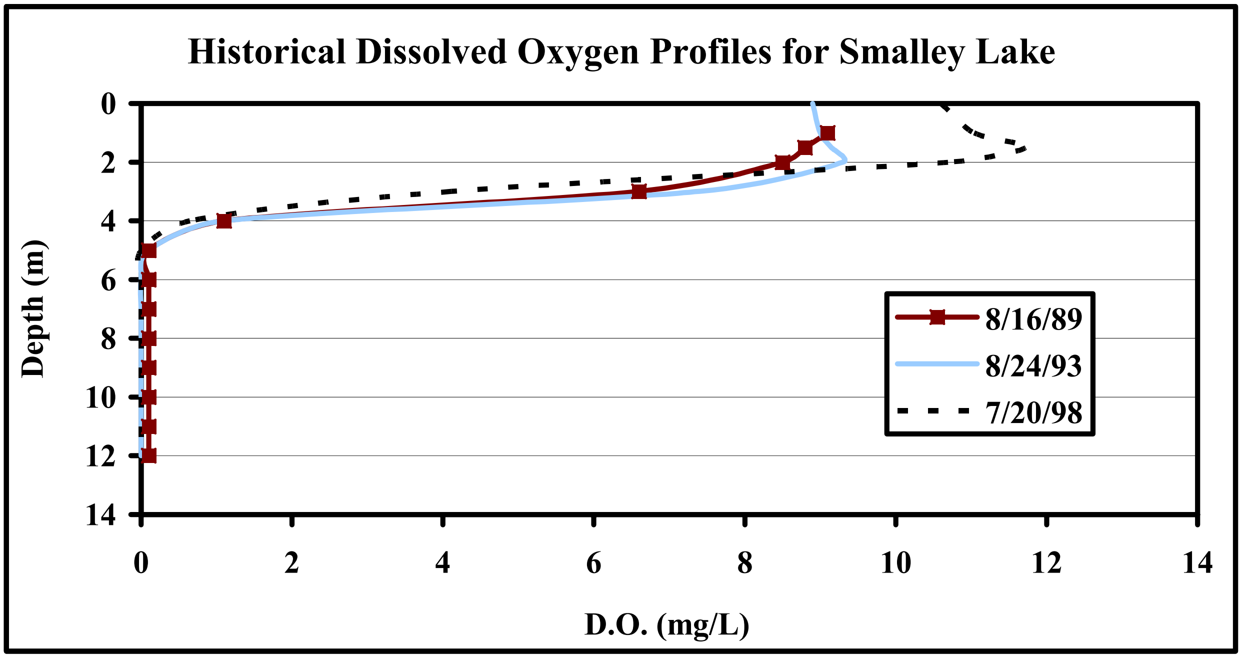

Figure 28. Historical dissolved oxygen profiles for Smalley Lake, which were sampled by the Clean Lakes Program during 1989, 1993, and 1998.

Because of the comprehensive nature of the Clean Lakes Program (CLP) assessments, it may be useful to provide the complete results of previous CLP examinations of Smalley Lake for comparison to the current study's results. Tables 20 through 22 outline those results. As noted above, the historical assessments show Smalley Lake suffers from relatively poor water quality and low oxygen levels. Its Secchi disk transparency depth ranged from 1.3 to 1.5 meters. Light transmission at 3 feet (0.9 m) was less than 50% in all three years. Only approximately 30% of the water column contained oxygen levels above 0.3 mg/L. This limits habitat availability for the lake's biota and creates conditions conducive for the release of phosphorus from the lake's bottom sediments.

The lake assessments also indicate that Smalley Lake possesses relatively high nutrient concentrations. Hypolimnetic soluble reactive phosphorus concentrations are particularly high, accounting for the vast majority of the total phosphorus concentration each year. The high level of dissolved phosphorus coupled with anoxic conditions suggests internal phosphorus release is indeed occurring in Smalley Lake. The lake also exhibits high hypolimnetic ammonia concentrations. Because ammonia is a by-product of decomposition, high hypolimnetic ammonia concentrations usually indicate that decomposition of organic materials is occurring in the lake's bottom waters. High ammonia concentrations can also create inhospitable conditions for the lake's biota.

Tables 20 through 22 show that Smalley Lake consistently supports an algal community dominated by blue-green algae. Blue-green algae are considered nuisance algae and generally dominate the algal community in eutrophic lakes. Smalley Lake's historical data indicate that the lake is at least eutrophic if not hypereutrophic, so a dominance of blue-green algae is not unexpected.

Table 20. Historical water quality characteristics of Smalley Lake, 1989.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	ND	ND	-
Alkalinity	ND	ND	-
Conductivity	ND	ND	-
Secchi Depth Transparency	1.5 meters	-	6
Light Transmission @ 3 ft.	18 %	-	4
1% Light Level	ND	-	-
Total Phosphorous	0.049 mg/L	0.576 mg/L	4
Soluble Reactive Phosphorous	0.008 mg/L	0.460 mg/L	4
Nitrate-Nitrogen	5.564 mg/L	4.004 mg/L	4
Ammonia-Nitrogen	0.055 mg/L	2.511 mg/L	4
Organic Nitrogen	1.613 mg/L	1.752 mg/L	3
Oxygen Saturation @ 5ft.	103 %	-	0
% Water Column Oxic	30.77 %	-	3
Plankton Density	54,349 #/L	-	5
Blue-Green Dominance	98.81 %	-	10
Chlorophyll *a*	ND	-	-
ND – No Data		**TSI score**	**47**

Table 21. Historical water quality characteristics of Smalley Lake, 1993.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	ND	ND	-
Alkalinity	ND	ND	-
Conductivity	ND	ND	-
Secchi Depth Transparency	1.3 meters	-	6
Light Transmission @ 3 ft.	39 %	-	3
1% Light Level	ND	-	-
Total Phosphorous	0.024 mg/L	1.144 mg/L	4
Soluble Reactive Phosphorous	ND	1.325 mg/L	4
Nitrate-Nitrogen	0.022 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	2.639 mg/L	4
Organic Nitrogen	0.786 mg/L	ND	2
Oxygen Saturation @ 5ft.	109 %	-	0
% Water Column Oxic	27.4 %	-	4
Plankton Density	16,850 #/L	-	3
Blue-Green Dominance	84.33 %	-	10
Chlorophyll *a*	ND	-	-
ND – No Data		**TSI score**	**40**

Table 22. Historical water quality characteristics of Smalley Lake, 1998.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.53	7.3	-
Alkalinity	169 mg/L	223.9 mg/L	-
Conductivity	450 μmhos	345 μmhos	-
Secchi Depth Transparency	1.3 meters	-	6
Light Transmission @ 3 ft.	43 %	-	3
1% Light Level	11.5 feet	-	-
Total Phosphorous	0.028 mg/L	0.976 mg/L	4
Soluble Reactive Phosphorous	0.010 mg/L	0.944 mg/L	4
Nitrate-Nitrogen	0.213 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	2.015 mg/L	4
Organic Nitrogen	0.838 mg/L	0.814 mg/L	2
Oxygen Saturation @ 5ft.	150 %	-	4
% Water Column Oxic	30.76 %	-	3
Plankton Density	19,810 #/L	-	3
Blue-Green Dominance	83.66 %	-	10
Chlorophyll *a*	14.78 μg/L	-	-
		TSI score	**43**

4.2 Lake Assessment Methods

The water sampling and analytical methods used for Smalley Lake were consistent with those used in IDEM's Indiana Clean Lakes Program and IDNR's Lake and River Enhancement Program. Water samples were collected and analyzed for various parameters from Smalley Lake on July 29, 2003 from the surface waters (***epilimnion***) and from the bottom waters (***hypolimnion***) of the lake at a location over the deepest water. The parameters examined include pH, alkalinity, conductivity, total phosphorus, soluble reactive phosphorus, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, and organic nitrogen. In addition to these parameters, several other measurements of lake health were recorded. Secchi disk, light transmission, and oxygen saturation are single measurements made in the epilimnion. Only the epilimnetic sample was analyzed for chlorophyll. Dissolved oxygen and temperature were measured at one-meter intervals from the surface to the bottom. A tow to collect plankton was made from the 1% light level depth up to the water surface. Conductivity, temperature, and dissolved oxygen were measured *in situ* with an YSI Model 85 meter.

All lake samples were placed in the appropriate bottle (with preservative if needed) and stored in an ice chest until analysis at SPEA's laboratory in Bloomington. SRP samples were filtered in the field through a Whatman GF-C filter.

All sampling techniques and laboratory analytical methods were performed in accordance with procedures in *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (APHA, 1998). Plankton counts were made using a standard Sedgewick-Rafter counting cell. Fifteen fields per cell were counted. Plankton identifications were made according to: Prescott (1982), Ward and Whipple (1959), and Whitford and Schumacher (1984).

The following is a brief description of the parameters analyzed during the lake sampling efforts:

Temperature. Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. For example, water temperature affects the amount of oxygen dissolved in the water column. Likewise, life associated with the aquatic environment in any location has its species composition and activity regulated by water temperature. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana waters. For example, temperatures during the summer months should not exceed 90 ^{o}F (32.2 ^{o}C).

Dissolved Oxygen (D.O). D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 mg/L of D.O. Coldwater fish such as trout generally require higher concentrations of D.O. than warmwater fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. D.O. enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O. Conversely, dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 μmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 μmhos per mg/L of dissolved solids yields a specific conductance range of approximately 1000 to 1360 μmhos. This report presents conductivity measurements at each site in μmhos.

pH. The pH of water describes the concentration of acidic ions (specifically H+) present in water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6 to 9 pH units for the protection of aquatic life. pH concentrations in excess of 9 are considered acceptable when the concentration occurs as daily fluctuations associated with photosynthetic activity.

Alkalinity. Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH.

Nutrients. Limnologists measure nutrients to predict the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a lake or stream. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake or stream. Complete elimination of algae and/or rooted plants is neither desirable nor even possible and should, therefore, never be the goal in managing a lake or stream. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake or stream. Limnologists commonly measure nutrient concentrations in aquatic ecosystem evaluations to determine the potential for such nuisance growth.

Like terrestrial plants, algae and rooted aquatic plants rely primarily on phosphorus and nitrogen for growth. Aquatic plants receive these nutrients from fertilizers, human and animal waste, atmospheric deposition in rainwater, and yard waste or other organic material that reaches the lake or stream. Nitrogen can also diffuse from the air into the water. This nitrogen is then "fixed" by certain algae species into a usable, "edible" form of nitrogen. Because of this readily available source of nitrogen (the air), phosphorus is usually the "limiting nutrient" in aquatic ecosystems. This means that it is actually the amount of phosphorus that controls plant growth in a lake or stream.

Phosphorus and nitrogen have several forms in water. The two common phosphorus forms are **soluble reactive phosphorus (SRP)** and **total phosphorus (TP)**. SRP is the dissolved form of phosphorus. It is the form that is "usable" by algae. Algae cannot directly digest and use particulate phosphorus. Total phosphorus is a measure of both dissolved and particulate forms of phosphorus. The most commonly measured nitrogen forms are **nitrate-nitrogen (NO_3)**, **ammonium-nitrogen (NH_4^+)**, and **total Kjeldahl nitrogen (TKN)**. Nitrate is a dissolved form of nitrogen that is commonly found in the upper layers of a lake or anywhere that oxygen is readily available. In contrast, ammonium-nitrogen is generally found where oxygen is lacking. ***Anoxia***, or a lack of oxygen, is common in the lower layers of a lake. Ammonium is a byproduct of decomposition generated by bacteria as they decompose organic material. Like SRP, ammonium is a dissolved form of nitrogen and the one utilized by algae for growth. The TKN measurement parallels the TP measurement to some extent. TKN is a measure of the **total organic nitrogen** (particulate) and ammonium-nitrogen in the water sample.

While the United States Environmental Protection Agency (USEPA) has established some nutrient standards for drinking water safety, it has not established similar nutrient standards for protecting the biological integrity of a lake. (The USEPA, in conjunction with the States, is currently working on developing these standards.) The USEPA has issued recommendations for numeric nutrient criteria for lakes (USEPA, 2000a). While these are not part of the Indiana Administrative Code, they serve as potential target conditions for which watershed managers might aim. Other researchers have suggested thresholds for several nutrients in lake ecosystems as well (Carlson, 1977; Vollenweider, 1975). Lastly, the Indiana Administrative Code (IAC) requires that all waters of the state have a nitrate concentration of less than 10 mg/L, which is the drinking water standard for the state.

With respect to lakes, limnologists have determined the existence of certain thresholds for nutrients above which changes in the lake's biological integrity can be expected. For example, Correll (1998) found that soluble reactive phosphorus concentrations of 0.005 mg/L are enough to maintain eutrophic or highly productive conditions in lake systems. For total phosphorus concentrations, 0.03 mg/L (0.03 ppm – parts per million or 30 ppb – parts per billion) is the generally accepted threshold. Total phosphorus concentrations above this level can promote nuisance algae blooms in lakes. The USEPA's recommended nutrient criterion for total phosphorus is fairly low, 14.75 μg/L (USEPA, 2000a). This is an unrealistic target for many Indiana lakes. It is unlikely that IDEM will recommend a total phosphorus criterion this low for incorporation in the IAC. Similarly, the USEPA's recommended nutrient criterion for nitrate-nitrogen in lakes is low at 8 μg/L. This is below the detection limit of most laboratories. In general, levels of inorganic nitrogen (which includes nitrate-nitrogen) that exceed 0.3 mg/L may also promote algae blooms in lakes. High levels of nitrate-nitrogen can be lethal to fish. The nitrate LC_{50} is 5 mg/L for logperch, 40 mg/L for carp, and 100 mg/L for white sucker. (Determined by performing a bioassay in the laboratory, the LC_{50} is the concentration of the pollutant being tested, in this case nitrogen, at which 50% of the test population died in the bioassay.) The USEPA's recommended criterion for total Kjeldahl nitrogen in lakes is 0.56 mg/L.

It is important to remember that none of the threshold or recommended concentrations listed above are state standards for water quality. They are presented here to provide a frame of reference for the concentrations found in Smalley Lake. The IAC sets only nitrate-nitrogen and ammonia-nitrogen standards for waterbodies in Indiana. The Indiana Administrative Code requires that all waters of the state have a nitrate-nitrogen concentration of less than 10 mg/L, which is the drinking water standard for the state. The IAC standard for ammonia-nitrogen depends upon the water's pH and temperature, since both can affect ammonia-nitrogen's toxicity. The Smalley Lake samples did not exceed the state standard for either nitrate-nitrogen or ammonia-nitrogen.

Secchi Disk Transparency. This refers to the depth to which the black and white Secchi disk can be seen in the lake water. Water clarity, as determined by a Secchi disk, is affected by two primary factors: algae and suspended particulate matter. Particulates (for example, soil or dead leaves) may be introduced into the water by either runoff from the land or from sediments already on the bottom of the lake. Many processes may introduce sediments from runoff; examples include erosion from construction sites, agricultural land, and riverbanks. Bottom sediments may be resuspended by bottom feeding fish such as carp, or in shallow lakes, by motorboats or strong winds. In general, lakes possessing Secchi disk transparency depths greater than 15 feet (4.5 m) have outstanding clarity. Lakes with Secchi disk transparency depths less than 5 feet (1.5 m) possess poor water clarity (ISPCB, 1976; Carlson, 1977). The USEPA recommended a numeric criterion of 10.9 feet (3.33m) for Secchi disk depth in lakes (USEPA, 2000a).

Light Transmission. Similar to the Secchi disk transparency, this measurement uses a light meter (photocell) to determine the rate at which light transmission is diminished in the upper portion of the lake's water column. Another important light transmission measurement is determination of the 1% light level. The 1% light level is the water depth to which one percent of the surface light penetrates. This is considered the lower limit of algal growth in lakes. The volume of water above the 1% light level is referred to as the ***photic zone***.

Plankton. Plankton are important members of the aquatic food web. Plankton include the algae (microscopic plants) and the zooplankton (tiny shrimp-like animals that eat algae). Plankton are collected by towing a net with a very fine mesh (63-micron openings = 63/1000 millimeter). The plankton net is towed up through the lake's water column from the one percent light level to the surface. Of the many different planktonic species present in the water, the blue-green algae are of particular interest. Blue-green algae are those that most often form nuisance blooms and their dominance in lakes may indicate poor water conditions.

Chlorophyll *a*. The plant pigments in algae consist of the chlorophylls (green color) and carotenoids (yellow color). Chlorophyll *a* is by far the most dominant chlorophyll pigment and occurs in great abundance. Thus, chlorophyll *a* is often used as a direct estimate of algal biomass. In general, chlorophyll *a* concentrations below 2 μg/L are considered low, while those exceeding 10 μg/L are considered high and indicative of poorer water quality. The USEPA recommended a numeric criterion of 2.6 μg/L as a target concentration for lakes in Aggregate Nutrient Ecoregion VII (USEPA, 2000a).

4.3 Lake Assessment Results

The results from the Smalley Lake water quality assessment are included in Tables 23 and 24 and Figure 29.

Table 23. Water quality characteristics of Smalley Lake, 7/29/2003.

Parameter	Epilimnetic Sample (1 m)	Hypolimnetic Sample (12 m)	Indiana TSI Points (based on mean values)
pH	8.2	7.5	-
Alkalinity	154 mg/L	234 mg/L	-
Conductivity	455.6 μmhos	376.4 μmhos	-
Secchi Depth Transparency	1.1 meters	-	6
Light Transmission @ 3 ft.	13 %	-	4
1% Light Level	8.0 feet	-	-
Total Phosphorous	0.047 mg/L	0.585 mg/L	4
Soluble Reactive Phosphorous	0.010 mg/L	0.559 mg/L	4
Nitrate-Nitrogen	1.455 mg/L	0.022 mg/L	2
Ammonia-Nitrogen	0.035 mg/L	2.186 mg/L	4
Organic Nitrogen	1.370 mg/L	0.851 mg/L	3
Oxygen Saturation @ 5ft.	102 %	-	0
% Water Column Oxic	21.9 %	-	4
Plankton Density	165,183 #/L	-	20
Blue-Green Dominance	96.18 %	-	10
Chlorophyll *a*	19.37 μg/L	-	-
		TSI score	**61**

Table 24. The plankton sample representing the species assemblage on 7/29/2003.

Species	Abundance (#/L)
Blue-Green Algae (Cyanophyta)	
Aphanizomenon	148,779
Anabaena	4,621
Microcystis	1,094
Oscillatoria	3,982
Lyngbya	122
Coelosphaerium	30
Aphanocapsa	243
Green Algae (Chlorophyta)	
Pediastrum	152
Ulothrix	1,003
Staurastrum	91
Diatoms (Bacillariophyta)	
Synedra	30
Fragilaria	1,550
Asterionella	334
Other Algae	
Chrysosphaerella	152
Mallomonas	61
Ceratium	2,310
Dinobryon	152
Zooplankton	
Filinia	61
Keratella	243
Polyarthra	91
Nauplius	48.4
Cyclopoid Copepod	10.7
Calanoid Copepod	8.5
Bosmina	0.7
Daphnia	7.8
Diaphanosoma	2.8
Total	**165,183**

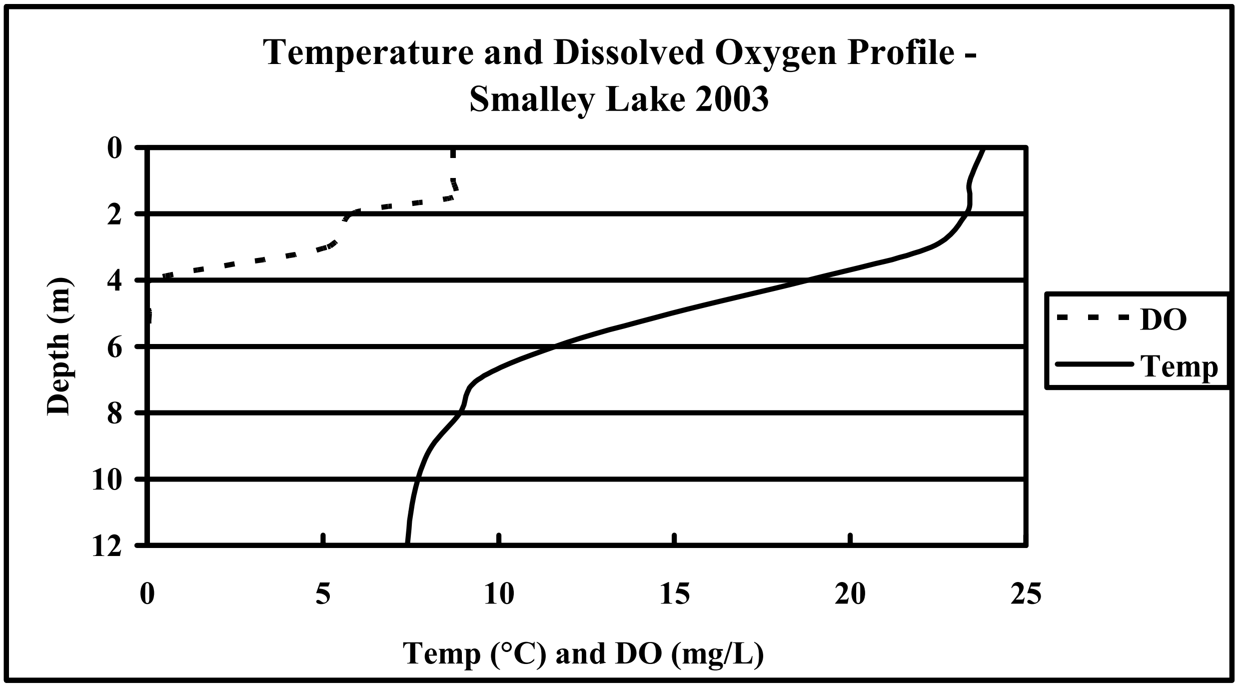

Figure 29. Temperature and dissolved oxygen profiles for Smalley Lake on 7/29/2003.

The temperature profile for Smalley Lake shows that the lake was stratified at the time of sampling (Figure 29). During thermal stratification, the bottom waters (***hypolimnion***) of the lake are isolated from the well-mixed surface waters (***epilimnion***) by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the ***metalimnion***. At the time of sampling, the epilimnion was confined to the upper 3 meters of water. The sharp decline in temperature between 3 and 7 meters defines the metalimnion or transition zone. The hypolimnion occupied water deeper than 7 meters.

As shown in Figure 29, the upper 1.5 meters of the lake was well oxygenated. Dissolved oxygen level declined between 1.5 and 4 meters, becoming anoxic between the depths of 3m and 4m. This is likely due to biochemical oxygen demand (BOD) from excess organic detritus in the deeper waters and the sediments. Algae and other organic matter washed into the lake from the watershed constantly settle down through the lake's water column to the lake sediments. If the quantity of such material is high enough, the decomposing bacteria consume all the available oxygen and undecomposed organic matter collects on the lake bottom. Because of these processes, water below 4 meters had no oxygen to support fish and other aquatic organisms. The lack of oxygen at the lake-sediment interface created conditions conducive to the release of phosphorus from the lake's sediments. Only 22% of the lake's water column is oxic, limiting the amount of habitat available for aquatic fauna.

The pH values determined from Smalley Lake samples are slightly alkaline. Values of pH are slightly higher in the epilimnion where the process of photosynthesis consumes carbon dioxide, a weak acid. The lack of photosynthesis in the hypolimnion and the liberation of carbon dioxide by respiring bacteria keep pH levels lower in the hypolimnion. Conductivity values, a measure of dissolved ions, are within the normal range for Indiana lakes.

Alkalinity is a measure of the water's ability to resist change in pH, or acid content. It is also referred to as acid neutralizing capacity or buffering capacity. This buffering action is important because it ensures a relatively constant chemical and biological environment in lakes. Alkalinity is determined largely by the availability and chemistry of carbonate in water. Sources of carbonate to natural waters include limestone (calcium carbonate) and carbon dioxide. The alkalinity concentrations within Smalley Lake suggest that the lake is moderately buffered.

Water clarity is poor in Smalley Lake. The lake exhibited a Secchi disk transparency depth of just over 3.5 feet (1.1 m). This is much poorer than the target Secchi disk transparency depth of nearly 11 feet (3.3 m) recommended by the USEPA (2000a). Light transmission at 3 feet (0.9 m) measurement reflects the poor water clarity in the lake. Only 13% of the incident light was measured at 3 feet (0.9 m) below the water's surface. The lake's dense plankton community and non-algal turbidity both degrade the lake's water clarity.

The 1% light level, which limnologists use to determine the lower limit of sufficient light to support plant photosynthesis, extended to 8 feet (2.4 m). Based on the depth-area curve in Figure 25, approximately 17 acres of lake area (about 25% of the total area) overlies water less than 8 feet deep. This means that about 25% of the lake area has sufficient light to support rooted aquatic plants. This area is called the ***littoral zone***. Furthermore, based on the depth-volume curve (Figure 26), a volume of approximately 450 acre-feet (30% of Smalley Lake's total volume) lies above the 1% light level. This area, referred to as the ***photic zone***, represents the amount of water with sufficient light to support algae growth. These two zones provide insight into the potential for primary production (plant growth) in Smalley Lake.

Phosphorus and nitrogen are the primary plant nutrients in lakes. The total phosphorus concentration was relatively low to moderate for Indiana lakes in the epilimnion. Despite this, the epilimnion total phosphorus concentration of 0.047 mg/L still exceeds the 0.03 mg/L concentration threshold that is considered high enough to support eutrophic conditions (Wetzel, 2001). The total phosphorus concentration was considerably higher in the hypolimnion, 0.585 mg/L. Soluble reactive phosphorus concentration in the epilimnion was below the laboratory detection limit. This is typical in lakes since SRP is readily consumed by algae in the lake's epilimnion. The SRP concentration in Smalley Lake's hypolimnion was high. The data indicate that most of the total phosphorus concentration in the hypolimnion consists of SRP. This dominance of the dissolved form of phosphorus coupled with the lack of oxygen in the deep waters over the bottom sediments suggests that dissolved phosphorus is being released from the lake's bottom sediments. This is called ***internal phosphorus loading*** and can be a significant additional source of phosphorus in some lakes. The extent of internal phosphorus loading will be examined using a model later in this report.

The concentration of nitrate-nitrogen was high in the epilimnion (1.455 mg/L). Ammonia oxidizes rapidly to nitrate in the presence of adequate oxygen and nitrifying bacteria. The high nitrate concentration in the epilimnion coupled with the high ammonia concentration in the lake's hypolimnion suggest ammonia is diffusing into the epilimnion from the hypolimnion and being converted to nitrate in the well-oxygenated epilimnion. The lake also receives relatively high nitrate loads from its two tributaries.

Nitrate is reduced to ammonia when oxygen is low. Smalley Lake's hypolimnion lacks oxygen suggesting any nitrate reaching the lake's lower waters is quickly converted to ammonia. Ammonia is also a byproduct of bacterial decomposition. The decomposition of organic materials in the lake's hypolimnion contributes to the relatively high ammonia concentration observed in Smalley Lake. Organic nitrogen levels in Smalley Lake's epilimnion and hypolimnion were moderate to high for Indiana lakes.

At the time of sampling Smalley Lake supported a fairly dense plankton community. *Aphanizomenon*, a blue-green algae, was by far the most dominant genera found, and was the reason for the high overall plankton density. Blue-green algae are usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they: 1) may form extremely dense nuisance blooms; 2) may cause taste and odor problems; and 3) are unpalatable as food for many zooplankton grazers. The high *Aphanizomenon* amount is the primary reason for the much higher TSI score in 2003 as compared to previous years.

4.5 Lake Assessment Discussion

The interpretation of a comprehensive set of water quality data can be quite complicated. Often, attention is directed at the important plant nutrients (phosphorus and nitrogen) and to water transparency (Secchi disk) since dense algal blooms and poor transparency greatly affect the health and use of lakes.

To more fully understand the water quality data, it is useful to compare data from the lake in question to standards, if they exist, to other lakes, or to criteria that most limnologists agree upon. Because there are no nutrient standards for Indiana lakes, the Smalley Lake results are compared below with data from other lakes and with generally accepted criteria.

Comparison with Vollenweider's Data

Results of studies conducted by Richard Vollenweider in the 1970s are often used as guidelines for evaluating concentrations of water quality parameters. His results are given in Table 25. Vollenweider relates the concentrations of selected water quality parameters to a lake's *trophic state.* The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: ***oligotrophic***, ***mesotrophic***, ***eutrophic***, and ***hypereutrophic***. Lake conditions characteristic of these trophic states are:

Oligotrophic - lack of plant nutrients keep productivity low (ie. few rooted plants and not algae blooms); lake contains oxygen at all depths; clear water, deeper lakes can support trout.

Mesotrophic - moderate plant productivity; hypolimnion may lack oxygen in summer; moderately clear water, warm water fisheries only - bass and perch may dominate.

Eutrophic - contains excess nutrients; blue-green algae dominate during summer; algae scums are probable at times; hypolimnion lacks oxygen in summer; poor transparency; rooted macrophyte problems may be evident.

Hypereutrophic - algal scums dominate in summer; few macrophytes; no oxygen in hypolimnion; fish kills possible in summer and under winter ice.

The units in the table are either milligrams per liter (mg/L) or micrograms per liter (μg/L). One mg/L is equivalent to one part per million (ppm) while one microgram per liter is equivalent to one part per billion (ppb). These are only guidelines, similar concentrations in a particular lake may not cause problems if something else is limiting the growth of algae or rooted plants.

Table 25. Mean values of some water quality parameters and their relationship to lake production (after Vollenweider, 1975).

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (mg/L or ppm)	0.008	0.027	0.084	>0.750*
Total Nitrogen (mg/L or ppm)	0.661	0.753	1.875*	-
Chlorophyll *a* (μg/L or ppb)	1.7	4.7	14.3*	-

Values for Smalley Lake are indicated by the asterisk (*) in the table above. Smalley Lake's total phosphorus concentration was similar to lakes in Vollenweider's hypereutrophic category, while the concentration of total nitrogen and chlorophyll *a* suggest that Smalley Lake is more eutrophic in nature using Vollenweider's criteria.

Comparison with Other Indiana Lakes

The Smalley Lake results can also be compared to other Indiana lakes. Table 26 presents data from 355 Indiana lakes collected during July and August 1994-98 under the Indiana Clean Lakes Program. The set of data summarized in the table show mean values of epilimnetic and hypolimnetic samples for each of the 355 lakes. It should be noted that a wide variety of conditions, including geography, morphometry, time of year, and watershed characteristics, could influence the water quality of lakes. Thus, it is difficult to predict or even explain the reasons for the water quality of a given lake.

All the nutrient concentrations and the chlorophyll *a* level measured at Smalley Lake were above the median values measured for the set of Indiana lakes, while Smalley Lake's Secchi depth was less than the median depth in the set of Indiana lakes. This suggests that Smalley Lake had worse overall water quality than most Indiana lakes at the time of the July 29, 2003 sampling.

Table 26. Water quality characteristics of 355 Indiana lakes sampled from 1994 thru 1998 by the Indiana Clean Lakes Program. Means of epilimnion and hypolimnion samples were used.

	Secchi Disk (m)	NO_3 (mg/L)	NH_4 (mg/L)	TKN (mg/L)	TP (mg/L)	SRP (mg/L)	Chl. *a* (μg/L)
Median	1.8	0.025	0.472	1.161	0.097	0.033	5.33
Maximum	9.2	9.303	11.248	13.794	4.894	0.782	230.9
Minimum	0.1	0.022	0.018	0.230	0.001	0.001	0
Smalley Lake	**1.1**	**0.739**	**1.111**	**2.221**	**0.316**	**0.285**	**19.37**

Using a Trophic State Index

In addition to simple comparisons to other lakes, lake water quality data can be evaluated through the use of a trophic state index or TSI. Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake.

The Indiana TSI

The Indiana TSI (ITSI) was developed by the Indiana Stream Pollution Control Board and published in 1986 (IDEM, 1986). The original ITSI differed slightly from the one in use today. Today's ITSI uses ten different water quality parameters to calculate a TSI score. Table 27 shows the point values assigned for each parameter.

Table 27. The Indiana Trophic State Index.

Parameter and Range			Eutrophy Points
I.	Total Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
II.	Soluble Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
III.	Organic Nitrogen (ppm)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
V.	Ammonia (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3
	D.	1.0 or more	4

VI. Dissolved Oxygen: Percent Saturation at 5 feet from surface

A.	114% or less	0
B.	115% to 119%	1
C.	120% to 129%	2
D.	130% to 149%	3
E.	150% or more	4

VII. Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen

A.	28% or less	4
B.	29% to 49%	3
C.	50% to 65%	2
D.	66% to 75%	1
E.	76% to 100%	0

VIII. Light Penetration (Secchi Disk)

A.	Five feet or under	6

IX. Light Transmission (Photocell): Percent of light transmission at a depth of 3 feet

A.	0 to 30%	4
B.	31% to 50%	3
C.	51% to 70%	2
D.	71% and up	0

X. Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface

A.	less than 3,000 organisms/L	0
B.	3,000 - 6,000 organisms/L	1
C.	6,001 - 16,000 organisms/L	2
D.	16,001 - 26,000 organisms/L	3
E.	26,001 - 36,000 organisms/L	4
F.	36,001 - 60,000 organisms/L	5
G.	60,001 - 95,000 organisms/L	10
H.	95,001 - 150,000 organisms/L	15
I.	150,001 - 5000,000 organisms/L	20
J.	greater than 500,000 organisms/L	25
K.	Blue-Green Dominance: additional points	10

Values for each water quality parameter are totaled to obtain an ITSI score. Based on this score, lakes are then placed into one of five categories:

TSI Total	Water Quality Classification
0-15	Oligotrophic
16-31	Mesotrophic
32-46	Eutrophic
47-75	Hypereutrophic
*	Dystrophic

Four of these categories correspond to the qualitative lake productivity categories described earlier. The fifth category, dystrophic, is for lakes that possess high nutrient concentrations but have limited rooted plant and algal productivity (IDEM, 2000). A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening, while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI score that do not necessarily indicate a long-term change in lake condition.

The Indiana Trophic State Index value calculated for Smalley Lake is 61 (see Table 23). This value falls within the hypereutrophic range of the Indiana TSI. This conclusion is consistent with the results obtained from the comparison of the Smalley Lake data to Vollenweider's data (Table 25) and other Indiana lakes (Table 26). The Vollenweider data indicate that the lake lies in the eutrophic-hypereutrophic category. As will be described below, the Indiana TSI score for Smalley Lake is also consistent with the analysis of the lake data using Carlson's TSI.

Because the ITSI captures one snapshot of a lake in time, using the ITSI to track trends in lake productivity may be the best use of the ITSI. Table 19 presents historical ITSI scores for Smalley Lake. Historical ITSI scores show a slight decrease in water quality from the 1970's to the 1990's but relatively stable water quality in the past 10+ years. The current ITSI score of 61 suggests a further decrease in water quality. (Jones (1996) suggests that changes in TSI scores of 10 or more points are indicative of a changes in trophic status, while smaller changes in TSI scores may be more attributable to natural fluctuations in water quality parameters.) It should be noted that nearly half of the 61 points came from algae parameters. The Indiana TSI has been criticized for its heavy reliance of algae compared to the weight given to transparency and nutrient parameters. (Thirty-five of the possible 75 points can come from the plankton category.) Thus, it is important to consider the lake's biological and chemical parameters within the context of several evaluation methods such as those presented in this document. Despite the reliance on algae parameters, the ITSI score for Smalley Lake would likely still fall in the eutrophic or hypereutrophic categories if algae parameters were weighted equally with transparency and nutrient parameters. Thus, the ITSI score of 61 is likely a good reflection of the lake's productivity or at least its potential productivity.

Using the ITSI to compare Smalley Lake to other lakes in the region, Smalley Lake's water quality is worse than most lakes in the region. Based on data collected by the Indiana Clean Lakes Program 1998 assessment, approximately 12% of the lakes in the Upper Wabash Basin (which includes the Smalley Lake watershed) were classified as oligotrophic (IDEM, 2000). Another 35% rated as mesotrophic. Forty five percent fell in the eutrophic category, while 8% fell in the hypereutrophic category. Smalley Lake's placement in the hypereutrophic category based on the ITSI suggests its water quality is among the bottom 10% of lakes in the region when ranked by water quality. This evaluation is consistent with the comparison of raw data scores for the lake to those for all lakes in Indiana (Table 26).

The Carlson TSI

Because the Indiana TSI has not been statistically validated and because of its heavy reliance of algal parameters, the Carlson TSI may be more appropriate for evaluating Indiana lake data. Developed by Bob Carlson (1977), the Carlson TSI is the most widely used and accepted TSI. Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships, and these relationships form the basis of the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a*, or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass (Figure 30).

As a further aid in interpreting TSI results, Carlson's scale is divided into four lake productivity categories: oligotrophic (least productive), mesotrophic (moderately productive), eutrophic (very productive), and hypereutrophic (extremely productive).

Using Carlson's index, a lake with a summer time Secchi disk depth of 1 meter (3.3 feet) would have a TSI of 60 points (located in line with the 1 meter (3.3 feet)). This lake would be in the eutrophic category. Because the index was constructed using relationships among transparency, chlorophyll, and total phosphorus, a lake having a Secchi disk depth of 1 meter (3.3 feet) would also be expected to have 20 μg/L chlorophyll and 48 μg/L total phosphorus.

Not all lakes have the same relationship between transparency, chlorophyll *a*, and total phosphorus as Carlson's lakes do. Other factors such as high suspended sediments or heavy predation of algae by zooplankton may keep chlorophyll concentrations lower than might be otherwise expected from the total phosphorus concentrations. High suspended sediments would also make transparency worse than otherwise predicted by Carlson's index.

It is also useful to compare the actual trophic state points for a particular lake from one year to the next to detect any trends in changing water quality. While climate and other natural events will cause some variation in water quality over time (possibly 5-10 trophic points), larger point changes may indicate important changes in lake quality.

CARLSON'S TROPHIC STATE INDEX

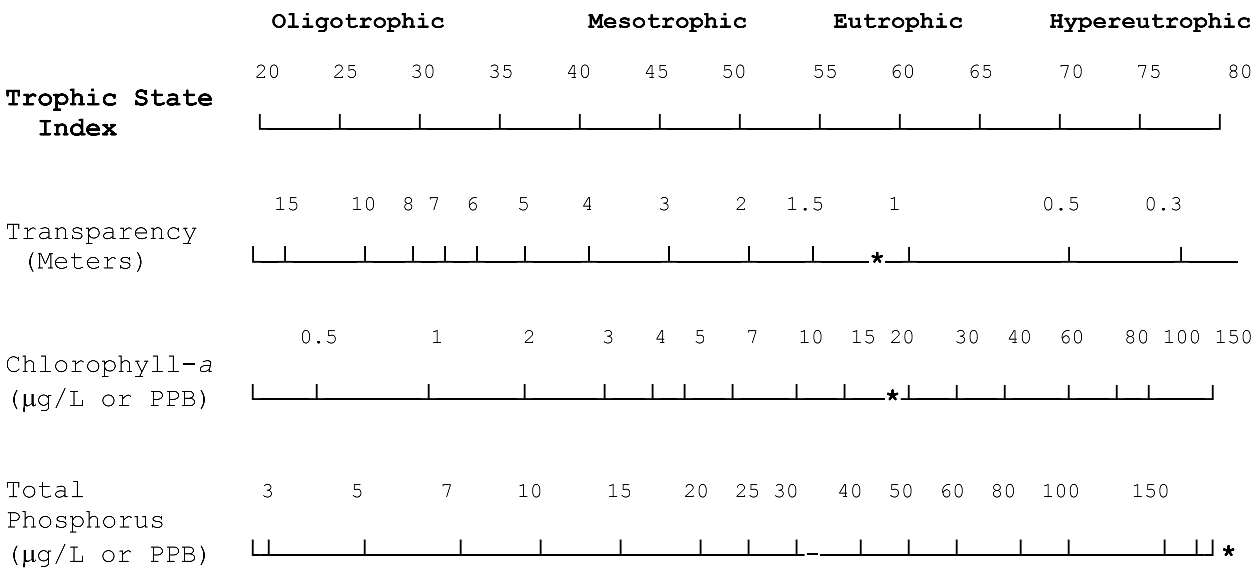

Figure 30. Carlson's Trophic State Index with Smalley Lake values indicated by an asterisk (⋆).

Analysis of Smalley Lake total phosphorus, transparency, and chlorophyll *a* data according to Carlson's TSI suggests that the lake is eutrophic to hypereutrophic (see asterisks in Figure 30). The lake's poor water clarity and relatively high chlorophyll *a* concentrations place the lake in the eutrophic category. The lake's high total phosphorus concentration does not register on the figure above. The high total phosphorus concentration creates conditions suitable for high levels of productivity. For some reason (other than one measured in this study), Smalley Lake's algae have not fully utilized the large supply of phosphorus available in the lake.

5.0 MACROPHYTE INVENTORY

5.1 Macrophyte Inventory Introduction

There are many reasons to conduct an aquatic rooted plant survey as part of a complete assessment of a lake and its watershed. Like other biota in a lake ecosystem (e.g. fish, microscopic plants and animals, etc.), the composition and structure of the lake's rooted plant community often provide insight into the long term water quality of a lake. While sampling the lake water's chemistry (dissolved oxygen, nutrient concentrations, etc.) is important, water chemistry sampling offers a single snapshot of the lake's condition. Because rooted plants live for many years in a lake, the composition and structure of this community reflects the water quality of the lake over a longer term. For example, if one samples the water chemistry of a typically clear lake immediately following a major storm event, the results may suggest that the lake suffers from poor clarity. However, if one examines the same lake and finds the rooted plant species, such as northern water milfoil, white stem pondweed, and large leaf pondweed, all of which prefer clear water, dominate the plant community, one is more likely to conclude that the lake is typically clear and its current state of turbidity is due to the storm rather than being its inherent nature.

The composition and structure of a lake's rooted plant community also help limnologists understand why the lake's fish community has a certain composition and structure. For example, lakes with dense stands of rooted submerged plants often have large, stunted bluegill populations. Dense rooted plant stands provide ample cover or protection for small prey fish such as bluegills from larger predators such as largemouth bass. With greater coverage, the prey fish may begin to overpopulate the lake since fewer are being eaten by the predators. As the prey fish overpopulate, their food resources are spread thinner. This, in turn, leads to stunting of the prey fish. Similarly, lakes with depauperate emergent plant communities may have difficulty supporting some top predators that require the emergent vegetation for spawning. In these and other ways, the lake's rooted plant community illuminates possible reasons for a lake's fish community composition and structure.

A lake's rooted plant community impacts the recreational uses of the lake. Swimmers and power boaters desire lakes that are relatively plant-free, at least in certain portions of the lake. In contrast, anglers prefer lakes with adequate rooted plant coverage, since those lakes offer the best fishing opportunity. Before lake users can develop a realistic management plan for a lake, they must understand the existing rooted plant community and how to manage that community. This understanding is necessary to achieve the recreational goals lake users may have for a given lake.

For the reasons outlined above, as well as several others, JFNew conducted a general macrophyte (rooted plant) survey on Smalley Lake as part of the overall lake and watershed diagnostic study. Before detailing the results of the macrophyte survey, it may be useful to outline the conditions under which lakes may support macrophyte growth. Additionally, an understanding of the roles that macrophytes play in a healthy, functioning lake ecosystem is necessary for lake users to manage the lake's macrophyte community. The following paragraphs provide some of this information.

Conditions for Growth

Like terrestrial vegetation, aquatic vegetation has several habitat requirements that need to be satisfied in order for the plants to grow or thrive. Aquatic plants depend on sunlight as an energy source. The amount of sunlight available to plants decreases with depth of water as algae, sediment, and other suspended particles block light penetration. Consequently, most aquatic plants are limited to maximum water depths of approximately 10-15 feet (3-4.5 m), but some species, such as Eurasian water milfoil, have a greater tolerance for lower light levels and can grow in water deeper than 32 feet (10 m) (Aiken et al., 1979). Hydrostatic pressure rather than light often limits plant growth at greater water depths (15-20 feet or 4.5-6 m).

Water clarity affects the ability of sunlight to reach plants, even those rooted in shallow water. Lakes with clearer water have an increased potential for plant growth. Smalley Lake possesses poorer water clarity than the average Indiana lake. The Secchi disk depth measured during the plant survey was 3.25 feet (1 m), which was consistent with the Secchi disk depth measured during the in-lake sampling portion of the study (3.6 feet or 1.1 m). The poor water clarity likely impairs aquatic plant growth. As a general rule of thumb, rooted plant growth is restricted to the portion of the lake where water depth is less than or equal to 2-3 times the lake's Secchi disk depth. This is true in Smalley Lake, where rooted plants were not observed in water deeper than 10 feet, which is approximately 3 times the lake's average Secchi disk depth.

Aquatic plants also require a steady source of nutrients for survival. Aquatic macrophytes differ from microscopic algae (which are also plants) in their uptake of nutrients. Aquatic macrophytes receive most of their nutrients from the sediments via their root systems rather than directly utilizing nutrients in the surrounding water column. Some competition with algae for nutrients in the water column does occur. The amount of nutrients taken from the water column varies for each macrophyte species. Because macrophytes obtain most of their nutrients from the sediments, lakes which receive high watershed inputs of nutrients to the water column will not necessarily have aquatic macrophyte problems.

A lake's substrate and the forces acting on the substrate also affect a lake's ability to support aquatic vegetation. Lakes that have mucky, organic, nutrient-rich substrates have an increased potential for plant growth compared to lakes with gravelly, rocky substrates. Sandy substrates that contain sufficient organic material typically support healthy aquatic plant communities. Smalley Lake possesses a sandy silt substrate which provides good habitat for rooted plants. Lakes that have significant wave action that disturb the bottom sediments have decreased ability to support plants. Disturbance of bottom sediment may decrease water clarity, limiting light penetration, or may affect the availability of nutrients for the macrophytes. Wave action may also create significant shearing forces prohibiting plant growth altogether.

Boating activity may affect macrophyte growth in conflicting ways. Rooted plant growth may be limited if boating activity regularly disturbs bottom sediments. Alternatively, boating activity in rooted plant stands of species that can reproduce vegetatively, such as Eurasian water milfoil, may increase macrophyte density rather than decrease it. Boating activity may be increasing the size and density of the Eurasian water milfoil stands in Smalley Lake.

Ecosystem Roles

Aquatic plants are a beneficial and necessary part of healthy lakes. Plants stabilize shorelines holding bank soil with their roots. The vegetation also serves to dissipate wave energy further protecting shorelines from erosion. Plants play a role in a lake's nutrient cycle by up-taking nutrients from the sediments. Like their terrestrial counterparts, aquatic macrophytes produce oxygen which is utilized by the lake's fauna. Plants also produce flowers and unique leaf patterns that are aesthetically attractive.

Emergent and submerged plants provide important habitat for fish, insects, reptiles, amphibians, waterfowl, shorebirds, and small mammals. Fish utilize aquatic vegetation for cover from predators and for spawning and rearing grounds. Different species depend upon different percent coverages of these plants for successful spawning, rearing, and protection for predators. For example, bluegill require an area to be approximately 15-30% covered with aquatic plants for successful survival, while northern pike achieve success in areas where rooted plants cover 80% or more of the area (Borman et al., 1997).

Aquatic vegetation also serves as substrate for aquatic insects, the primary diet of insectivorous fish. Waterfowl and shorebirds depend on aquatic vegetation for nesting and brooding areas. Numerous aquatic waterfowl were observed utilizing Smalley Lake as habitat during the macrophyte survey. Aquatic plants such as pondweed, coontail, duckweed, water milfoil, and arrowhead, also provide a food source for waterfowl. Duckweed in particular has been noted for its high protein content and consequently has served as feed for livestock. Turtles and snakes utilize emergent vegetation as basking sites. Amphibians rely on the emergent vegetation zones as primary habitat.

5.2 Macrophyte Inventory Methods

JFNew surveyed Smalley Lake on August 26, 2003 following the Indiana State Tier One sampling protocol (Schuler and Hoffmann, 2002). JFNew examined the entire littoral zone of the lake and one shoal area located in the southwest portion of the lake during the survey. As defined in the protocol, Smalley Lake's littoral zone was estimated to be approximately three times the lake's Secchi disk depth. This estimate approximates the 1% light level, or the level at which light penetration into the water column is sufficient to support plant growth. (See the **Lake Assessment** section for a full discussion of the 1% light level and the reading recorded during the in-lake sampling effort.) At the time of sampling, Smalley Lake's Secchi disk depth was 3.25 feet (1.0 m); thus its 1% light level was estimated to be slightly less than 10 feet (3.0 m). Consequently, JFNew sampled that area of Smalley Lake that was less than ten feet deep.

A survey crew, consisting of an aquatic ecologist and botanist, surveyed Smalley Lake in a clockwise manner, starting at the public boat launch. The survey crew drove their boat in a zig-zag pattern across the littoral zone while visually identifying plant species. The crew maintained a tight pattern to ensure the entire zone was observed. In areas of dense plant coverage, rake grabs were performed to ensure all species were identified. Once the crew had visually surveyed an entire plant bed, the crew visually estimated species abundance, canopy coverage by strata (emergent, rooted floating, non-rooted floating, and submergent), and bed size. The crew also noted the bed's bottom substrate type. The crew recorded all data on data sheets (Appendix F). After completing one bed, the crew continued surveying the littoral zone until all plant beds were identified and the appropriate data were recorded.

5.3 Macrophyte Inventory Results

A relatively narrow band of aquatic plants rings the edge of Smalley Lake. The aquatic plant community extends from the lake's shoreline to water depths between 5 and 10 feet (1.5 and 3 m). This is consistent with the estimated extent of the littoral zone based on the lake's Secchi disk depth of 3.25 feet (1 m), measured at the time of the aquatic plant survey. (Three times the Secchi disk depth is 9.75 feet (3 m).) Despite the fact that the plant community rings the entire lake, the Smalley Lake aquatic plant community can be roughly divided into four beds. The beds differ in community composition and structure. Three of the beds lie within Smalley Lake's littoral zone; the fourth lies off shore in a shallow shoal area. Figure 31 shows the approximate location and extent of each bed.

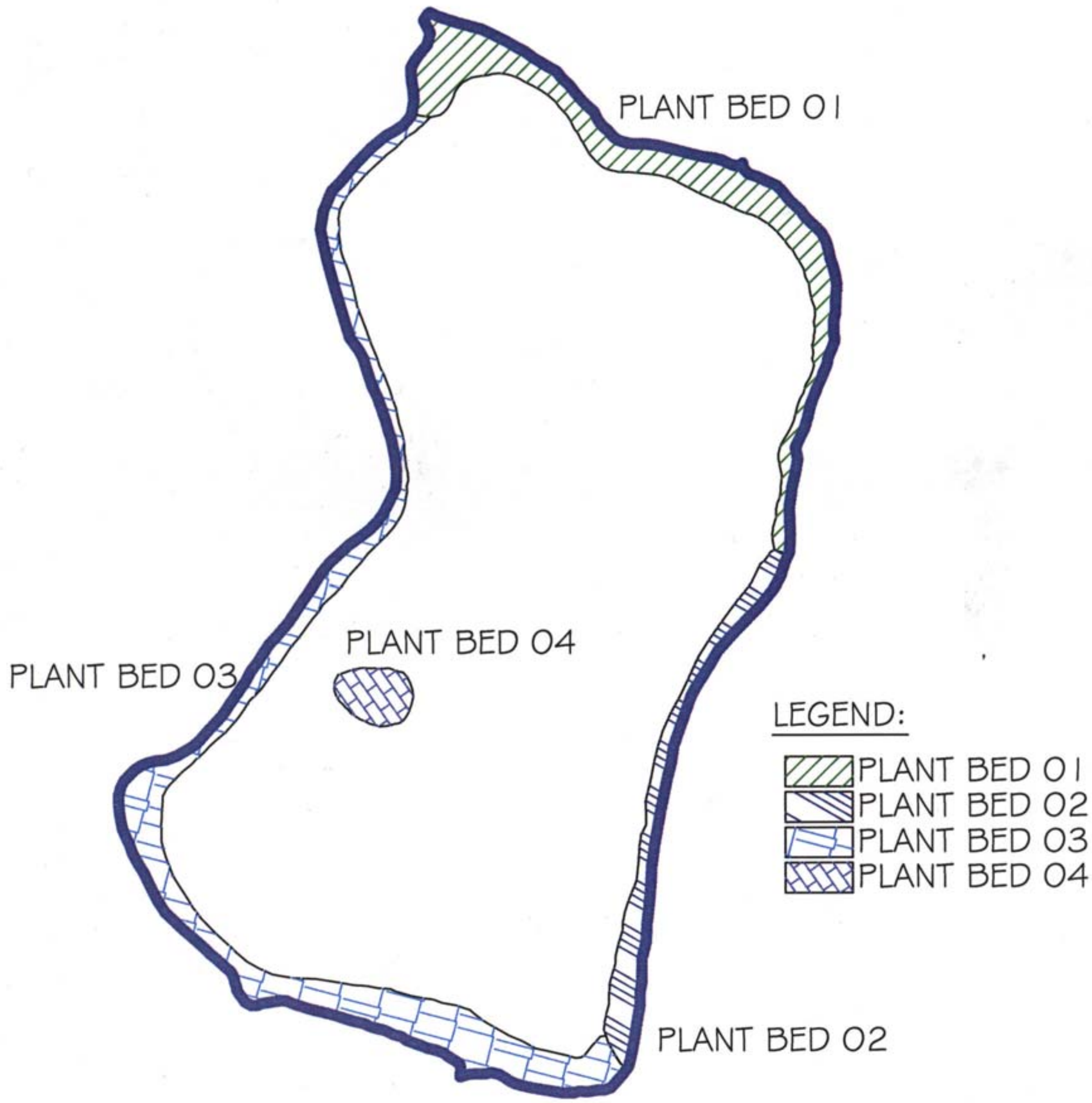

Figure 31. Approximate location and extent of the Smalley Lake plant beds.
Scale: 1"=400'.

The aquatic plant survey of Smalley Lake revealed the presence of 36 species throughout the lake. The northern and southern ends of the lake (Beds 01 and 03) possess the greatest diversity of aquatic plants. Smalley Lake has representative species from all three major strata (emergent, floating, and submerged) of plant communities. Emergent plant species are the most diverse group in the lake accounting for 64% (23 species) of the total plant species by number. Most of these emergent species, however, are present in low numbers. The exceptions to this are pickerel weed and arrow arum. Healthy populations of pickerel weed and arrow arum grow along the northern and southern edges of the lake. Only five submerged species grow in Smalley Lake. Of these five, two are not native to Indiana lakes (Eurasian water milfoil and curly leaf pondweed) and one, coontail, although native to Indiana, has established some thick, potentially nuisance stands in some areas.

The density of aquatic plant growth and canopy coverage vary across the lake's littoral zone. The northern portion of the lake supports the densest plant growth. Emergent and submergent strata canopy coverage falls in the 21-60% range in this area (Bed 01). Floating plants covered up to an additional 20% of the northern plant bed. In contrast, aquatic plant growth along the eastern and western shorelines is much sparser. Along the eastern shoreline (Bed 02), no strata covered more than 20% of the entire plant bed. The following paragraphs detail the composition and structure of each plant bed in Smalley Lake.

Bed 01

Bed 01 borders the northern shoreline of Smalley Lake. Based on measurements made in the field, the bed is approximately 1.8 acres (0.7 ha) in size. The bed lies adjacent to approximately 2,200 feet (671 m)of shoreline and extends on average approximately 35 feet (10.7 m) from shore. The bed's maximum lakeward extension is approximately 45 feet (13.7 m). Bed 01's sandy silt substrate supports a total of 31 species. All three strata (emergent, submerged, and floating) have representative species in Bed 01; however, two thirds of bed's total species are emergent species.

The northern shoreline where Bed 01 is located is minimally developed for residential use and still maintains a largely natural look. Consequently, Bed 01 supports the most diverse emergent community on the lake. Both low and tall profile emergent species vegetate the shallow shoreline water. Dominate emergent species include arrow arum, pickerel weed, and cattails. Several taller herbaceous emergent species such as softstem bulrush, chairmaker's rush, water willow, and giant burred grow in Bed 01. Woody emergent species, including various willows and silver maple, grow along the lake's wet edge in this area as well.

In addition to supporting the greatest number of plant species, Bed 01 also provides the densest coverage of plants. Emergent species cover 21-60% of the surface area of Bed 01. In Beds 02 and 03, emergent species cover 20% or less of the respective bed's surface area. (Bed 04 is located in a shoal area where emergent species are less likely.) Submerged species cover 21-60% of Bed 01's surface area, compared to 2-20% observed in Beds 02-04. Floating species are also a significant component of Bed 01's plant community covering approximately 2-20% of the bed's surface area.

Bed 02

Bed 02 lies immediately adjacent to Bed 01 and parallels Smalley Lake's eastern shoreline. The bed is approximately 1,400 feet (427 m) long and extends approximately 30 feet (9 m) into the lake, making it nearly one acre (0.4 ha) in size. Eurasian water milfoil dominates the plant community of Bed 02. White water lilies, coontail, Illinois pondweed, and Sago pondweed are also common components of the community. The scarcity of emergent vegetation marks the transition from Bed 01 to Bed 02. Emergent species diversity drops from 19 to 7 and total emergent canopy coverage is less than 2%. Most species are represented by a single individual. This loss in diversity and density is not uncommon in developed areas. Bed 02 lies along the portion of Smalley Lake that has been developed for residential uses. Beaches and lawns have replaced the lake's natural shoreline in this area. Overall, Bed 02 is much more sparsely vegetated compared to Bed 01. Canopy abundance for submerged and floating species is approximately 2-20% for each stratum. As noted above, emergent species cover less than 2% of the bed.

Bed 03

Bed 03 parallels the undeveloped southern and western edges of Smalley Lake. Along the southern edge of the lake, Bed 03 blends into the emergent wetland through which the Tippecanoe River runs. Bed 03's average width along the southern lake edge is approximately 60 feet (18 m). The bed's greatest lakeward extension is approximately 100 feet (30.5 m). The transition from lake to upland is more distinct along the western edge of Smalley Lake. Along this portion of Bed 03, the average bed width is approximately 30 feet (9 m). In total, Bed 03 covers nearly 4 acres.

Bed 03 is similar to Bed 01 in species composition and structure. Bed 03 is characterized by a dominance of emergent species and high emergent density. Pickerel weed and arrow arum are major components of Bed 03. Taller emergent herbaceous species such as cattails, softstem bulrush, chairmaker's rush, water willow, hibiscus, and giant burred grow along the edge of Bed 03. Woody emergent species (willows, button bush) are present in Bed 03 as well. The diversity and coverage of floating species also increases in Bed 03 compared to Bed 02. All three common genera of duckweed (*Lemna*, *Wolffia*, *Spirodella*) grow in Bed 03. Both white water lilies and spatterdock are major components of Bed 03; each species possesses visual abundance ratings of 20-61%.

Bed 04

Bed 04 is located off shore in a shallow area in the southwest portion of the lake. Lake depths in this area range from 3 to 10 feet (1-3 m). Bed 04 is approximately circular in shape and 0.4 acre (0.2 ha) in size. A lack of emergent species and poor diversity in general distinguish this bed from the others on the lake. Eurasian water milfoil and white water lilies dominate the plant bed. Sago pondweed and coontail are also common components of Bed 04. Floating species (mainly white water lily) cover approximately 21-60% of the bed, while submerged species cover only about 2-20% of Bed 04.

5.4 Macrophyte Inventory Discussion

The results of this survey are consistent with the results of surveys conducted by the Indiana Department of Natural Resources, Division of Fish and Wildlife in 1982 and 1988 (Pearson, 1982 and 1988). Both this survey and historical surveys document poor species richness in the Smalley Lake aquatic plant community. Like the current survey, historical surveys revealed the presence of only five submerged species. Similarly, the three surveys list Eurasian water milfoil as a dominant component of the aquatic plant community. Finally, historical surveys agree with the current survey on the limited extent of the littoral zone. Historical surveys indicate Smalley Lake's plant community extended into water only as deep as six feet (1.8 m). The current survey did not find plants deeper than 10 feet (3 m).

Smalley Lake's poor water clarity likely plays a large role in shaping the composition and structure of the aquatic plant community. Smalley Lake's Secchi disk depth, a measure of water clarity, was 3.25 feet (1 m) on the day of the plant survey and 3.6 feet (1.1 m) on the day of the in-lake sampling. The median Secchi disk depth for Indiana lakes is nearly twice as deep (CLP, 2000). The 1% light level measured during the in-lake sampling was only 8 feet (2.4 m), further highlighting how poor the lake's water clarity is. (It is important to remember that the 1% light level represents an extreme limit for rooted plant growth; typically only algae exist at or near the 1% light level.) The lack of light penetrating the Smalley Lake column is preventing the growth of rooted plants in water deeper than 5-10 feet (1.5-3 m). Similarly, the plant community's species composition reflects the low light levels. Eurasian water milfoil, Sago pondweed, and coontail, which dominate Smalley Lake's plant community, are all very tolerant of low light levels.

Smalley Lake's productivity also affects the species composition found in the lake. The lake possesses relatively high nutrient levels and a very high chlorophyll *a* concentration suggesting the lake is fairly productive. Smalley Lake falls in the eutrophic and hypereutrophic ranges when evaluated using the Carlson's Trophic State Index (TSI) or the Indiana TSI. The lake's plant community reflects this high productivity. Eurasian water milfoil, Sago pondweed, and coontail, which dominate Smalley Lake's plant community, are all very tolerant of eutrophic conditions. Similarly, the dominance of species such as coontail, duckweed, and filamentous algae in some locations is not surprising since these are species that can utilize nutrients directly from the water column. Given the high nutrient levels in Smalley Lake, these species have a competitive edge over other species that cannot directly utilize nutrients from the water column.

While Smalley Lake's water quality likely helps shape its aquatic plant community's composition and structure, the composition and structure of the plant community likely play a role in shaping the lake's fish community. Historical fisheries surveys (Pearson, 1982 and Pearson 1988) indicate that bluegill dominate Smalley Lake's fish community. This species accounts for over 70% of the community by number. Additionally, a follow up study showed that bluegill growth rates were low and the number of bluegill 8 inches (20 cm) or larger had declined from the 1980's (Pearson, 1993). These problems are symptomatic of lakes that support dense aquatic plant beds as Smalley Lake does along the northern and southern portions of the lake's edge. Dense plant beds offer cover for bluegill and other forage species, protecting them from predators such as largemouth bass. As a result, the bluegill population grows unchecked. As the population grows, there are fewer food resources to support the population, resulting in slow growth rates and stunted individuals.

Large beds of coontail and Eurasian water milfoil are a particular problem for establishing a balanced fishery. The structure of these species is such that individual plants growing side by side can form a tight network of leaflets and branches. This leaves little room for larger fish. In contrast beds of species such as big leaf pondweed possess a looser network of leaves and provide larger holes for fish.

Nuisance and Exotic Plants

Smalley Lake supports several nuisance and/or exotic aquatic plant species. The plant survey revealed the presence of two submerged aggressive exotics: Eurasian water milfoil and curly leaf pondweed. It also supports two emergent exotic plant species: purple loosestrife and reed canary grass. As nuisance species, these species have the potential to proliferate if left unmanaged.

The presence of Eurasian water milfoil in Smalley Lake is of concern, but it is not uncommon for lakes in the region. Eurasian water milfoil is an aggressive, non-native species. It often grows in dense mats excluding the establishment of other plants. For example, once the plant reaches the water's surface, it will continue growing horizontally across the water's surface. This growth pattern has the potential to shade other submerged species preventing their growth and establishment. In addition, Eurasian water milfoil does not provide the same habitat potential for aquatic fauna as many native pondweeds. Its leaflets serve as poor substrate for aquatic insect larva, the primary food source of many panfish.

Depending upon water chemistry curly leaf pondweed can be less aggressive than Eurasian water milfoil. Despite this, its presence in the lake is still of concern. Like many exotics, curly leaf pondweed gains a competitive advantage over native submerged species by sprouting early in the year. The species can do this because it is very tolerant of cooler water temperature compared to many of the native submerged species. Curly leaf pondweed experiences a die back during early to mid summer. This die back can degrade water quality by releasing nutrients into the water column and increasing the biological oxygen demand. This is particularly harmful to Smalley Lake since the lake already has high nutrient levels and low levels of oxygen. (See the **Lake Assessment** section for more details.)

Purple loosestrife is an aggressive, exotic species introduced into this country from Eurasia for use as an ornamental garden plant. Like Eurasian water milfoil, purple loosestrife has the potential to dominate habitats, in this case wetland and shoreline communities, excluding native plants. The stiff, woody composition of purple loosestrife makes it a poor food source substitute for many of the native emergents it replaces. In addition, the loss of diversity that occurs as purple loosestrife takes over plant communities lowers the wetland and shoreline habitat quality for waterfowl, fishes, and aquatic insects.

Like purple loosestrife, reed canary grass is native to Eurasia. Farmers used (and many likely still use) the species for erosion control along ditch banks or as marsh hay. The species escaped via ditches and has spread to many of the wetlands in the area. Swink and Wilhelm (1994) indicate that reed canary grass commonly occurs at the toe of the upland slope around a wetland. Reed canary grass was often observed above the ordinary high water mark around Smalley Lake. Like other nuisance species, reed canary grass forms a monoculture mat excluding native wetland/shoreline plants. This limits a wetland's or shoreline's diversity ultimately impacting the habitat's functions.

The presence of Eurasian water milfoil, curly leaf pondweed, and other exotics is typical in northern Indiana lakes. Of the lakes surveyed by aquatic control consultants and IDNR Fisheries Biologists, nearly every lake supported at least one exotic species (White, 1998a). In fact, White (1998a) notes the absence of exotics in only seven lakes in the 15 northern counties in Indiana. These 15 counties include all of the counties in northeastern Indiana where most of Indiana's natural lakes are located. Of the northern lakes receiving permission to treat aquatic plants in 1998, Eurasian water milfoil was listed as the primary target in those permits (White, 1998b). Despite the ubiquitous presence of nuisance species, lakeshore property owners and watershed stakeholders should continue management efforts to limit nuisance species populations. Management options will be discussed in further detail below.

5.5 Aquatic Plant Management Recommendations

A good aquatic plant management plan that takes into account the composition and structure of a lake's current and historical plant community as well as the recreational goals of the lake's users is part of any overall lake and watershed management plan. While development of a complete aquatic plant management plan is beyond the scope of this diagnostic study, the following is a list of recommendations that should form the foundation of any plan. A brief description of aquatic plant management techniques applicable to Smalley Lake follows list. Finally, lake users should remember that rooted plants are a vital part of a healthy functioning lake ecosystem; complete eradication of rooted plants is neither desirable nor feasible. A good aquatic plant management plan will reflect these facts.

Any aquatic plant management plan for Smalley Lake should include the following components:

1. Due to sparseness of the vegetative community along the developed eastern shoreline, aquatic plant management techniques aimed at reducing plant growth are not recommended at this time in this area. The vegetation present likely does not inhibit most recreational uses of the area. If individual residents feel the amount of plant growth in front of their property is limiting the recreational potential of the lake, these residents might consider management techniques such as hand harvesting of plant material or the use of bottom covers.

   Pro-active residents should consider planting emergent species along their shorelines. The eastern shoreline lacks emergent plant coverage. Planting emergent species would help filter pollutants entering the lake via stormwater runoff and provide additional habitat for fish and other water dependent fauna. Emergent vegetation often discourages geese, which in large numbers can impair a lake's water quality, from taking up residence on lakes. (See the **Management** section for additional information on shoreline restoration.)

2. In portions of the lake adjacent to natural habitat (northern and southern portions of the lake), residents should consider thinning the submerged plant community. Residents should only consider this ***if*** their goal is to increase fishing opportunities on the lake. In the northern and southern portion of the lake, canopy coverage of Eurasian watermilfoil and coontail often exceeds 50%. This creates an abundance of cover for prey fish (e.g. bluegills) to hide from predators. The result in situations like this is an explosion in panfish populations and consequent stunting of these fish due to increased competition for limited resources. One potential aquatic plant management techniques that may be applicable in this situation is the use of a harvester to cut cruising lanes for predators (bass). Any aquatic plant management techniques utilized should include removal of the aquatic plant material from the lake. Dead plant material releases nutrients and utilizes oxygen when it decomposes. In-lake sampling indicates that Smalley Lake already has high nutrient levels, and it does not need additional input from plant decay. Furthermore, only approximately 20% of the lake is oxic. Plant decay would reduce oxygen levels even more, limiting fish habitat and increasing the potential for release of phosphorus from the lake's bottom sediments. Any aquatic plant management efforts undertaken to

improve fishing opportunities should include consultation with the IDNR Division of Fish and Wildlife. Division of Fish and Wildlife biologists have managed the region's lakes for decades and would provide the best guidance on steps residents can take to manage the Smalley Lake fishery.

3. Take action to address the Eurasian water milfoil population in the lake. Although the amount of Eurasian water milfoil in Smalley Lake is not high relative to some other lakes in the region, this species has the potential to proliferate and cover a large portion of the lake. Eurasian water milfoil offers poor habitat to the lake's inhabitants and often interferes with recreational uses of the lake. Spot chemical treatments may be the best management tool at this time to control the spread of the species. Lake users should also educate themselves on the species. Taking precautionary measures such as ensuring that all plant material is removed from their boat propellers following boat use prevents the spread of the species. Lake users should also refrain from boating through stands of Eurasian water milfoil. Pieces of the plant as small as one inch in length that are cut by a boat propeller as it moves through a stand of Eurasian water milfoil can sprout and establish a new plant. Signage at the public boat ramp informing visitors of these best management practices would also be useful. IDNR approval is required to post any signs at the public boat ramp.

4. Implement watershed and in-lake management techniques to improve the lake's water quality. The lake's poor water quality is likely limiting the establishment of a diverse submerged aquatic plant community. Historical and current surveys of lakes located upstream of Smalley Lake indicate that a much more diverse submerged aquatic plant community is possible. While it is not realistic to expect the return of rarer more sensitive species such as Fries pondweed or minor bladderwort, it is realistic to expect the growth of species as such eel grass, elodea, and floating leaf pondweed. These species are generally tolerant of poor water clarity and commonly found in eutrophic lakes in the area. An improvement in Smalley Lake's water quality and clarity might allow the return of these species, creating a more diverse and healthy aquatic plant community.

The following is a brief description of aquatic plant management techniques recommended in the list above. A good aquatic plan management plan includes a variety of management techniques applicable to different parts of a lake depending on the lake's water quality, the characteristics of the plant community in different parts of the lake, and lake users' goals for different parts of the lake. Many management techniques, including chemical control, harvesting, and biological control, require a permit from the IDNR. Depending upon the size and location of the treatment area, even individual residents may need a permit to conduct a treatment. Residents should contact the IDNR Division of Fish and Wildlife before conducting any treatment.

5.5.1 Chemical Control

Herbicides are the most traditional means of controlling aquatic vegetation. Herbicides have been used in the past on Smalley Lake. Last year, the Indiana Department of Natural Resources, Division of Fish and Wildlife issued one permit for the treatment of 0.5 acre (0.2 ha) on Smalley Lake (Jed Pearson, personal communication). It is likely that some residents may have conducted their own spot treatments around piers and swimming areas. It is important for residents to remember that any chemical herbicide treatment program should always be developed with the help of a certified applicator who is familiar with the water chemistry of the lake. As noted above, application of a chemical herbicide may require a permit from the IDNR, depending on the size and location of the treatment area. Information on permit requirements is available from the IDNR Division of Fish and Wildlife or conservation officers.

Herbicides vary in their specificity to given plants, method of application, residence time in the water, and the use restrictions for the water during and after treatments. Herbicides (and algaecides; chara is an algae) that are non-specific and require whole lake applications to work are generally not recommended with some exceptions. Such herbicides can kill non-target plants and sometimes even fish species in a lake. Costs of an herbicide treatment vary from lake to lake depending upon the type of plant species present in the lake, the size of the lake, access availability to the lake, the water chemistry of the lake, and other factors. Typically, in northern Indiana costs for treatment range from $275 to $300 per acre or $680 to $750 per hectare (Jim Donahoe, Aquatic Weed Control, personal communication).

While providing a short-term fix to the nuisances caused by aquatic vegetation, chemical control is not a lake restoration technique. Herbicide and algaecide treatments do not address the reasons why there is an aquatic plant problem, and treatments need to be repeated each year to obtain the desired control. In addition, some studies have shown that long-term use of copper sulfate (algaecide) has negatively impacted some lake ecosystems. Such impacts include an increase in sediment toxicity, increased tolerance of some algae species, including some blue-green (nuisance) species, to copper sulfate, increased internal cycling of nutrients, and some negative impacts on fish and other members of the food chain (Hanson and Stefan, 1984 cited in Olem and Flock, 1990).

Chemical treatment should be used with caution on Smalley Lake since treated plants are often left to decay in the water. This will contribute nutrients to the water column which already possesses high levels of nutrients. Additionally, plants left to decay in the water column will consume oxygen, reducing the already low volume of lake water with sufficient oxygen to support fish. Spot chemical treatments are recommended only for patches of Eurasian water milfoil.

5.5.2 Mechanical Harvesting

Harvesting involves the physical removal of vegetation from lakes. Harvesting should also be viewed as a short-term management strategy. Like chemical control, harvesting needs to be repeated yearly and sometimes several times within the same year. (Some carry-over from the previous year has occurred in certain lakes.) Despite this, harvesting is often an attractive management technique because it can provide lake users with immediate access to areas and activities that have been affected by excessive plant growth. Mechanical harvesting is also beneficial in situations where removal of plant biomass will improve a lake's water chemistry. (Chemical control leaves dead plant biomass in the lake to decay and consume valuable oxygen.)

Macrophyte response to harvesting often depends upon the species of plant and particular way in which the management technique is performed. Pondweeds, which rely on sexual reproduction for propagation, can be managed successfully through harvesting. However, many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces left in the water. Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke et al., 1993). Harvesting plants at their roots is usually more effective than harvesting higher up on their stems (Olem and Flock, 1990). This is especially true with Eurasian water milfoil and curly leaf pondweed. Benefits are also derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen.

The cost of the harvester is typically the largest single outlay of money. Depending upon the capacity of the harvester, costs can range from $3,500 to over $100,000 (Cooke et al., 1993). Other costs associated with harvesting include labor, disposal site availability and proximity, amortization rate, size of lake, density of plants, reliability of the harvester, and other factors. Depending upon the specific situation, harvesting costs can range up to $650 per acre ($1,600 per hectare, Prodan, 1983; Adams, 1983). Estimated costs of the mechanical harvesting program at Lake Lemon in Bloomington, Indiana averaged $267 per acre ($659 per hectare, Zogorski et al., 1986). In general, however, excluding the cost of the machine, the cost of harvesting is comparable to that for chemical control (Cooke et al., 1993, Olem and Flock, 1990).

Given the rather limited coverage of aquatic plants in Smalley Lake, large scale mechanical harvesting does not make economic sense. Additionally, large scale harvesting is only recommended in areas dominated by coontail rather than Eurasian water milfoil. When small fragments of Eurasian water milfoil break off, they are capable of sprouting roots and becoming established as an individual plant. Large scale harvesting efforts often create many small fragments of plants despite vigilant efforts to capture all cut plant material. Thus, the benefits derived from harvesting (reduction of plant density and removal of potential source of nutrients) Eurasian water milfoil may not outweigh the risks of spreading the species throughout the lake. As with chemical control, a permit from the IDNR will likely be required for any large-scale harvesting of aquatic plants.

5.5.3 Hand Harvesting

Hand harvesting may be the best option to manage aquatic plants in small areas where human uses are hampered by extensive growth (docks, piers, beaches, boat ramps). In these small areas, plants can be efficiently cut and removed from the lake with hand cutters such as the Aqua Weed Cutter (Figure 32). In less than one hour every 2-3 weeks, a homeowner can harvest ‘weeds’ from along docks and piers. Depending on the model, hand-harvesting equipment for smaller areas cost from $50 to $1500 (McComas, 1993). To reduce the cost, several homeowners can invest together in such a cutter. Alternatively, a lake association may purchase one for its members. This sharing has worked on other Indiana lakes with aquatic plant problems. Use of a hand harvester is more efficient and quick-acting, and less toxic for small areas than spot herbicide treatments. Again, depending upon the size and location of the treatment area, individual residents may need to obtain a permit from the IDNR to hand harvest aquatic plants along their shoreline.

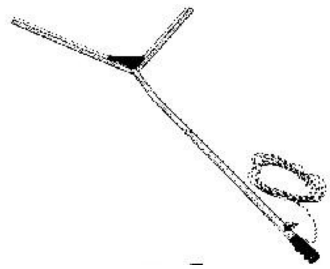

Figure 32. An aquatic weed cutter, designed to cut emergent weeds along the edge of ponds. It has a 48" cutting width, uses heavy-duty stainless steel blades, can be sharpened, and comes with an attached 20' rope and blade covers.

5.5.4 Biological Control

Biological control involves the use of one species to control another species. Often when a plant species that is native to another part of the world is introduced to a new country with suitable habitat, it grows rapidly because its native predators have not been introduced to the new country along with the plant species. This is the case with some of the common pest plants in northeast Indiana such as Eurasian water milfoil and purple loosestrife. Neither of these species is native to Indiana, yet both exist in the Smalley Lake watershed.

Researchers have studied the ability of various insect species to control both Eurasian water milfoil and purple loosestrife. Cooke et al. (1993) points to four different species that may reduce Eurasian water milfoil infestations: *Triaenodes tarda*, a caddisfly, *Cricotopus myriophylii*, a midge, *Acentria nivea*, a moth and *Litodactylus leucogaster*, a weevil. Recent research efforts have focused on the potential for *Euhrychiopsis lecontei*, a native weevil, to control Eurasian water milfoil. Purple loosestrife biocontrol researchers have examined the potential for three insects, *Gallerucella calmariensis, G. pusilla*, and *Hylobius transversovittatus,* to control the plant.

While the populations of Eurasian water milfoil and purple loosestrife in Smalley Lake are relatively small and therefore may not be suitable for biological control efforts, it may be worthwhile for Smalley Lake residents to understand the common biocontrol mechanisms for these two species should the situation on the lake change. Permits from the IDNR are required for the release of biological control agents in public lakes.

Eurasian Water Milfoil

Euhrychiopsis lecontei has been implicated in a reduction of Eurasian water milfoil in several Northeastern and Midwestern lakes (EPA, 1997). *E. lecontei* weevils reduce milfoil biomass by two means: one, both adult and larval stages of the weevil eat different portions of the plant and two, tunneling by weevil larvae cause the plant to lose buoyancy and collapse, limiting its ability to reach sunlight. The weevils' actions also cut off the flow of carbohydrates to the plant's root crowns impairing the plant's ability to store carbohydrates for over wintering (Madson, 2000). Techniques for rearing and releasing the weevil in lakes have been developed, and under appropriate conditions, use of the weevil has produced good results in reducing Eurasian water milfoil. A nine-year study of nine southeastern Wisconsin lakes suggested that weevil activity might have contributed to Eurasian water milfoil declines in the lakes (Helsel et al, 1999). The Indiana Department of Natural Resources is currently conducting field trials on three Indiana lakes.

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian water milfoil (Christina Brant, EnviroScience, personal communication). Cost advantages include the weevil's low maintenance and long-term effectiveness versus the annual application of an herbicide. In addition, use of the weevil does not have use restrictions that are required with some chemical herbicides. Use of the weevil has a few drawbacks. The most important one to note is that reductions in Eurasian water milfoil are seen over the course of several years in contrast to the immediate response seen with traditional herbicides. Therefore, lake residents need to be patient. Additionally, the weevils require natural shorelines for over-wintering. Because Smalley Lake's densest populations of Eurasian water milfoil are located adjacent to natural shoreline, the lake may be a good candidate for weevil release if the need arises. Finally, the Indiana Department of Natural Resources is currently conducting field trials on three Indiana lakes. Waiting for the independent monitoring results of these field trials may be best before even considering the application of *E. lecontei* weevils in Smalley Lake.

Purple Loosestrife

Biological control may also be possible for inhibiting the growth and spread of the emergent purple loosestrife. Like Eurasian water milfoil, purple loosestrife is an aggressive non-native species. Once purple loosestrife becomes established in an area, the species will readily spread and take over the habitat, excluding many of the native species which are more valuable to wildlife. Conventional control methods including mowing, herbicide applications, and prescribed burning have been unsuccessful in controlling purple loosestrife.

Some control has been achieved through the use of several insects. A pilot project in Ontario, Canada reported a decrease of 95% of the purple loosestrife population from the pretreatment population (Cornell Cooperative Extension, 1996). Four different insects were utilized to achieve this control. These insects have been identified as natural predators of purple loosestrife in its native habitat. Two of the insects specialize on the leaves, defoliating a plant (*Gallerucella calmariensis* and *G. pusilla*), one specializes on the flower, while one eats the roots of the plant (*Hylobius transversovittatus*). Insect releases in Indiana to date have had mixed results. After six years, the loosestrife of Fish Lake in LaPorte County is showing signs of deterioration.

Like biological control of Eurasian water milfoil, use of purple loosestrife predators offers a cost-effective means for achieving long-term control of the plant. Complete eradication of the plant cannot be achieved through use of a biological control. Insect (predator) populations will follow the plant (prey) populations. As the population of the plant decreases, so will the population of the insect since their food source is decreasing.

Because of the limited extent of purple loosetrife along Smalley Lake, management should focus on hand removal of the species. (This may require educating lake residents in identifying purple loosestrife.) Given the relatively small and scattered distribution of the species, release of a biological control would not be cost effective at this time.

5.5.5 Bottom covers

Bottom shading by covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Unfortunately, sand or gravel anchors used to hold buoyant materials in place can act as substrate for new macrophyte growth. Any cover materials placed at the lake bottom must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are non-buoyant and allow gases to escape, but cost more (up to $66,000 per acre or $163,000 per hectare for materials, Cooke and Kennedy, 1989). Indiana regulations specifically prohibit the use of bottom covering material as a base for beaches.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in areas of high sedimentation, since sediment accumulated on the sheeting material provides a substrate for macrophyte growth. The IDNR requires a permit for any permanent structure on the lake bottom, including anchored sheeting.

5.5.6 Preventive Measures

Preventive measures are necessary to curb the spread of nuisance aquatic vegetation. Although milfoil is thought to 'hitchhike' on the feet and feathers of waterfowl as they move from infected to uninfected waters, the greatest threat of spreading this invasive plant is humans. Plant fragments snag on boat motors and trailers as boats are hauled out of lakes (Figure 33). Milfoil, for example, can survive for up to a week in this state; it can then infect a milfoil-free lake when the boat and trailer are launched next. It is important to educate boaters to clean their boats and trailers of all plant fragments each time they retrieve them from a lake.

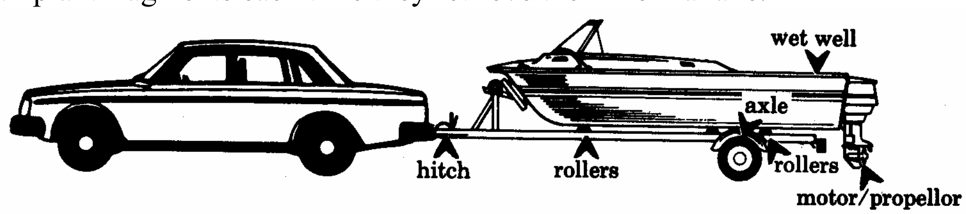

Figure 33. Locations where aquatic macrophytes are often found on boats and trailers.

Educational programs are effective ways to manage and prevent the spread of aquatic nuisance species (ANS) such as Eurasian watermilfoil, zebra mussels, and others. Of particular help are signs at boat launch ramps asking boaters to check their boats and trailers both before launching and after retrieval. All plants should be removed and disposed of in refuse containers where they cannot make their way back into the lake. The Illinois-Indiana Sea Grant Program has examples of boat ramp signs and other educational materials that can be used at the Smalley Lake. Although Eurasian water milfoil already exists in Smalley Lake, educational programs and lake signage will help prevent the spread of this nuisance species to other lakes that Smalley Lake users visit. Signs addressing any best management practices will ultimately help Smalley Lake as new nuisance (often non-native) species are finding their way to Indiana lakes all the time.

6.0 FISHERIES

The Indiana Department of Natural Resources (IDNR) has conducted relatively few fishery surveys on Smalley Lake likely due to the lack of public access prior to 1986. The IDNR conducted a comprehensive fishery survey in 1982 (Pearson, 1982) and another in 1988 (Pearson, 1988) after the establishment of the IDNR public access site. The IDNR conducted a species specific fish study and creel survey in 1992 (Pearson, 1993) to obtain more information on Smalley Lake's bass and bluegill populations.

Smalley Lake contains a mix of lake and riverine fish species. Riverine species, such as the spotted gar, enter the lake from its tributaries. A total of 21 fish species representing 9 families have been found in Smalley Lake. During the 1982 survey, a total of 17 species were collected. In 1988, a total of 19 species were collected. An entire species list was not available for the 1992 survey since only bass and bluegill were netted during the study. (A list of fish species collected from Smalley Lake is included in Appendix G. This list was developed from the 1982 and 1988 surveys.) During each survey year, gamefish dominated the community representing 93-94% of the total catch. Bluegill has been the most abundant fish species by number and weight. In 1982 and 1988, they accounted for 71% and 73% of the catch, respectively (Figure 34). In 1988, a tiger musky, the hybrid of a musky and northern pike, was collected from the lake. This single fish most likely migrated to Smalley Lake from Loon Lake, which is located upstream (Pearson, 1993). Nongame species have been a minor component of the community. White sucker, the most abundant nongame fish, accounted for only 2-4% of the total catch numbers during the 1982 and 1988 surveys (Figure 34).

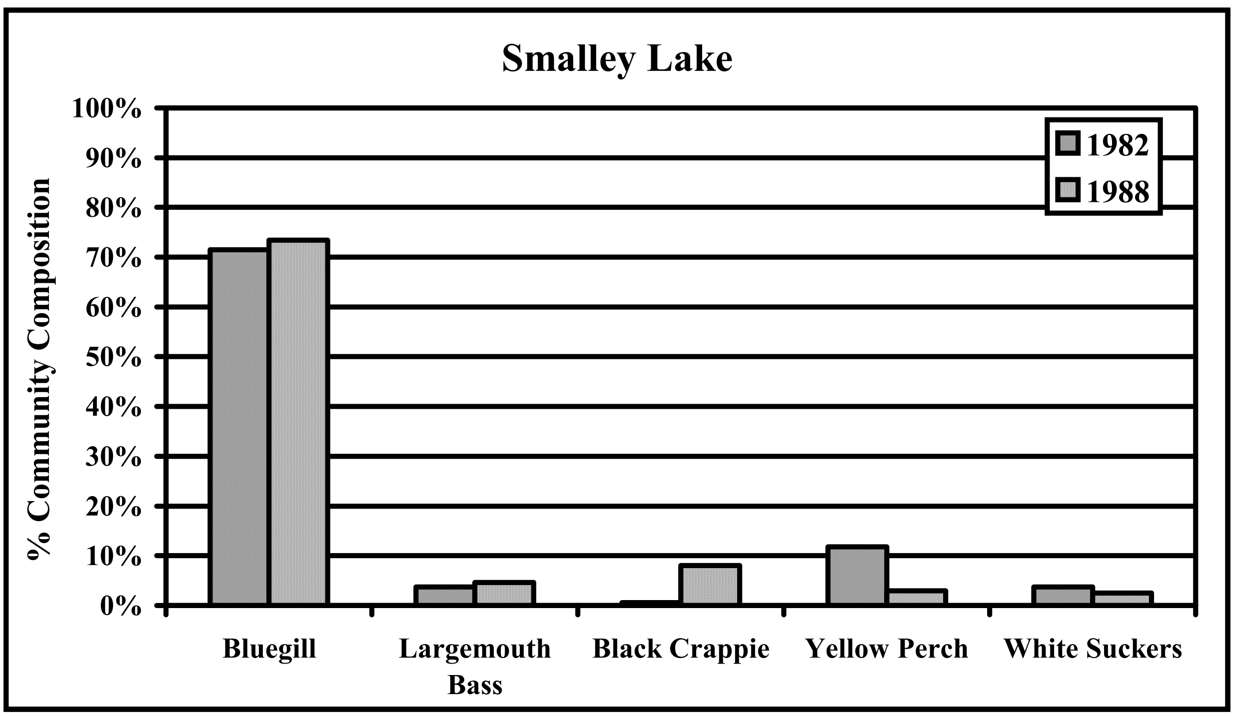

Figure 34. Dominant game and nongame fish species by percent community composition in Smalley Lake.

As shown in Figure 34, the fish community was relatively stable between surveys except for the decline in yellow perch and the increase in black crappies between 1982 and 1988 (Pearson, 1993). These two populations, however, are relatively small components of the fishery compared to the bluegill population. Some fish species that were observed in one survey year were not observed in the other. Six species in the Smalley Lake fish community were only collected in either 1982 or 1988. Brook silversides, bowfin, carp, tiger musky, and logperch were represented by a single individual during a given survey. Two grass pickerel were collected in 1988; however, none were collected in 1982. This indicates low relative abundance for these species. Other individuals were likely present in the lake during the survey; however the odds of encountering them on a given day were relatively low.

A species specific study was conducted in 1992 to gather more information on Smalley Lake's largemouth bass and bluegill populations (Pearson, 1993). This study was also undertaken to evaluate the response of the largemouth bass population to the 12-inch size limit imposed in 1990. The 1992 study included a mark-capture survey to determine the size of the largemouth bass population. Smalley Lake's largemouth bass population was estimated at 925 (±180) stock-size bass (≥8"), or 13/acre. The average for Indiana natural lakes is 15/acre. Growth of largemouth bass was considered average for the area. Bluegill catch rates were considered moderate with a catch rate of 575/hour. Growth rates for bluegill were found to be below average. In 1992, only 1.4% of stock-size bluegill were ≥ 8 inches compared to 14% in 1982 and 1988.

A creel survey was also conducted in 1992 from May to August (Pearson, 1993). Anglers fished for a total of 6,413 hours or 93 hrs/acre on Smalley Lake. Most anglers targeted bluegill (57%) followed by largemouth bass (26%). Anglers harvested a total of 4,228 fish during the creel survey of which 3,285 were bluegill, or nearly 78% of the total harvest. A total of 118 largemouth bass were harvested, or approximately 23% of the largemouth bass population. Largemouth bass harvest and angling mortality were considered moderate.

The below average growth rates for bluegill in Smalley Lake may be the result of several forces acting on the fish community. Pearson (1993) proposes that mild winters may have increased bluegill recruitment. The increased number of bluegills must compete for the same limited supply of food in the lake. This increase results in the stunting of the bluegill population since there is not enough food to go around. Dense plant beds covering large portions of the lake shallows can also be a factor in increasing bluegill numbers by providing too much cover for effective predation by largemouth bass. The percent plant coverage was not addressed in the 1993 IDNR report. However, curlyleaf pondweed and milfoil were documented around the entire lake perimeter. The plant survey conducted as a part of this diagnostic study confirmed that dense beds of aquatic plants did exist in the northern and southern parts of the lake. As noted above, an increase in bluegill numbers can promote stunting as more fish compete for the same pool of food resources. The IDNR hopes that the 12-inch bass size limit will improve bluegill growth rates and size (Pearson, 1993). Increasing largemouth bass population numbers and average size should result in greater predation pressure on the bluegill population. Reduction in bluegill numbers should reduce forage and habitat competition and, therefore, stunting of the population.

Smalley Lake's fish community would also benefit from an improvement in water quality. Indiana Trophic State Index (TSI) scores have increased over time. This increase in productivity may have helped promote the growth of various plant species including the nuisance species Eurasian water milfoil. As noted above, dense plant beds provide cover for bluegill and other forage species protecting them from predators such as largemouth bass. As a result, the bluegill population grows unchecked, skewing the lake's fishery. Additionally, dissolved oxygen levels declined from 11 mg/L in 1972 to 0.1 mg/L in 1989 at a depth of 15 feet. (5.0 mg/L is the minimum dissolved oxygen concentration required to support most fish species.) This dissolved oxygen barrier at 15 feet reduces the amount of habitat available for fish in Smalley Lake creating more competition for limited resources. If improvements in water quality and bluegill percent composition decline, other species may begin to recover in relative abundance.

7.0 MODELING

7.1 Water Budget

Inputs of water to Smalley Lake are limited to:
1. direct precipitation to the lake
2. discharge from the inlet streams
3. sheet runoff from land immediately adjacent to the lake
4. groundwater

Water leaves Smalley Lake from:
1. discharge from the outlet channel
2. evaporation
3. groundwater

There are no discharge gages in the watershed to measure water inputs and the limited scope of this study did not allow the determination of annual water inputs or outputs. Therefore the water budget for Smalley Lake was estimated from other records.

- Direct precipitation to the lake was calculated from mean annual precipitation falling directly on the lake's surface.
- Runoff from the lake's watershed was estimated by applying runoff coefficients. A runoff coefficient refers to the percentage of precipitation that occurs as surface runoff, as opposed to that which soaks into the ground. Runoff coefficients may be estimated by comparing discharge from a nearby gaged watershed of similar land and topographic features, to the total amount of precipitation falling on that watershed. The nearest gaged watershed is a U.S.G.S. gaging station on the Tippecanoe River near North Webster, Indiana (Stewart et al., 2002). The 16-year (1986–2002) mean annual runoff for this watershed is 13.32 inches. With mean annual precipitation of 35.52 inches (Staley, 1989), this means that on average, 37.5 % of the rainfall falling on this watershed runs off of the land surface.
- No groundwater records exist for the lake so it was assumed that groundwater inputs equal outputs or groundwater effects are insignificant compared to surface water impacts. The size of Smalley Lake's watershed makes this latter assumption plausible.

- Evaporation losses were estimated by applying evaporation rate data to the lake. Evaporation rates are determined at six sites around Indiana by the National Oceanic and Atmospheric Administration (NOAA). The nearest site to the Smalley Lake watershed is located in Valparaiso, Indiana. Annual evaporation from a 'standard pan' at the Valparaiso site averages 28.05 inches per year. Because evaporation from the standard pan overestimates evaporation from a lake by about 30%, the evaporation rate was corrected by this percentage, yielding an estimated evaporation rate from the lake surface of 19.95 inches per year. Multiplying this rate times the surface area of each lake yields estimated volume of evaporative water loss from Smalley Lake.

The water budget for Smalley Lake, based on the assumptions discussed above, is shown in Table 28. When the volume of water flowing out of Smalley Lake is divided by the lake's volume, a *hydraulic residence time* of 0.07 years (25.6 days) results. This means that on average, water entering the lake stays in the lake for only 25.6 days before it leaves. This hydraulic flushing rate is extremely rapid for lakes in this part of the country. In a study of 95 north temperate lakes in the U.S., the mean hydraulic residence time for the lakes was 2.12 years (Reckhow et al., 1980). The short hydraulic residence time for Smalley Lake is due to its very large watershed. There are nearly 248 acres of watershed draining into each acre of Smalley Lake. Most glacial lakes have a watershed area to lake surface area ratio of around 10:1. Smalley Lake's ratio is more typical of reservoirs, where the watershed area to reservoir surface area typically ranges between 100:1 and 300:1 (Vant, 1987).

Table 28. Water budget calculations for Smalley Lake.

Parameter	Data
Watershed size (ac)	17,076.4
Mean Watershed Runoff (ac-ft/yr)	18,933
Lake Volume (ac-ft)	1,350
Runoff Estimates	
Closest gauged stream	Tippecanoe River at North Webster
Stream watershed (mi2)	49.3
Stream watershed (acres)	31,552
Mean annual Q (cfs)	48.32
Mean annual Q (ac-ft/yr)	34,982
Mean precipitation (in/yr)	35.52
Mean watershed precipitation (ac-ft/yr)	93,394
Watershed C	0.37456
Evaporation Estimates	
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	69
Estimated lake evaporation (ac-ft)	113
Direct precipitation to lake (ac-ft)	204
Water Budget Summary	
Direct precipitation to lake (ac-ft)	204
Runoff from watershed (ac-ft)	18,933
Evaporation (ac-ft)	113
TOTAL LAKE OUTPUT (ac-ft)	19,024
Hydraulic Residence Time (yr)	0.07
Watershed Area:Lake Area	247.8

7.2 Phosphorus Budget

Since phosphorus is the limiting nutrient in Smalley Lake, a phosphorus model was used to estimate the dynamics of this important nutrient. With its role as the limiting nutrient, phosphorus should be the target of management activities to lower the biological productivity of Smalley Lake.

The limited scope of this study did not allow for the outright determination of phosphorus inputs and outputs. Therefore, a standard phosphorus model was utilized to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies. They used these phosphorus loss rates to calculate phosphorus export coefficients for various land uses. Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. Table 29 shows the phosphorus export coefficients developed by Reckhow and Simpson (1980).

Table 29. Phosphorus export coefficients (units are kg/hectare except the septic category, which are kg/capita-yr).

Estimate Range	Agriculture	Forest	Precipitation	Urban	Septic
High	3.0	0.45	0.6	5.0	1.8
Mid	0.40-1.70	0.15-0.30	0.20-0.50	0.80-3.0	0.4-0.9
Low	0.10	0.2	0.15	0.50	0.3

Source: Reckhow and Simpson, 1980.

To obtain an annual estimate of the phosphorus exported to Smalley Lake from the lake's watershed, the export coefficient for a particular land use was multiplied by the area of land in that land use category. Mid-range estimates of phosphorus export coefficient values for all watershed land uses (Table 29) were used in this calculation.

Direct phosphorus input via precipitation to Smalley Lake was estimated by multiplying mean annual precipitation in the region (0.9 m/yr) times the surface area of the lake times a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). For septic system inputs, the number of permanent homes on the lake was multiplied by an average of 3 residents per home to calculate per capita years. Using a mid-range phosphorus export of 0.5 kg/capita-yr and a soil retention coefficient of 0.75 (this assumes that the drain field retains 75% of the phosphorus applied to it), phosphorus export from septic systems was calculated.

Adding the phosphorus export loads from the watershed, septic systems, and precipitation, yielded an estimated 7,548 kg of phosphorus loading to Smalley Lake annually (Table 30).

Table 30. Phosphorus model results for Smalley Lake.

LAKE:	Smalley		**DATE:**	12/8/2003
COUNTY:	Kosciusko			
STATE:	Indiana			
INPUT DATA		**Unit**		
Area, Lake	69	acres		
Volume, Lake	1350	ac-ft		
Mean Depth	19.6	ft		
Hydraulic Residence Time	0.07			
Flushing Rate	14.08	1/yr		
Mean Annual Precipitation	0.90	m		
[P] in precipitation	0.03	mg/L		
[P] in epilimnion	0.047	mg/L		
[P] in hypolimnion	0.585	mg/L		
Volume of epilimnion	685	ac-ft		
Volume of hypolimnion	665	ac-ft		
Land Use (in watershed)	**Area**		**P-export Coefficient**	
Deciduous Forest	729.91	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	53.83	hectare	0.1	kg/ha-yr
Evergreen Forest	14.26	hectare	0.15	kg/ha-yr
High Intensity Residential	2.59	hectare	1.5	kg/ha-yr
High Intensity:Commercial/Ind	5.65	hectare	1.3	kg/ha-yr
Low Intensity Residential	48.4	hectare	0.6	kg/ha-yr
Mixed Forest	0.8	hectare	0.175	kg/ha-yr
Pasture/Hay	992.2	hectare	0.6	kg/ha-yr
Row Crops	4480.9	hectare	1.5	kg/ha-yr
Woody Wetlands	166.3	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
Total	6494.89			
Other Data				
Soil Retention coefficient	0.75	--------		
# Permanent Homes	35	homes		
Use of Permanent Homes	1.0	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	7527.3	kg/yr		
P load from precipitation	7.55	kg/yr		
P load from septic systems	13.13	kg/yr		
Total External P load	7547.92	kg/yr		
Areal P loading	27.069	g/m2-yr		
Predicted P from Vollenweider	0.288	mg/L		
Back Calculated L total	29.365	g/m2-yr		
Estimation of L internal	2.296	g/m2-yr		
% of External Loading	92.2	%		
% of Internal Loading	7.8	%		

The relationships among the primary parameters that affect a lake's phosphorus concentration were examined employing the widely used Vollenweider (1975) model. Vollenweider's empirical model says that the concentration of phosphorus ([P]) in a lake is proportional to the areal phosphorus loading (L, in g/m^2 lake area - year) and inversely proportional to the product of mean depth ($\bar{z}$) and hydraulic flushing rate (ρ) plus a constant (10):

$$[P] = \frac{L}{10 + \bar{z}\rho}$$

During the July 29, 2003 sampling of Smalley Lake, the mean volume weighted phosphorus concentration in the lake was 0.312 mg/L. It is useful to determine how much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.312 mg/L in Smalley Lake. Plugging this mean concentration of 0.312 mg/L along with the lake's mean depth and flushing rate into Vollenweider's phosphorus loading model and solving for L yields an areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 29.365 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.312 mg/L in Smalley Lake, a total of 29.365 grams of phosphorus must be delivered to each square meter of lake surface area per year.

Total phosphorus loading (L_T) is composed of external phosphorus loading (L_E) from outside the lake (watershed, septic systems, and precipitation) and internal phosphorus loading (L_I). Since L_T = 29.365 g/m^2-yr and L_E = 27.069 g/m^2-yr (estimated from the watershed loading in Table 30), internal phosphorus loading (L_I) equals 2.296 g/m^2-yr. Thus, internal loading accounts for about 8% of total phosphorus loading to Smalley Lake.

It is important to check this conclusion that internal phosphorus loading accounts for 8% of total phosphorus loading to Smalley Lake with the data collected on July 29, 2003. There is evidence in Smalley Lake that soluble phosphorus is being released from the sediments during periods of anoxia. For example, the concentration of soluble phosphorus in Smalley Lake's hypolimnion on July 29 was 12 times higher than concentration in the epilimnion (0.585 mg/L vs. 0. 047 mg/L). The source of this hypolimnetic phosphorus is primarily internal loading in most lakes. This internal loading can be a major source of phosphorus in many productive lakes.

The significance of Smalley Lake's phosphorus areal loading rate is better illustrated in Figure 35 in which areal phosphorus loading is plotted against the product of mean depth times flushing rate. Overlain on this graph is a curve, based on Vollenweider's model, which represents an acceptable loading rate that yields a phosphorus concentration in lake water of 30 µg/L (0.03 mg/L). Smalley Lake's areal phosphorus loading rate is well above the acceptable line.

This figure can also be used to evaluate management needs. For example, areal phosphorus loading to Smalley Lake would have to be reduced from 29.365 g/m^2-yr to 2.827 g/m^2-yr (the downward vertical intercept with the line) to yield a mean lake water concentration of 0.030 mg/L. This represents a reduction in areal phosphorus loading of 26.538 g/m^2-yr to the lake (90.4%), which is equivalent to a total phosphorus mass loading reduction of nearly 7,400 kg/yr. Eliminating internal phosphorus loading (640 kg/yr) alone will not meet this reduction need. A significant reduction in watershed phosphorus loading will be required to reduce the trophic state of Smalley Lake.

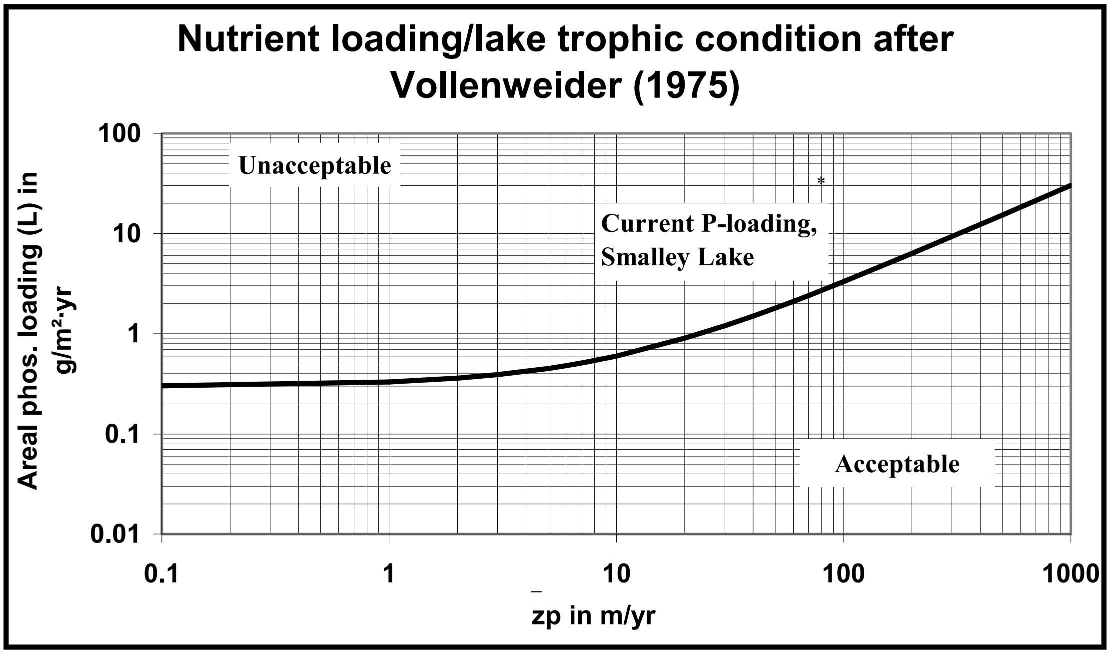

Figure 35. Phosphorus loadings to Smalley Lake compared to acceptable loadings determined from Vollenweider's model. The dark line represents the upper limit for acceptable loading.

8.0 MANAGEMENT

Research by scientists as well as trial-and-error by lake managers, has resulted in the development of numerous lake and watershed management techniques available to treat or correct many problems facing lakes today. While each one of these techniques may provide some benefit to a given lake, application of *every* available management technique is beyond the financial and labor resources of most lake managers and associations. Consequentl, most lake managers, facing limited financial and labor resources, must decide which management techniques will provide the most cost-effective treatment for their lakes. In order to select the most cost-effective management techniques, lake managers must have a comprehensive understanding of their lake and its watershed. This understanding will also allow the lake manager to set realistic goals for lake restoration. The preceding sections of this report provide a comprehensive analysis of Smalley Lake and its watershed. The following paragraphs summarize this analysis with four key ideas in an effort to help watershed stakeholders direct the management of Smalley Lake and set realistic goals for its restoration.

1. Smalley Lake is a eutrophic to hypereutrophic lake.
Smalley Lake is a very productive lake. Its productivity is characteristic of eutrophic to hypereutrophic lakes. When assessed with the Indiana Trophic State Index, the lake falls in the

hypereutrophic range with a score of 61. Evaluations using the Carlson's Trophic State Index yielded similar results; its Secchi disk transparency depth and chlorophyll *a* concentration place the lake in the eutrophic category, while its total phosphorus concentration suggests the lake is severely hypereutrophic using Carlson's TSI. The lake's biological communities also highlight the lake's highly productive state. Stunted bluegill with slow growth rates dominate the Smalley Lake fish community, representing more than 70% of the total fish community. Dominance of small bluegill with poor growth rates is characteristic of overly productive lakes. Similarly, blue-green algae dominate the lake's plankton. This is also characteristic of productive lakes. Finally, Smalley Lake's macrophyte community lends further evidence to the idea that the lake is productive to highly productive. Eurasian water milfoil, Sago pondweed, and coontail, which dominate Smalley Lake's plant community, are all very tolerant of eutrophic conditions. The water chemistry and biological data from Smalley Lake all support the same conclusion: Smalley Lake is a eutrophic to hypereutrophic lake.

2. Smalley Lake's productivity may be increasing (i.e. water quality may be worsening).
Historical data show that while the lake may have always been eutrophic its productivity is increasing slightly. The lake's Secchi disk transparency depth ranged from 5 to 7 feet (1.5 to 2.1 m) in the ten years spanning from 1972 to 1982. From 1989 to 1998, Secchi disk transparency depth ranged from 4 to 5 feet (1.3 to 1.5 m). The Secchi disk transparency depth in 2003 was even lower. Total phosphorus concentrations increased nearly tenfold from 0.05 mg/L in the 1970s to a range of 0.3 to 0.5 mg/L in the late 1980's to the present study. The lake's increase in eutrophy is also observed in the increase in Indiana TSI score. Smalley Lake possessed an Indiana TSI score of 34 in 1974. This increased to scores between 40 and 47 during the late 1980s and 1990s. Presently, the lake has an Indiana TSI score of 61. These data suggest that the water quality in Smalley Lake has worsened slightly over time and that a realistic goal for Smalley Lake's restoration is to return it to moderately eutrophic conditions.

3. Smalley Lake's watershed has the potential to deliver high pollutant loads to the lake.
Also important to directing management efforts is the fact that the Smalley Lake watershed has the potential to deliver high pollutant loads to the lake. The geology of the lake is such that Morley soils dominate the watershed's landscape. Morley soils are prone to erosion and, for various reasons, do not make good septic adsorption fields. The dominance of Morley soils increases the potential for the release of soil and soil-attached nutrients from the landscape to Smalley Lake. Additionally, most of the Smalley Lake watershed is used for agricultural purposes. Agricultural land use covers a greater percentage of the Smalley Lake watershed than the percentages observed for Noble and Whitley Counties and the larger Upper Tippecanoe River basin. A high percentage of agricultural use coupled with low usage of conservation tillage on corn fields in Whitley County increases the likelihood of pollutant release from the landscape.

The watershed's biotic and habitat impairment also affect the pollutant loading to Smalley Lake. Both inlet streams to Smalley Lake possessed low QHEI scores suggesting the in-stream and riparian habitat is impaired. Healthy, contiguous, forested riparian zones play a critical role in sequestering pollutants in stream water, preventing these pollutants from reaching downstream waterbodies (Ohio EPA, 1999). Additionally, streams must be hydrologically connected to the riparian zones in order to obtain the benefits of riparian zones. While the Tippecanoe River has some stretches of forested riparian land, many of these stretches have been channelized and high levees separate the stream from its riparian zone/floodplain. Both inlet streams to Smalley Lake supported impaired biotic communities as demonstrated by the mIBI scores. Like healthy riparian zones, healthy, diverse biotic communities assist in processing and sequestering nutrient loads in a stream (Ohio EPA, 1999). The impairment of these communities in the Smalley Lake watershed streams affects the ability of these biotic communities to reduce pollutant loads to Smalley Lake.

4. Watershed processes exert a greater influence over Smalley Lake's water quality than in-lake processes.

Certain lake and watershed characteristics indicate that watershed processes exert a greater influence over Smalley Lake's water quality than in-lake processes. For example, Smalley Lake possesses a watershed area to lake area ratio of 248:1. This ratio is more similar to reservoirs' watershed area to lake area ratios than it is to typical glacial lake watershed area to lake area ratios. This large ratio indicates that a very large watershed drains to a relatively small lake. Thus, watershed processes are more likely to determine water quality than in-lake processes. This hypothesis is further supported by Smalley Lake's relatively short hydraulic residence time of 25 days. This means that every 25 days, the entire volume of water in Smalley Lake is flushed and replaced with new water from its inlets. Finally, the phosphorus model shows that external phosphorus loading accounts for roughly 92% of the total phosphorus load, while internal (in-lake processes) account for only 8% of the total phosphorus load. In other northeastern Indiana lakes, internal phosphorus loading accounts for 25-75% of the total phosphorus load. The dominance of external phosphorus loading in Smalley Lake's phosphorus budget highlights the influence that the lake's watershed has on the lake's water quality.

Some of the watershed characteristics cannot be "treated" or changed. For example, Morley soils will always dominate the watershed's landscape. Similarly watershed stakeholders cannot easily alter the watershed area to lake area ratio. These characteristics create certain barriers or limitations to lake restoration and help establish the lake's natural trophic level. In the case of Smalley Lake, the nature of the lake's watershed and the influence the watershed has on the lake coupled with the morphological characteristics of the lake itself (i.e. its relative shallowness and small size) suggest that Smalley Lake will always be eutrophic in nature. Historical evidence from the early 1970's supports this as the lake had a TP concentration in the eutrophic range (based on Carlson's TSI) and exhibited an Indiana TSI score in the eutrophic category. Thus, watershed stakeholders should set returning the lake to eutrophic conditions from its current hypereutrophic state as a realistic goal for restoration of Smalley Lake.

The lake and watershed characteristics summarized above also suggest that watershed stakeholders should prioritize watershed management techniques over in-lake management techniques. Smalley Lake's short hydraulic residence time of 25 days means that every 25 days the entire volume of water in Smalley Lake is flushed and replaced with new water from its inlets. Thus, improving the water entering the lake is more cost-effective than treating the water that exists in the lake since the lake is continually replenished with new water from the watershed. The limited evidence that Smalley Lake is serving as a sediment trap and other watershed characteristics such as the dominance of external phosphorus loading in the total phosphorus budget and the extremely high watershed area to lake area further support the idea that watershed management should be targeted before turning resources to in-lake management efforts.

Because the data collected during this study indicate that watershed stakeholders should prioritize watershed management techniques over in-lake management techniques, the following discussion of management techniques suitable for the Smalley Lake watershed will focus on watershed management. Several watershed surveys were conducted during the course of this study to identify potential areas of concerns within the Smalley Lake watershed or areas where management techniques might be employed to improve the water quality in Smalley Lake. These surveys included a desktop review of existing maps of the watershed, a riparian habitat survey as part of the stream assessment, and a windshield tour of the entire watershed. Figure 36 summarizes the results of these surveys. The following paragraphs discuss management options for the Smalley Lake watershed. Appendix H provides information on potential funding sources available to help fund the implementation of watershed management projects.

Riparian restoration and filter strip installation

Healthy, forested riparian zones play a critical role in processing, sequestering, and assimilating pollutants in a stream's water column. Forested riparian zones also indirectly influence the processing and assimilation of nutrients in a stream's water column by determining the species composition of the biotic communities in streams (Ohio EPA, 1999). Unfortunately, surveys of the Smalley Lake watershed showed that much of the riparian corridor adjacent to the watershed streams is impaired. Along some portions of the Tippecanoe River, trees had been removed presumably to dredge the channel (Figure 37). In other areas, farming operations occurred right along the stream edge (Figure 38). Additionally, the watershed streams received moderately low channel morphology and riparian zone scores on the QHEI. Despite receiving nine out of ten points in the riparian zone category, the reach evaluated along the Tippecanoe River inlet showed evidence of channelization. Channelized streams lack a hydrologic connection between the stream and the riparian zone, limiting the ability of the riparian zone to sequester and assimilate pollutants. Poor habitat scores likely played a role in the observed impairment of the biotic community. Impaired biotic communities have a decreased ability to process and assimilate nutrients in a stream's water column.

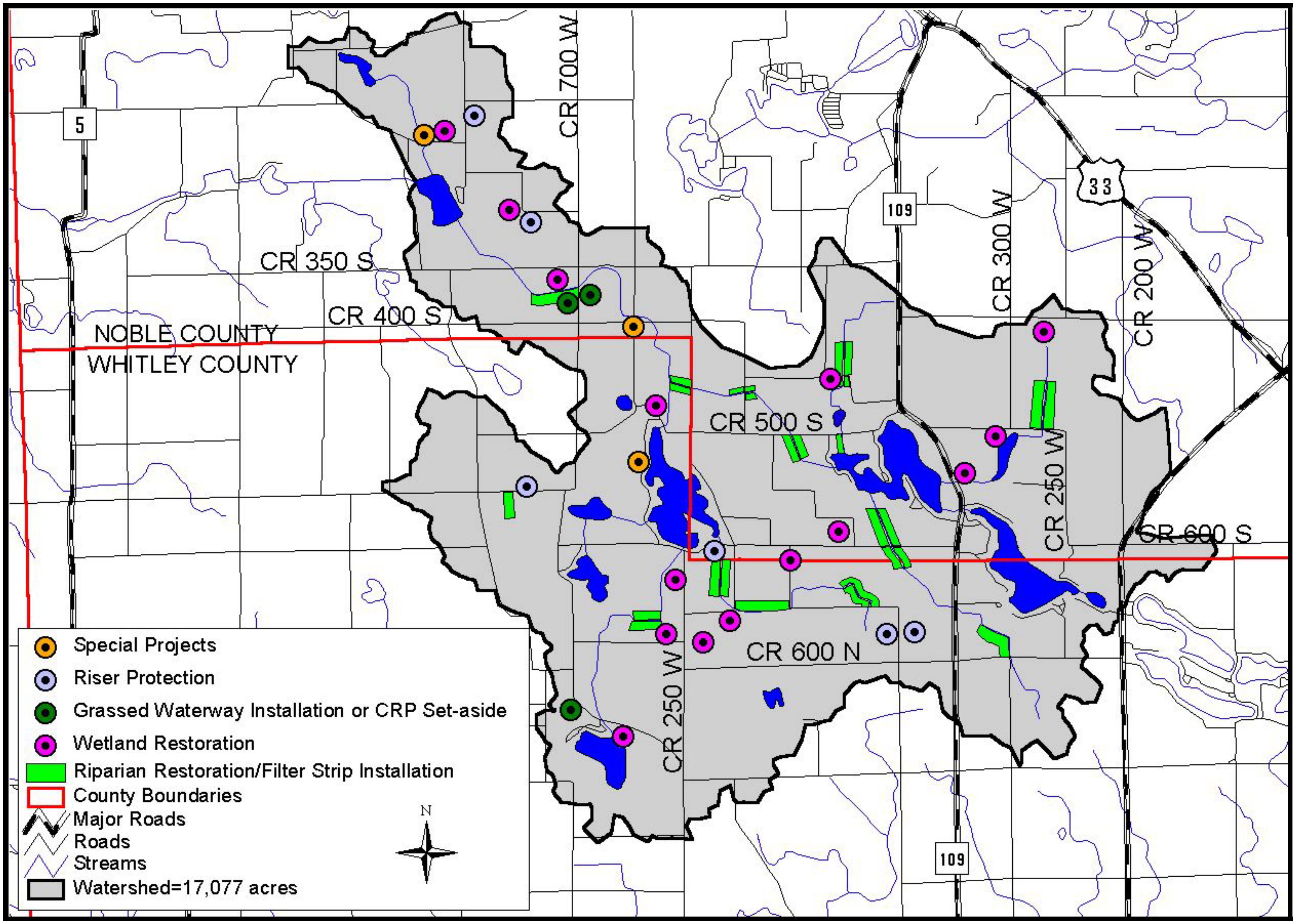

Figure 36. Watershed management techniques recommended for the Smalley Lake watershed.
Source: See Geographic Information Systems map data sources appendix (Appendix A). Scale: 1”=7,000’.

Figure 37. A typical view of the Tippecanoe River upstream of Smalley Lake where riparian trees were removed.

Figure 38. A typical view of the Tippecanoe River where farming operations were occurring very close to the stream's edge.

While restoring the riparian zone along the Tippecanoe River inlet and Smalley Lake's northern inlet to a natural 150-foot (45-m) wooded corridor may be unrealistic at this time given the current land use, restoration of reaches along the stream or scaled back restoration should be considered. Isenhart et al. (1997) offers a flexible riparian management model that includes a 45-foot (14-m) wooded buffer and a 21-foot herbaceous buffer adjacent to the wooded buffer. Monitoring studies of Isenhart et al.'s (1997) riparian management system showed a decrease in sediment and nitrate-nitrogen reaching the stream from the adjacent agricultural land. The system also stabilized the stream banks, provided wildlife habitat, and created the opportunity for a more natural energy and nutrient transfer between the stream and its riparian corridor, increasing the potential for a healthy biotic community.

Even scaled back restorations of the riparian zone to a wooded corridor may not be acceptable to many property owners. On these properties, herbaceous filter strips should be installed. Filter strips slow overland flows from adjacent land and reduce the flow volume by increasing infiltration of the runoff. Slower runoff velocities and reduced flow volumes lead to decreased stream bed and bank erosion downstream. Filter strips also help stabilize stream banks, although not to the same extent as wooded riparian buffers.

The most important role of filter strips may, however, be their ability to remove portions of the pollutant load reaching them from adjacent agricultural areas. Many researchers have verified the effectiveness of filter strips in removing sediment from runoff with reductions ranging from 56-97% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction in sediment load occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips are most effective when they: 1. are adequately sized to treat the amount of runoff reaching them; 2. include a diverse variety of species; 3. contain species appropriate for filter strips; and 4. are regularly maintained. Filter strip size depends on the purpose of the strip, but should ideally have at least a 30-foot flow path length (the minimum length across which water flows prior to reaching the adjacent waterbody). The variety of species planted in a filter strip depends upon the desired uses of the strip. For instance, if the filter strip will be grazed or if a landowner wishes to attract a diverse bird community, specific seed mixes should be used in the filter strip. The NRCS or an ecological consultant can help landowners adjust filter strip seed mixes to suit specific needs.

The need for riparian zone restoration or minimally filter strip installation is great in the Smalley Lake watershed. Figure 36 shows the locations in the watershed where riparian zone restoration or filter strip installation is recommended. Property owners should work closely with the Noble and Whitley County Drainage Boards to ensure riparian restoration needs are balanced with drainage needs and restoration work completed in the watershed will not be disturbed during subsequent dredging operations.

Wetland restoration
Visual observation and historical records indicate at least a portion of the Smalley Lake watershed has been altered to increase its drainage capacity. The relative lack of wetlands in the Smalley Lake watershed compared to the Upper Tippecanoe River watershed lends evidence to this idea. The 1978 Census of Agriculture found that drainage is artificially enhanced on 35% and 45% of the land in Noble and Whitley Counties, respectively (cited in Hudak, 1995). Riser tiles in low spots on the landscape and tile outlets along the Tippecanoe River confirm the fact that the landscape has been hydrologically altered. Shoreline development around lakes in areas that are mapped in hydric soils also supports the hypothesis that the landscape has been hydrologically altered.

This hydrological alteration and subsequent loss of wetlands has implications for the watershed's water quality. Wetlands serve a vital role storing water and recharging the groundwater. When wetlands are drained with tiles, the stormwater reaching these wetlands is directed immediately to nearby ditches and streams. This increases the peak flow velocities and volumes in the ditch. The increase in flow velocities and volumes can in turn lead to increased stream bed and bank erosion, ultimately increasing sediment delivery to downstream water bodies. Wetlands also serve as nutrient sinks at times. The loss of wetlands can increase pollutant loads reaching nearby streams and downstream waterbodies.

Restoring wetlands in the Smalley Lake watershed could return many of the functions that were lost when these wetlands were drained. Figure 36 shows the locations where wetland restoration is recommended. While other areas of the watershed could be restored to wetland conditions, the areas shown in Figure 36 were selected because they are areas where large scale restoration is possible and will likely provide the most water quality improvement benefits due to their proximity to a waterbody.

Livestock fencing
Livestock that have unrestricted access to a lake or stream have the potential to degrade the waterbody's water quality and biotic integrity. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream and lake ecosystems indirectly. Trampling and removal of vegetation through grazing of the riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in the riparian zone decreasing the area's ability to infiltrate water runoff. Removal of vegetation in

the riparian zone also limits the area's ability to filter pollutants in runoff. The degradation of a waterbody's water quality and habitat typically results in the impairment of the biota living in the waterbody.

Livestock have unrestricted access to at least one of the Smalley Lake watershed's streams. Livestock were observed both in and around the northern inlet during various watershed surveys (Figure 36 and Figure 39; Shown as a "Special Project".). The unrestricted access livestock have to the northern inlet may be at least partially responsible for the observed poor water quality in the northern inlet. At base flow, the northern inlet possessed a high concentration of nitrate-nitrogen and *E. coli* and a low concentration of dissolved oxygen. Direct input of animal waste to the stream is likely the cause of these water quality problems. The northern inlet also possessed the most impaired habitat and biotic community as measured by the QHEI and the mIBI, respectively. The removal of riparian vegetation, trampling of stream substrate, and other indirect causes of the livestock's presence in the stream are, at least in part, responsible for the poor habitat and biotic integrity scores.

Figure 39. Livestock with unrestricted access to Smalley Lake's northern inlet.

Restoration of this area will require several phases. First, the livestock in this area should be restricted from having access to the northern inlet. If necessary an alternate source of water should be created for the livestock. Second, the riparian zone along the northern inlet in this area should be restored, or minimally, filter strips should be installed along both banks of the northern inlet in this area. Finally, if possible, drainage from the pasture land should be directed to flow through a constructed wetland to reduce the nitrate-nitrogen load to the northern inlet. Complete restoration of this area will help reduce pollutant loading (particularly nitrate-nitrogen, sediment, and pathogens) to Smalley Lake. It will also improve the biotic community and habitat quality in the northern inlet.

Conservation Reserve Program

The Conservation Reserve Program (CRP) is a cost-share program designed to encourage landowners to remove a portion of their land from agricultural and establish vegetation on the land in an effort to reduce soil erosion, improve water quality, and enhance wildlife habitat. The CRP targets highly erodible land or land considered to be environmentally sensitive. The CRP provides funding for a wide array of conservation techniques including set-asides, filter strips (herbaceous), riparian buffer strips (woody), grassed waterways, and windbreaks. The preceding paragraphs discuss some of the conservation techniques available under the CRP. This section will focus on grassed waterways and set-asides.

Grassed waterways are natural or constructed channels within agricultural fields that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity. Grassed waterways provide similar functions as filter strips. The grassed waterway's vegetation stabilizes the soil beneath it, holding it in place on the landscape. The vegetation also slows runoff water reaching the grassed waterway, reducing the runoff water's erosive power. The vegetation also filters pollutants, particularly sediment from runoff. Like filter strips, the size and shape of the waterway along with what species are planted with and how regularly it is maintained determine the ability of the grassed waterway to perform these functions.

Set-asides are simply what the name implies; they are land that "set aside" or removed from agricultural production and planted with herbaceous or woody vegetation. Like grassed waterways, they stabilize the soil on a property. Vegetation on the land set aside in CRP can also filter any runoff reaching it. More importantly, land set aside and planted to prairie or a multi-layer community (i.e. herbaceous, shrub, and tree layers) can help restore a landscape's natural hydrology. Rainwater infiltrates into the soil more readily on land covered with prairie grasses and plants compared to land supporting row crops. This reduces the erosive potential of rain and decreases the volume of runoff. Multi-layer vegetative communities intercept rainwater at different levels, further reducing the erosive potential of rain and volume of runoff.

Given the functions that grassed waterways and set-asides perform, it is not surprising that removing land from production and planting it with vegetation has a positive impact on water quality. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI score is indicative of lower productivity and better water quality.

Field investigations conducted during this study resulted in the identification of three areas where the use of grassed waterways or conversion of at least a portion of a farm field to native prairie or other vegetation would improve water quality (Figure 36 and Figure 40). Each of the three areas is farmed. Each area is also mapped at least partially in Morley soils that have severe limitations for use in agriculture due to the risk of soil erosion. Additionally, during the windshield tour, the presence of rills and the beginning of gully formation was noted in each of these fields. While other areas of the watershed would benefit from enrollment in the CRP program, these areas were prioritized due to the characteristics listed above and, in the case of the areas in Noble County, their proximity to the Tippecanoe River and Smalley Lake.

Figure 40. Tilled field in the Smalley Lake watershed that would benefit from enrollment in the Conservation Reserve Program.

Conservation tillage

Removing land from agricultural production is not always feasible. Conservation tillage methods should be utilized on highly erodible agricultural land where removing land from production is not an option. Conservation tillage refers to several different tillage methods or systems that leave at least 30% of the soil covered with crop residue after planting (Holdren et al., 2001). Tillage methods encompassed by the phrase "conservation tillage" include no-till, mulch-till, and ridge-till. The crop residue that remains on the landscape helps reduce soil erosion and runoff water volume.

Several researchers have demonstrated the benefits of conservation tillage in reducing pollutant loading to streams and lakes. A comprehensive comparison of tillage systems showed that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (Conservation Technology Information Center, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower mean lake trophic state index scores in ecoregions with higher percentages of conservation tillage. A lower TSI score is indicative of lower productivity and better water quality.

Although an evaluation of the percentage of crop land on which producers were utilizing conservation tillage methods was beyond the scope of this study, county-wide estimates from tillage transect data provide a reasonable estimate of the amount of crop land on which producers are utilizing conservation tillage methods in the Smalley Lake watershed. Tillage transect data collected in 2002 and 2003 for Noble and Whitley Counties showed producers in both counties utilized no-till methods on a higher percentage of soybean fields than the average Indiana county. However, in 2002 both counties registered a decrease in the percentage of soybean fields on which no-till was utilized. The reverse was shown in the 2002 and 2003 tillage transect data for corn fields in these two counties. The data showed producers utilized no-till methods on a lower percentage of corn fields than the average Indiana county. In 2002, both counties registered an increase in the percentage of corn fields on which no-till was utilized (Purdue University and IDNR, no date).

Collectively, the tillage transect data suggest that producers in Noble and Whitley Counties, and therefore the Smalley Lake watershed, should continue utilizing no-till methods on their soybean fields and increase their usage of no-till methods on corn fields. The areas targeted for CRP implementation noted above should be farmed using no-till methods if removal of the land of production is not a feasible option. No-till methods should be used with care in the northern inlet subwatershed. Water in the northern inlet possessed a high nitrate-nitrogen concentration. No-till tillage methods can increase nitrate-nitrogen concentration in surface runoff (Sharpley and Smith, 1994; Indiana Agrinews, 2001). (It is important to note other sources of nitrate exist in that watershed and controlling those sources may decrease the nitrate-nitrogen concentration in the northern inlet. This could make the risk of increased nitrate-nitrogen concentration in runoff associated with conservation tillage acceptable given the benefits to the stream.)

Residential and commercial development erosion control

Although little residential and commercial development is occurring in the Smalley Lake watershed compared to other areas of northeast Indiana, some areas particularly those around the watershed's lakes continue to experience development pressure. Active construction sites are a common source of sediment to nearby waterways. Sediment loss from active construction sites can be several orders of magnitude greater than sediment loss from a completed subdivision. Use of appropriate erosion control management techniques on active construction sites is necessary to reduce pollutant loading to nearby waterbodies. During the watershed inspection, several active construction sites lacked erosion control, resulting in the release of sediment from the site (Figure 36; Shown as a "Special Projects".). Erosion problems on these sites could be controlled with properly installed silt fencing. Smalley Lake watershed stakeholders should monitor development sites to ensure erosion control methods are being utilized. Under new regulations, anyone planning to disturb more than an acre of land must file an erosion control plan with the State.

Individual property management

Individual property owners can take several actions to improve the lakes and streams in the Smalley Lake watershed. First, watershed property owners should reduce or eliminate the use of fertilizers and pesticides. These lawn and landscape-care products are a source of nutrients and toxins to the lakes and streams. Landowners typically apply more fertilizer to lawns and landscaped areas than necessary to achieve the desired results. Plants can only utilize a given amount of nutrients. Nutrients not absorbed by the plants or soil can run into the lakes and streams either directly from those residents' lawns along the lakes' shoreline or indirectly via storm drains. This simply fertilizes the rooted plants and algae in the lakes and impairs the biotic communities in both the lakes and streams in the watershed. At the very minimum, landowners should follow dosing recommendations on product labels and avoid fertilizer/pesticide use within 10 feet of hard surfaces such as roads, driveways, and sidewalks and within 10 to 15 feet of the water's edge. Where possible, natural landscapes should be maintained to eliminate the need for pesticides and fertilizers. Alternatively, landowners should consider replacing high maintenance turf grasses with grasses that have lower maintenance requirements such as some fescue (*Festuca*) species.

If a landowner considers fertilizer use necessary, the landowner should apply phosphorus-free fertilizers. Most fertilizers contain both nitrogen and phosphorus. However, the soil usually contains enough natural phosphorus to allow for plant growth. As a consequence, fertilizers with only nitrogen work as well as those with both nutrients. The excess phosphorus that cannot be absorbed by the grass or plants can enter the lakes or streams, again either directly or via storm drains. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The local Purdue University extension office or a local supplier can usually provide information on soil testing.

Shoreline landowners should also avoid depositing lawn waste such as leaves and grass clippings in the lakes and streams as this adds to the nutrient base in these aquatic systems. Pet and other animal waste that enters the watershed lakes and streams also contributes nutrients and pathogens to the waterbodies. All of these substances require oxygen to decompose. This increases the oxygen demand on Smalley Lake. Yard, pet, and animal waste should be placed in residents' solid waste containers to be taken to the landfill rather than leaving the waste on the lawn or piers to decompose.

Each lake property owner should investigate local drains, roads, parking areas, driveways, and rooftops. Resident surveys conducted on other northern Indiana lakes have indicated that many lakeside houses have local drains of some sort on their properties. These drains contribute to sediment and nutrient loading and thermal pollution to the lakes. Where possible, alternatives to piping the water directly to the lake should be considered. Alternatives include French drains (gravel filled trenches), rain gardens, wetland filters, catch basins, and native plant overland swales.

Residents should disconnect stormwater drainage paths and consider the installation of vegetative filters, rain gardens, gravel infiltration trenches, or other drainage structures that promote infiltration and pollutant treatment over stormwater conveyance. While connecting downspouts with street drains keeps lawns well drained, these direct drainages prevent any pollutant treatment or infiltration (and therefore loss of stormwater volume) that the lawn or natural landscape may provide. Disconnecting these individual stormwater conduits should especially be encouraged in the areas of the watershed where soils are best suited for this.

Individuals should take steps to prevent unnecessary pollutant release from their property. With regard to car maintenance, property owners should clean any automotive fluid (oil, antifreeze, etc.) spills immediately. Driveways and street fronts should be kept clean and free of sediment. Regular hardscape cleaning would help reduce sediment and sediment-attached nutrient loading to the waterbodies in the watershed. Street cleaning would also reduce the watershed loading of heavy metals and other toxicants associated with automobile use. Residents should avoid sweeping driveway silt and debris into storm drains. Rather, any sediment or debris collected during cleaning should be deposited in a solid waste container.

Finally, individual property owners should take steps to minimize the water quality impacts of their on-site waste water treatment systems (i.e. septic systems). Overloaded or leaking septic systems deliver nutrients and other pollutants such as *E. coli* to nearby waterbodies. This can increase the waterbodies' productivity and threaten human health. To address the problems posed by septic systems, properties owners should conduct regular septic tank maintenance. This means homeowners should have their tanks pumped once a year. For forgetful residents, many septic companies have programs in which the company automatically comes out once a year. Where necessary, systems should be upgraded to ensure they can handle any increases in waste stream that have occurred over the years (i.e. modernization of home, increases in residence time, etc.) Water conservation measures such as using low-flow toilets or taking shorter showers will also decrease loading to septic systems.

Those are the minimum steps that should be taken to prevent an increase in pollution from septic systems. Alternatives that actually reduce the waste stream should also be considered. For example, wastewater wetlands typically produce cleaner effluent at the end of a leach field than traditional systems. This is particularly true during the summer months, when plants in such a wetland operate at peak evapotranspiration capacity. Very little effluent leaves the wetlands. This reduction in effluent release corresponds with the peak times for potential algae blooms in the lake. The wetland is working hardest to prevent nutrients from reaching the lake at the exact time when nuisance algae blooms could develop if sufficient nutrients are present. Leach fields of wastewater wetlands are smaller than traditional leach fields making them more attractive on lots where limited space is available. Finally, because of the relative isolation of some of the areas in the Smalley Lake watershed, the installation of a sanitary sewer system is not likely to be economically feasible in the near future. However, new subdivisions such as the one in the northeast corner of the wetland might utilize an expanded waste water wetland to treat all waste water from this area rather than relying on individual septic systems.

9.0 RECOMMENDATIONS

The following list summarizes the recommendations for improving Smalley Lake's chemical, biological, and physical condition. The recommendations are separated in two groups based on priority. Recommendations in the first group are of higher priority than recommendations in the second group since implementation of these recommendations would provide greater and more tangible benefits to Smalley Lake than implementation of recommendations in the second group. That's not to say that recommendations in the second group are not important and should be ignored. Each of the following recommendations should be implemented and will help restore Smalley Lake to a more natural condition.

Regardless of the order in which the following recommendations are implemented, watershed stakeholders should understand that restoration of Smalley Lake and its watershed will require a long-term, concerted effort. The lake and watershed characteristics of Smalley Lake do not point to a single "smoking gun" responsible for the observed increase in productivity or degradation in water quality. Thus, the installation of a single buffer strip, restoration of a single wetland, utilization of conservation tillage on a single field, or implementation of erosion control methods on a single residential construction site will have little noticeable effect on Smalley Lake's water quality. Restoration of Smalley Lake to a more natural, eutrophic condition from its current hypereutrophic condition will only be achieved by the implementation of these recommendations across the watershed over the long term.

Primary Recommendations

1. Restore riparian zones along the Tippecanoe River and its tributaries where possible; minimally, install filter strips along the Tippecanoe River and its tributaries. Target areas shown on Figure 36.

2. Restore as many wetlands as possible in the Smalley Lake watershed, focusing first on the Tippecanoe River subwatershed and targeting those areas shown in Figure 36. Watershed stakeholders should try to restore wetland acreage so that the percentage of the Smalley Lake watershed covered by wetlands equals or exceeds the percentage of land in the greater Upper Tippecanoe River basin that is covered by wetlands.

3. Install fencing to protect Smalley Lake's northern inlet from grazing cattle. Install an alternative water source if necessary. Restore the riparian zone where grazing cattle have damaged the stream habitat. Consider directing drainage from an adjacent grazed field through a constructed wetland to reduce nitrate inputs to the northern inlet.

4. Increase the usage of no-till conservation tillage on corn fields in the Smalley Lake watershed.

5. Utilize the Conservation Reserve Program to implement grassed waterways and remove land mapped in highly erodible soils from agricultural production. Target areas shown in Figure 36 first.

6. Monitor and improve erosion control techniques on residential and commercial development sites. Bring areas of concern to appropriate authorities. Management efforts should focus on Big Lake and Smalley Lake where the active construction sites exist and lack of erosion control techniques were observed.

7. Plant vegetative filter areas around unprotected risers shown in Figure 36.

8. Implement individual property owner management techniques. These apply to all watershed property owners rather than simply those who live adjacent to Smalley Lake.

   a. Reduce the frequency and amount of fertilizer and herbicide/pesticide used for lawn care.
   b. Use only phosphorus-free fertilizer. (This means that the middle number on the fertilizer package listing the nutrient ratio, nitrogen:phosphorus:potassium is 0.)
   c. Consider re-landscaping lawn edges, particularly those along the watershed's lakes and streams, to include low profile prairie species that are capable of filtering runoff water better than turf grass.
   d. Consider planting native emergent vegetation along shorelines or in front of existing seawalls to provide fish and invertebrate habitat and dampen wave energy.
   e. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.

f. Properly maintain septic systems. Systems should be pumped regularly and leach fields should be properly cared for.
g. Examine all drains that lead from roads, driveways, or rooftops to the watershed's lakes and/or streams; consider alternate routes for these drains that would filter pollutants before they reach the water.
h. Obey no-wake zones.
i. Clean boat propellers after lake use and refrain from dumping bait buckets into the lake to prevent the spread of exotic species.

Secondary Recommendations

1. Work with the Noble and Whitley County Drainage Boards to balance drainage needs with the benefits provided by healthy riparian zones.

2. Implement watershed restoration techniques within the framework established in the Upper Tippecanoe River Watershed Management Plan.

3. Become an active volunteer in the Indiana Clean Lakes Program volunteer monitoring program. Smalley Lake currently lacks a volunteer. Volunteer monitoring is easy and does not take much time. The CLP staff provides the training and equipment needed to participate in the program. The data collected by the volunteer monitor will be extremely useful in tracking long-term trends in the lake water quality and measuring the success of any restoration measures implemented in the watershed.

4. In the future, consider installation of a sewer system or alternate waste water treatment system.

5. Continue implementation of recommendations made in previous watershed studies.

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APPENDICES

APPENDIX A:

GEOGRAPHIC INFORMATION SYSTEMS (GIS) MAP DATA SOURCES

GEOGRAPHIC INFORMATION SYSTEM MAP DATA SOURCES

Figure 2. Smalley Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 3. Smalley Lake subwatersheds.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Subwatershed boundaries were delineated based using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI.

Figure 4. Topographical relief of the Smalley Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Relief coverage is the U.S. Geological Survey National Elevation Data set.

Figure 5. The major soil associations covering the Smalley Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soil associations digitized from McCarter, 1977 and Reusch, 1990.

Figure X. Land use in the Smalley Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Land use comes from the USGS Indiana Land Cover Data Set. The data set was corrected based on field investigations conducted in 2002.

Figure X. Wetlands in the Smalley Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Wetland location source is U.S. Fish and Wildlife Service National Wetland Inventory GIS coverage.

Figure X. Location of Smalley lake stream sampling sites.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

APPENDIX B:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, SMALLEY LAKE WATERSHED

January 28, 2003

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED
FROM THE SMALLEY LAKE WATERSHED, NOBLE AND WHITLEY COUNTIES, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENTS
LORANE							
Vascular Plant	ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	T32NR08E 12	1920	
Vascular Plant	CAREX ATLANTICA SSP ATLANTICA	ATLANTIC SEDGE	ST	**	T32NR08E 12	1917	
Vascular Plant	CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	T32NR08E 12	1917	
Vascular Plant	CAREX LIMOSA	MUD SEDGE	SE	**	T32NR08E 12	1917	
Vascular Plant	ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	T32NR08E 12	1917	
Vascular Plant	POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	T32NR08E 12	NO D	
MERRIAM							
Fish	COREGONUS ARTEDI	CISCO	SSC	**	T32NR09E 03 NH	1997	
Fish	COREGONUS ARTEDI	CISCO	SSC	**	T33NR09E 33 WH	1945	
Vascular Plant	ARISTIDA INTERMEDIA	SLIM-SPIKE THREE-AWN GRASS	SR	**	T33NR09E 33	1945	
Vascular Plant	CALLA PALUSTRIS	WILD CALLA	SE	**	T33NR09E 33	1900	
Vascular Plant	CRATAEGUS PRONA	ILLINOIS HAWTHORN	SE	**	T33NR09E 33 & 34	1935	
Vascular Plant	PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	T33NR09E 33 & 34	1935	
CROOKED LAKE NATURE PRESERVE							
Lake	LAKE - LAKE	LAKE	SG	**	T32NR09E 03 & 04	1994	
Reptile	EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	T32NR09E 03 SEQ SWQ NEQ	1992	
Vascular Plant	POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	T32NR09E 03 & 04	1962	
Vascular Plant	POTAMOGETON PRAELONGUS	WHITE-STEM PONDWEED	SE	**	T33NR09E 03 & 04 4	1985	
Vascular Plant	POTAMOGETON ROBBINSII	FLATLEAF PONDWEED	ST	**	T32NR09E 03 & 04	1962	
Vascular Plant	POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	T32NR09E 03 & 04	1962	
CROOKED LAKE NATURE PRESERVE (ORIG							
Forest	FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	T32NR09E 03 NH	1980	
Forest	FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	T32NR09E 03 NH	1980	
Vascular Plant	ELEOCHARIS EQUISETOIDES	HORSE-TAIL SPIKERUSH	SE	**	T33NR09E 03 NEQ SEQ NWQ	1982	
Vascular Plant	SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	T33NR09E 03 NWQ SWQ NEQ	1987	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED
FROM THE SMALLEY LAKE WATERSHED, NOBLE AND WHITLEY COUNTIES, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENTS
Vascular Plant	UTRICULARIA MINOR	LESSER BLADDERWORT	SE	**	T32NR09E 03 NWQ SWQ NEQ	1982	
ORMAS							
Bird	ARDEA HERODIAS	GREAT BLUE HERON	**	**	T32NR08E 02 EH NEQ	1993	
Vascular Plant	SCHEUCHZERIA PALUSTRIS SSP	AMERICAN SCHEUCHZERIA	SE	**	T33NR08E 09	1938	
Vascular Plant	SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	T33NR08E 22	1929	
Vascular Plant	SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	T32NR08E 01	1924	
Vascular Plant	TRIGLOCHIN PALUSTRIS	MARSH ARROW-GRASS	ST	**	T33NR08E 09	1938	
Vascular Plant	UTRICULARIA CORNUTA	HORNED BLADDERWORT	ST	**	T33NR08E 09	1938	
Wetland	WETLAND - BOG ACID	ACID BOG	SG	**	T33NR08E 09 NWQ SEQ	1979	
Wetland	WETLAND - FEN FORESTED	FORESTED FEN	SG	**	T33NR09E 20 N-S THROUGH CENTER	NO D	
MERRY LEA NATURE PRESERVE							
Forest	FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	T33NR08E 13	1980	
Vascular Plant	ARALIA HISPIDA	BRISTLY SARSAPARILLA	SE	**	T33NR08E 13	1935	
Vascular Plant	VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	T33NR08E 13	1935	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX C:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, NOBLE AND WHITLEY COUNTIES, INDIANA

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NOBLE COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARALIA HISPIDA	BRISTLY SARSAPARILLA	SE	**	S1	G5
ARISTIDA INTERMEDIA	SLIM-SPIKE THREE-AWN GRASS	SR	**	S2	G?
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
CALLA PALUSTRIS	WILD CALLA	SE	**	S1	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CRATAEGUS PRONA	ILLINOIS HAWTHORN	SE	**	S1	G4G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
DRYOPTERIS CLINTONIANA	CLINTON WOODFERN	SX	**	SX	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GENTIANA ALBA	YELLOW GENTIAN	SR	**	S2	G4
GERANIUM BICKNELLII	BICKNELL NORTHERN CRANE'S-BILL	SE	**	S1	G5
GEUM RIVALE	PURPLE AVENS	SE	**	S1	G5
HYPERICUM PYRAMIDATUM	GREAT ST. JOHN'S-WORT	SE	**	S1	G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LATHYRUS VENOSUS	SMOOTH VEINY PEA	ST	**	S2	G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
LINNAEA BOREALIS	TWINFLOWER	SX	**	SX	G5
LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	S2	G5
LYCOPODIUM OBSCURUM	TREE CLUBMOSS	SR	**	S2	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MILIUM EFFUSUM	TALL MILLET-GRASS	SR	**	S2	G5
PANICUM LEIBERGII	LEIBERG'S WITCHGRASS	ST	**	S2	G5
PLATANTHERA CILIARIS	YELLOW-FRINGE ORCHIS	SE	**	S1	G5
PLATANTHERA LEUCOPHAEA	PRAIRIE WHITE-FRINGED ORCHID	SE	LT	S1	G2
PLATANTHERA ORBICULATA	LARGE ROUNDLEAF ORCHID	SX	**	SX	G5?
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
PYROLA ROTUNDIFOLIA VAR AMERICANA	AMERICAN WINTERGREEN	SR	**	S2	G5
SALIX SERISSIMA	AUTUMN WILLOW	ST	**	S2	G4
SCHEUCHZERIA PALUSTRIS SSP AMERICANA	AMERICAN SCHEUCHZERIA	SE	**	S1	G5T5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
SPIRANTHES ROMANZOFFIANA	HOODED LADIES'-TRESSES	SE	**	S1	G5
STIPA COMATA	SEWING NEEDLEGRASS	SX	**	SX	G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5
TRIGLOCHIN PALUSTRE	MARSH ARROW-GRASS	ST	**	S2	G5
UTRICULARIA CORNUTA	HORNED BLADDERWORT	ST	**	S2	G5
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

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ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NOBLE COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
VIBURNUM CASSINOIDES	NORTHERN WILD-RAISIN	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
LYCAENA DORCAS DORCAS	DORCAS COPPER	**	**	S2	G4TU
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
FISH					
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
THAMNOPHIS BUTLERI	BUTLER'S GARTER SNAKE	SE	**	S1	G4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
AMMODRAMUS HENSLOWII	HENSLOW'S SPARROW	SE	**	S3B,SZN	G4
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
AYTHYA COLLARIS	RING-NECKED DUCK	**	**	SHB,SZN	G5
BUTEO LINEATUS	RED-SHOULDERED HAWK	SSC	**	S3	G5
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
TYTO ALBA	BARN OWL	SE	**	S2	G5
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
LYNX RUFUS	BOBCAT	SE	**	S1	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLOODPLAIN WET	WET FLOODPLAIN FOREST	SG	**	S3	G3?

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ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NOBLE COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
FOREST - FLOODPLAIN WET-MESIC	WET-MESIC FLOODPLAIN FOREST	SG	**	S3	G3?
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
LAKE - POND	POND	SG	**	S?	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP FOREST	FORESTED SWAMP	SG	**	S2	G2?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

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November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM WHITLEY COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX ALOPECOIDEA	FOXTAIL SEDGE	SE	**	S1	G5
CAREX ATLANTICA SSP ATLANTICA	ATLANTIC SEDGE	ST	**	S2	G5T4
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX LIMOSA	MUD SEDGE	SE	**	S1	G5
COELOGLOSSUM VIRIDE VAR VIRESCENS	LONG-BRACT GREEN ORCHIS	ST	**	S2	G5T5
ELEOCHARIS EQUISETOIDES	HORSE-TAIL SPIKERUSH	SE	**	S1	G4
ERIOCAULON AQUATICUM	PIPEWORT	SE	**	S1	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
PHLOX OVATA	MOUNTAIN PHLOX	SE	**	S1	G4
PLANTAGO CORDATA	HEART-LEAVED PLANTAIN	SE	**	S1	G4
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON PRAELONGUS	WHITE-STEM PONDWEED	SE	**	S1	G5
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON ROBBINSII	FLATLEAF PONDWEED	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
UTRICULARIA MINOR	LESSER BLADDERWORT	SE	**	S1	G5
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
MOLLUSCA: GASTROPODA					
CAMPELOMA DECISUM	POINTED CAMPELOMA	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
POANES VIATOR VIATOR	BIG BROAD-WINGED SKIPPER	SR	**	S2	G5T4
FISH					
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
AMPHIBIANS					
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S3B,SZN	G5
STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	S2B	G5

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FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM WHITLEY COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
MAMMALS					
LYNX RUFUS	BOBCAT	SE	**	S1	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - FEN	FEN	SG	**	S3	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX D:

MACROINVERTEBRATE FAMILIES LIST
FOR THE SMALLEY LAKE WATERSHED STREAMS

Number and type of macroinvertebrate families found in the Smalley Lake watershed streams.

Order	Family	Site 1	Site 2	Site 3
Amphipoda	Talitridae	28	13	5
Colepotera	Elmidae	7		5
Colepotera	Haliplidae		6	
Colepotera	Hydrophilidae		3	
Diptera	Chironomidae	2	6	6
Diptera	Ephydridae	2		
Diptera	Simuliidae			1
Ephemeroptera	Baetidae	1	4	
Ephemeroptera	Caenidae		22	6
Ephemeroptera	Heptageniidae	30		
Gastropoda	Hydrobidae		3	
Hempitera	Belostomatidae		2	
Hempitera	Gerridae	1		1
Hempitera	Mesoveliidae		1	1
Hempitera	Notonectidae		1	
Hempitera	Veliidae	3		
Hirudinea	Glossiphoniidae	1	1	
Isopoda	Asillidae	1	5	1
Megaloptera	Sialidae	5		
Odonata	Aeshnidae	1		1
Odonata	Coenagrionidae	1		
Odonata	Corduliidae		32	1
Odonata	Petaluridae		4	
Platyhelminthes	Planaria	2	12	10
Trichoptera	Hydropsychidae	15		86
Trichoptera	Polycentropodidae	2		
	Number of Individuals	**102**	**115**	**124**
	Number of Taxa	**16**	**15**	**12**

APPENDIX E:

QUALITATIVE HABITAT EVALUATION INDEX (QHEI) DATA SHEETS FOR SMALLEY LAKE WATERSHED STREAMS

STREAM: Tippecanoe River inlet-Site 1 **RIVER MILE:** ______ **DATE:** 8/14/2003 **QHEI SCORE** 48

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 4

TYPE			POOL	RIFFLE				POOL	RIFFLE
		BLDER/SLAB(10)					GRAVEL(7)	x	
		BOULDER(9)					SAND(6)		
		COBBLE(8)	x				BEDROCK(5)		
x		HARDPAN(4)	x		x		DETRITUS(3)	x	
		MUCK/SILT(2)	x				ARTIFIC(0)	x	

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [x] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [x] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Used Ohio EPA's new definition on the number of substrate types.

2) INSTREAM COVER: **COVER SCORE** 12

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 6

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [ ] LOW(2) [x] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [x] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [x] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [ ] MODERATE(2) [x] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 9

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	
x	X	WIDE >150 ft.(4)
		MODERATE 30-150 ft.(3)
		NARROW 15-30 ft.(2)
		VERY NARROW 3-15 ft.(1)
		NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
X	X	FOREST, SWAMP(3)			URBAN OR INDUSTRIAL(0)
		OPEN PASTURE/ROW CROP(0)			SHRUB OR OLD FIELD(2)
		RESID.,PARK,NEW FIELD(1)			CONSERV. TILLAGE(1)
		FENCED PASTURE(1)			MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
		NONE OR LITTLE(3)
X	X	MODERATE(2)
		HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 11

MAX.DEPTH (Check 1): [x] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [X] POOL WIDTH>RIFFLE WIDTH(2) [ ] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [X] MODERATE(1) [X] SLOW(1) [X] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [x] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [X] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [X] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 3.7 **% POOL** 25 **% RIFFLE** ____ **% RUN** 75 **GRADIENT SCORE** 6

STREAM: Northern inlet-Site 2 **RIVER MILE:** ______ **DATE:** 8/14/2003 **QHEI SCORE** 46

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 1

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[ ]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)	x	
[x]	[x]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all)	
[ ] LIMESTONE(1)	[ ] RIP/RAP(0)
[x] TILLS(1)	[ ] HARDPAN(0)
[ ] SANDSTONE(0)	
[ ] SHALE(-1)	
[ ] COAL FINES(-2)	

SILT COVER (one)	
[x] SILT-HEAVY(-2)	[ ] SILT-MOD(-1)
[ ] SILT-NORM(0)	[ ] SILT-FREE(1)

Extent of Embeddedness (check one)	
[x] EXTENSIVE(-2)	[ ] MODERATE(-1)
[ ] LOW(0)	[ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 16

TYPE (Check all that apply)			AMOUNT (Check only one or Check 2 and AVERAGE)
[ ] UNDERCUT BANKS(1)	[x] DEEP POOLS(2)	[ ] OXBOWS(1)	[x] EXTENSIVE >75%(11)
[x] OVERHANGING VEGETATION(1)	[ ] ROOTWADS(1)	[x] AQUATIC MACROPHYTES(1)	[ ] MODERATE 25-75%(7)
[ ] SHALLOWS (IN SLOW WATER)(1)	[ ] BOULDERS(1)	[x] LOGS OR WOODY DEBRIS(1)	[ ] SPARSE 5-25%(3)
			[ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 7

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER	
[ ] HIGH(4)	[ ] EXCELLENT(7)	[ ] NONE(6)	[ ] HIGH(3)	[ ] SNAGGING	[ ] IMPOUND
[ ] MODERATE(3)	[ ] GOOD(5)	[ ] RECOVERED(4)	[ ] MODERATE(2)	[ ] RELOCATION	[ ] ISLAND
[x] LOW(2)	[ ] FAIR(3)	[x] RECOVERING(3)	[x] LOW(1)	[ ] CANOPY REMOVAL	[ ] LEVEED
[ ] NONE(1)	[x] POOR(1)	[ ] RECENT OR NO RECOVERY(1)		[ ] DREDGING	[ ] BANK SHAPING
				[ ] ONE SIDE CHANNEL MODIFICATION	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 6

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[x]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[x]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 8

MAX.DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)	
[x] >4 ft.(6)	[ ] POOL WIDTH>RIFFLE WIDTH(2)	[ ] TORRENTIAL(-1)	[ ] EDDIES(1)
[ ] 2.4-4 ft.(4)	[x] POOL WIDTH=RIFFLE WIDTH(1)	[ ] FAST(1)	[ ] INTERSTITIAL(-1)
[ ] 1.2-2.4 ft.(2)	[ ] POOL WIDTH<RIFFLE WIDTH(0)	[ ] MODERATE(1)	[ ] INTERMITTENT(-2)
[ ] <1.2 ft.(1)		[x] SLOW(1)	
[ ] <0.6 ft.(Pool=0)(0)			

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS	
[ ] GENERALLY >4 in. MAX.>20 in.(4)	[ ] STABLE (e.g., Cobble,Boulder)(2)	[ ] EXTENSIVE(-1)	[ ] NONE(2)
[ ] GENERALLY >4 in. MAX.<20 in.(3)	[ ] MOD.STABLE (e.g., Pea Gravel)(1)	[ ] MODERATE(0)	[x] NO RIFFLE(0)
[ ] GENERALLY 2-4 in.(1)	[ ] UNSTABLE (Gravel, Sand)(0)	[ ] LOW(1)	
[x] GENERALLY <2 in.(Riffle=0)(0)	[x] NO RIFFLE(0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 13.2

% POOL 30 % RIFFLE ____ % RUN 70 **GRADIENT SCORE** 8

STREAM: Smalley Lake outlet-Site 3 **RIVER MILE:** ______ **DATE:** 8/14/2003 **QHEI SCORE** 60

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 14

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			x	[ ]	GRAVEL(7)		x
[ ]	[ ]	BOULDER(9)			x	[ ]	SAND(6)		x
[ ]	[ ]	COBBLE(8)		x	[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)		x	[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [x] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [x] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Used Ohio EPA's new definition on number of substrate types.

2) INSTREAM COVER: **COVER SCORE** 10

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1) [ ] DEEP POOLS(2) [ ] OXBOWS(1)
[x] OVERHANGING VEGETATION(1) [X] ROOTWADS(1) [ ] AQUATIC MACROPHYTES(1)
[ ] SHALLOWS (IN SLOW WATER)(1) [ ] BOULDERS(1) [X] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

[ ] EXTENSIVE >75%(11)
[X] MODERATE 25-75%(7)
[ ] SPARSE 5-25%(3)
[ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 9

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [ ] LOW(2) [x] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [X] FAIR(3) [X] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [X] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [X] HIGH(3) [ ] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] IMPOUND [ ] RELOCATION [ ] ISLAND [ ] CANOPY REMOVAL [ ] LEVEED [ ] DREDGING [ ] BANK SHAPING [ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 5.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
x	X	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	X	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
X	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
X	X	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 6

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [x] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [X] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] EDDIES(1) [X] FAST(1) [ ] INTERSTITIAL(-1) [X] MODERATE(1) [ ] INTERMITTENT(-2) [X] SLOW(1)

COMMENTS:

RIFFLE SCORE 5

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [x] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [X] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] NONE(2) [ ] MODERATE(0) [ ] NO RIFFLE(0) [X] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 15.9 **% POOL** 15 **% RIFFLE** 15 **% RUN** 70 **GRADIENT SCORE** 10

APPENDIX F:

MACROPHYTE SURVEY DATA SHEETS FOR SMALLEY LAKE

Aquatic Vegetation Reconnaissance Sampling

Waterbody Cover Sheet

Surveying Organization: JFNew

Waterbody Name: Smalley Lake

Lake ID:

County: Noble County

Date: 8/26/03

Habitat Stratum: IL

Ave. Lake Depth (ft): 22 ft

Lake Level: 883 ft

GPS Metadata

Datum:

Zone:

Accuracy:

Crew Leader: M. Giolitto

Recorder: S. Namestnik

Method:

Secchi Depth (ft): 3.25 ft

Total # of Plant Beds Surveyed: 4

Total # of Species: 36

Littoral Zone Size (acres): 18 ac

- ❑ Measured
- ✓ Estimated

Littoral Zone Max. Depth (ft): 9.75 ft

- ❑ Measured
- ❑ Estimate (historical Secchi)
- ✓ Estimated (current Secchi)

Notable Conditions:

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	**DATE: 8/26/03**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 01	Waterbody Name: Smalley Lake				Center of the Bed
Bed Size: 1.8 ac					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 31				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 3	N: 1	F: 2	E: 3	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POCO	3			
NYOD	3			
MYSP	3			
CEDE	3			
PEVI	3			
TYLA	2			
STPE	2			
NUAD	1			
SCI VAC	1			
ACE SAI	1			
SA?LI	1			
POIL	1			
POL HYR	1			
PHA ARU	1			
EL?EO	1			
SCI PUN	1			
POL PER	1			
FRA PEN	1			
ASC INC	1			
PAN VIR	1			
LY?SI	1			
SPPO	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extension of the plant bed is approximately 45 feet, while the average width of the plant bed is about 35 feet. The bed lines approximately 2200 feet of shoreline along the northern and northeastern edges of the lake.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/26/03**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Smalley Lake				Center of the Bed
Bed Size: 1.8 ac					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 31				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 3	N: 1	F: 2	E: 3	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
LEMI	1			
CH?AR	1			
ALGA	1			
SPA EUR	1			
DEC VER	1			
POCR	1			
SAL NIG	1			
SAL GLA	1			
SAL INT	1			

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	DATE: 8/26/03

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 02	Waterbody Name: Smalley Lake				Center of the Bed
Bed Size: 1.0 ac					Latitude: NA
Substrate: 2	Waterbody ID:				Longitude: NA
Marl?	Total # of Species: 12				Max. Lakeward Extent of Bed
High Organic?	CanopyAbundance at Site				Latitude: NA
	S: 2	N: 1	F: 2	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYSP	3			
NYOD	2			
CEDE	2			
POIL	2			
STPE	2			
SAL INT	1			
SCI VAC	1			
SCI PUN	1			
POCO	1			
PEVI	1			
TYAN	1			
TYLA	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extension of the plant bed is approximately 50 feet, while the average width is about 30 feet. Vegetation in plant bed 2 was much more sparse than vegetation in plant bed 1. Bed extends along approximately 1400 feet of shoreline along the lake's eastern edge.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/26/03**

SITE INFORMATION

Plant Bed ID: 03	Waterbody Name: Smalley Lake			
Bed Size: 3.9 ac				
Substrate: 2	Waterbody ID:			
Marl?	Total # of Species: 22			
High Organic?	**CanopyAbundance at Site**			
	S: 2	N: 1	F: 3	E: 2

SITE COORDINATES

Center of the Bed

Latitude: NA

Longitude: NA

Max. Lakeward Extent of Bed

Latitude: NA

Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NYOD	3			
MYSP	3			
CEDE	3			
PEVI	3			
NUAD	3			
POCO	2			
ALGA	2			
POIL	1			
TYLA	1			
SCI PUN	1			
STPE	1			
SPPO	1			
LEMI	1			
WOL COL	1			
CEP OCC	1			
DEC VER	1			
PHA ARU	1			
SPA EUR	1			
SCI VAC	1			
SAL INT	1			
CH?AR	1			
HIB PAL	1			

Individual Plant Bed Survey

Comments: The maximum lakeward extension of the plant bed is approximately 100 feet. The average width of the plant bed is 30 feet on the west side of the lake and 60 feet on the south side. In total, Bed 03 parallels approximately 3900 feet of shoreline on the southern and western edges of the lake.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew				**DATE: 8/26/03**
SITE INFORMATION				**SITE COORDINATES**
Plant Bed ID: 04	Waterbody Name: Smalley Lake			Center of the Bed
Bed Size: 0.4 ac				Latitude: NA
Substrate: 2	Waterbody ID:			Longitude: NA
Marl?	Total # of Species: 6			Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**			Latitude: NA
	S: 2	N: 1	F: 3	E: 1 / Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYSP	3			
NYOD	3			
STPE	2			
CEDE	2			
SPI POL	1			
LE?MN	1			

Individual Plant Bed Survey

Comments: The bed is roughly oval in shape with a length of approximately 175 feet along its long axis and a width of approximately 150 feet along its short axis. The bed is located in a shoal area in the southwestern portion of the lake.

REMINDER INFORMATION

Substrate:
1 = Silt/Clay
2 = Silt w/Sand
3 = Sand w/Silt
4 = Hard Clay
5 = Gravel/Rock
6 = Sand

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

Overall Surface Cover
N = Nonrooted floating
F = Floating, rooted
E = Emergent
S = Submersed

Canopy:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

Abundance:
1 = < 2%
2 = 2-20%
3 = 21-60%
4 = > 60%

QE Code:
0 = as defined
1 = Species suspected
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not verified
2 = Taken, verified

Reference ID:
Unique number or letter to denote specific location of a species; referenced on attached map

Abbreviation	Plant Species	Common Name
ACE SAI*	*Acer saccharinum*	Silver maple
ALGA**		Filamentous algae
ASC INC	*Asclepias incarnata*	Swamp milkweed
CEDE	*Ceratophyllum demersum*	Coontail
CEP OCC	*Cephalanthus occidentalis*	Buttonbush
CH?AR	*Chara* species	Chara species
DEC VER	*Decodon verticillatus*	Water willow
EL?EO	*Eleocharis* species	Spikerush species
FRA PEN	*Fraxinus pennsylvanica*	Green ash
HIB PAL	*Hibiscus palustris*	Swamp rosemallow
LE?MN	*Lemna* species	Duckweed species
LEMI	*Lemna minor*	Lesser duckweed
LY?SI	*Lysimachia* species	Loosestrife species
MYSP	*Myriophyllum spicatum*	Eurasian water milfoil
NUAD	*Nuphar advena*	Spatterdock
NYOD	*Nymphaea odorata tuberosa*	White water lily
PAN VIR	*Panicum virgatum*	Switchgrass
PEVI	*Peltandra virginica*	Arrow arum
PHA ARU	*Phalarus arundinacea*	Reed canary grass
POCO	*Pontederia cordata*	Pickerel weed
POCR	*Potamogeton crispus*	Curly-leaf pondweed
POIL	*Potamogeton illinoensis*	Illinois pondweed
POL HYR	*Polygonum hydropiper*	Marshpepper smartweed
POL PER	*Polygonum persicaria*	Lady's thumb
SA?LI	*Salix* species	Willow species
SAL GLA	*Salix glaucophylloides*	Blue-leaved willow
SAL INT	*Salix interior*	Sandbar willow
SAL NIG	*Salix nigra*	Black willow
SCI PUN	*Scirpus pungens*	Chairmakers rush
SCI VAC	*Scirpus validus*	Softstem bullrush
SPA EUR	*Sparganium eurycarpum*	Giant burreed
SPPO	*Spirodela polyrrhiza*	Giant duckweed
STPE	*Stuckenia pectinata*	Sago pondweed
TYAN	*Typha angustifolia*	Narrow leaf cattail
TYLA	*Typha latifolia*	Broad leaf cattail
WOL COL	*Wolffia columbiana*	Columbia watermeal

* Six letter acronym system from the Plants of Chicago Region Database.
** Four letter acronym system from Shuler and Hoffmann (2002).

APPENDIX G:

FISH SPECIES LIST
FOR SMALLEY LAKE

Fish species collected from Smalley Lake (1982-1988). An X indicates the presence of the species during the survey date. Source: IDNR fisheries surveys.

Common Name	Scientific Name	1982	1988
Gars	***Lepisosteidae***		
Spotted Gar	*Lepisosteus oculatus*	X	X
Catfishes	***Ictaluridae***		
Brown Bullhead	*Ameiurus nebulosus*	X	X
Yellow Bullhead	*Ameiurus natalis*	X	X
Bowfins	***Amiidae***		
Bowfin	*Amia calva*		X
Pikes	***Esocidae***		
Grass Pickerel	*Esox americanus*		X
Tiger Muskellunge	*E. masquinongy x E. lucius*		X
Minnows	***Cyprinidae***		
Carp	*Cyprinus carpio*	X	
Golden Shiner	*Notemigonus crysoleucas*	X	X
Suckers	***Catostomidae***		
Spotted Sucker	*Minytrema melanops*	X	X
White Sucker	*Catostomus commersoni*	X	X
Lake Chubsucker	*Erimyson sucetta*	X	X
Siversides	***Atherinidae***		
Brook Silverside	*Labidesthes sicculus*	X	
Sunfishes	***Centrarchidae***		
Bluegill	*Lepomis macrochirus*	X	X
Largemouth Bass	*Micropterus salmoides*	X	X
Redear Sunfish	*Lepomis microlophus*	X	X
Black Crappie	*Pomoxis nigromaculatus*	X	X
Warmouth	*Lepomis gulosus*	X	X
Pumpkinseed	*Lepomis gibbosus*	X	X
Green Sunfish	*Lepomis cyanellus*	X	X
Perches	***Percidae***		
Logperch	*Percina caprodes*		X
Yellow Perch	*Perca flavescens*	X	X

APPENDIX H:

POTENTIAL FUNDING SOURCES

FUNDING SOURCES

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a single project or $300,000 for all projects on a lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. Both the LARE programs are recommended as a project funding source for the Smalley Lake watershed. More information about the LARE program can be found at http://www.in.gov/dnr/soilcons/programs/lare.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement. To qualify for implementation projects, there must be a watershed management plan for the receiving waterbody. This plan must meet all of the current 319 requirements. This diagnostic study serves as an n excellent foundation for developing a watershed management plan since it satisfies several, but not all, of the 319 requirements for a watershed management plan. More information about the Section 319 program can be obtained from http://www.in.gov/idem/water/planbr/wsm/319main.html.

Section 104(b)(3) NPDES Related State Program Grants

Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match. For more information on Section 104(b)(3) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/104main.html.

Section 205(j) Water Quality Management Planning Grants

Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on and 205(j) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/205jmain.html.

Other Federal Grant Programs

The USDA and EPA award research and project initiation grants through the U.S. National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture and is administered by the Natural Resources Conservation Service. Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program

The Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently, the program offers continuous sign-up for practices like grassed waterways and filter strips. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

Grassland Reserve Program

The Grassland Reserve Program (GRP) is funded by the USDA and is administered by the NRCS. GRP is a voluntary program that provides funding the restoration or improvement of natural grasslands, rangelands, prairies or pastures. To qualify for the program the land must consist of at least a 40 acre contiguous tract of land, be restorable, and provide water quality or wildlife benefit. Landowners may enroll land in the Grassland Reserve Program for 10, 15, 20, or 30 years or enter their land into a 30-year permanent easement. Landowners receive payment of up to 75% of the annual grazing value. Restoration cost-share funds of up to 75% for restored or 90% for virgin grasslands are also available.

Community Forestry Grant Program

The U.S. Forest Service through the Indiana Department of Natural Resources Division of Forestry provides three forms of funding for communities under the Community Forestry Grant Program. Urban Forest Conservation Grants (UFCG) are designed to help communities develop long term programs to manage their urban forests. UFCG funds are provided to communities to improve and protect trees and other natural resources; projects that target program development, planning, and education are emphasized. Local municipalities, not-for-profit organizations, and state agencies can apply for $2,000-20,000 annually. The second type of Community Forestry Grant Program, the Arbor Day Grant Program, funds activities which promote Arbor Day efforts and the planting and care of urban trees. $500-1000 grants are generally awarded. The Tree Steward Program is an educational training program that involves six training sessions of three hours each. The program can be offered in any county in Indiana and covers a variety of tree care and planting topics. Generally, $500-1000 is available to assist communities in starting a county or regional Tree Steward Program. Each of these grants requires an equal match.

Forest Land Enhancement Program (FLEP)

FLEP replaces the former Forestry Incentive Program. It provides financial, technical, and educational assistance to the Indiana Department of Natural Resources Division of Forestry to assist private landowners in forestry management. Projects are designed to enhance timber production, fish and wildlife habitat, soil and water quality, wetland and recreational resources, and aesthetic value. FLEP projects include implementation of practices to protect and restore forest lands, control invasive species, and preserve aesthetic quality. Projects may also include reforestation, afforestation, or agroforestry practices. The IDNR Division of Forestry has not determined how they will implement this program; however, their website indicates that they are working to determine their implementation and funding procedures. More information can be found at http://www.in.gov/dnr/forestry.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost-share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost-share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices, innovative approaches to enhance environmental investments like carbon sequestration or market-based credit trading, and groundwater and surface water conservation are also eligible for EQIP cost-share.

Small Watershed Rehabilitation Program

The Small Watershed Rehabilitation Program provides funding for rehabilitation of aging small watershed impoundments that have been constructed within the last 50 years. This program is newly funded through the 2002 Farm Bill and is currently under development. More information regarding this and other Farm Bill programs can be found at http://www.usda.gov/farmbill.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals of FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent to or within administered conservation areas.

Partners for Fish and Wildlife Program

The Partners for Fish and Wildlife Program (PFWP) is funded and administered by the U.S. Department of the Interior through the U.S. Fish and Wildlife Service. The program provides technical and financial assistance to landowners interested in improving native habitat for fish and wildlife on their land. The program focuses on restoring wetlands, native grasslands, streams, riparian areas, and other habitats to natural conditions. The program requires a 10-year cooperative agreement and a 1:1 match.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish, and other wildlife. The match for this program is on a 1:1 basis.

National Fish and Wildlife Foundation (NFWF)

The National Fish and Wildlife Foundation is administered by the U.S. Department of the Interior. The program promotes healthy fish and wildlife populations and supports efforts to invest in conservation and sustainable use of natural resources. The NFWF targets six priority areas which are wetland conservation, conservation education, fisheries, neotropical migratory bird conservation, conservation policy, and wildlife and habitat. The program requires a minimum of a 1:1 match. More information can be found at http://www.nfwf.org/about.htm.

Bring Back the Natives Grant Program

Bring Back the Natives Grant Program (BBNG) is a NFWF program that provides funds to restore damaged or degraded riverine habitats and the associated native aquatic species. Generally, BBNP supports on the ground habitat restoration projects that benefit native aquatic species within their historic range. Funding is jointly provided by a variety of federal organizations including the U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Department of Agriculture and the National Fish and Wildlife Foundation. Typical projects include those that revise land management practices to remove the cause of habitat degradation, provide multiple specie benefit, include multiple project partners, and are innovative solutions that assist in the development of new technology. A 1:1 match is required; however, a 2:1 match is preferred. More information can be obtained from http://www.nfwf.org.

Native Plant Conservation Initiative

The Native Plant Conservation Initiative (NPCI) supplies funding for projects that protect, enhance, or restore native plant communities on public or private land. This NFWF program typically funds projects that protect and restore of natural resources, inform and educate the surrounding community, and assess current resources. The program provides nearly $450,000 in funding opportunities annually awarding grants ranging from $10,000-50,000 each. A 1:1 match is required for this grant. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Freshwater Mussel Fund

The National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service fund the Freshwater Mussel Fund which provides funds to protect and enhance freshwater mussel resources. The program provides $100,000 in funding to approximately 5-10 applicants annually. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

U.S. Environmental Protection Agency Environmental Education Program

The USEPA Environmental Education Program provides funding for state agencies, non-profit groups, schools, and universities to support environmental education programs and projects. The program grants nearly $200,000 for projects throughout Illinois, Indiana, Michigan, Minnesota, Wisconsin, and Ohio. More information is available at http://www.epa.gov/region5/ened/grants.html.

Core 4 Conservation Alliance Grants

Core 4 provides funding for public/private partnerships working toward Better Soil, Cleaner Water, Greater Profits and a Brighter Future. Partnerships must consist of agricultural producers or citizens teaming with government representatives, academic institutions, local associations, or area businesses. CTIC provides grants of up to $2,500 to facilitate organizational or business plan development, assist with listserve or website development, share alliance successes through CTIC publications and other national media outlets, provide Core 4 Conservation promotional materials, and develop speakers list for local and regional use. More information on Core 4 Conservation Alliance grants can be found at http://www.ctic.purdue.edu/CTIC/GrantApplication.pdf.

Indianapolis Power and Light Company (IPALCO) Golden Eagle Environmental Grant

The IPALCO Golden Eagle Grant awards grants of up to $10,000 to projects that seek improve, preserve, and protect the environment and natural resources in the state of Indiana. The award is granted to approximately 10 environmental education or restoration projects each year. Deadline for funding is typically in January. More information is available at http://www.ipalco.com/ABOUTIPALCO/Environment/Golden_Eagle.html

Nina Mason Pulliam Charitable Trust (NMPCT)

The NMPCT awards various dollar amounts to projects that help people in need, protect the environment, and enrich community life. Prioritization is given to projects in the greater Phoenix, AZ and Indianapolis, IN areas, with secondary priority being assigned to projects throughout Arizona and Indiana. The trust awarded nearly $20,000,000 in funds in the year 2000. More information is available at www.nmpct.org