Pretty Lake Diagnostic Study
Lagrange County, Indiana

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PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

EXECUTIVE SUMMARY

Pretty Lake is a 184-acre (74.5-ha) natural lake that lies in the headwaters of the St. Joseph River Basin northeast of South Milford, Indiana. Pretty Lake's watershed encompasses approximately 1,230 acres (497.7 ha or 1.9 square miles). Most of the watershed (67%) is utilized for agricultural purposes (row crops, hay, and pasture). Remnants of the native landscape, including forested areas and wetlands, cover approximately 17% of the watershed, while residential and commercial land uses account for less than 2% of the watershed's total acreage. Pretty Lake itself covers 15% of the total watershed.

Pretty Lake has one primary tributary, Deal Ditch. Deal Ditch exhibited moderate water quality during both base flow and storm flow conditions. The stream possessed elevated nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli* concentrations; however, with the exception of *E. coli*, none of the parameters rated at a level of concern. The stream's biotic community integrity score reflected its moderate water quality; Deal Ditch's biotic community fell in the "moderately impaired" category using the Indiana Department of Environmental Management's scoring criteria. *E. coli* source tracking completed in the Deal Ditch watershed indicates that most *E. coli* results from human, horse, and hog sources.

Pretty Lake itself contains excellent water quality. Historical data for the lake suggest that Pretty Lake's water quality has remained relatively stable or improved slightly over the past 50 years. The lake possesses better water clarity and lower nutrient levels than most Indiana lakes. Evaluating the lake using various trophic state indices suggest the lake is oligotrophic to mesotrophic in nature. However, Pretty Lake's phosphorus concentration has the potential to increase the lake's productivity. Pretty Lake supports a diverse submerged plant community that includes two state listed species.

Continued good water quality in Pretty Lake will require both in-lake and watershed management. The lake possesses a long hydraulic residence time of 3.1 years. Thus, attention to watershed and near shore practices prior to addressing in-lake processes is necessary. The results of the inlet sampling and the phosphorus modeling indicate the watershed is capable of contributing significant amounts of nutrient and sediment to the lake, making good watershed management a necessity as well. Pretty Lake's relatively small watershed area to lake area ratio of 7:1 suggests near shore residents have substantial control over influencing the health of their lake.

Recommended watershed management techniques include: stream bed and bank stabilization, homeowner best management practices, manure management planning, wetland restoration, use of the Conservation Reserve Program and conservation tillage, and stormwater filtration. Within the lake itself, Pretty Lake stakeholders are encouraged to develop a rooted plant management plan and to consider restoration of emergent communities in selected locations to protect the lake's health.

ACKNOWLEDGMENTS

The Pretty Lake Diagnostic Study was made possible with funding from the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife, Lake and River Enhancement Program (LARE), and the Pretty Lake Conservation Club. The Pretty Lake Diagnostic Study was completed by JFNew and their subcontractor, Indiana University School of Public and Environmental Affairs. Contributors to this study included Gwen White, Angela Sturdevant, and Neil Ledet with the IDNR Division of Division of Fish and Wildlife and Ron Hellmich with the IDNR Division of Nature Preserves. Special thanks to the dedicated board directors and members of the Pretty Lake Conservation Club for their initiative and assistance in getting this study completed. Pretty Lake residents who participated in the study included: Jim Mertz, who served as the primary liaison between JFNew and the Pretty Lake Conservation Club; provided JFNew with directions and information during the watershed tour; and navigated us around the lake during the rooted plant survey; and Jack Dold, who provided useful historical information. Authors of this report included William Jones, Erin Miller, Aaron McMahon, Rachel Price, Emily Kara, and Melissa Clark at Indiana University and Sara Peel, John Richardson, Mark Pranckus, Betsy Ewoldt, and Scott Namestnik at JFNew.

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1.0 <u>INTRODUCTION</u>

Pretty Lake is a 184-acre (74.5-ha) natural lake that lies in southeast corner of Lagrange County, Indiana (Figure 1). Specifically, the lake is located in Sections 15 and 16 of Township 36 North, Range 11 East in Lagrange County. The Pretty Lake watershed stretches out to the north and west of the lake encompassing approximately 1,230 acres (497.7 ha or 1.9 square miles; Figure 2). Water discharges through the lake's outlet in the northeast corner. Water from Pretty Lake's outlet combines with water from Mud Lake to flow north into Little Turkey Lake. Water from Little Turkey Lake exits through Turkey Creek flowing north to empty into the Pigeon River near Mongo, Indiana. The Pigeon River transports water to the St. Joseph River which eventually discharges into Lake Michigan.

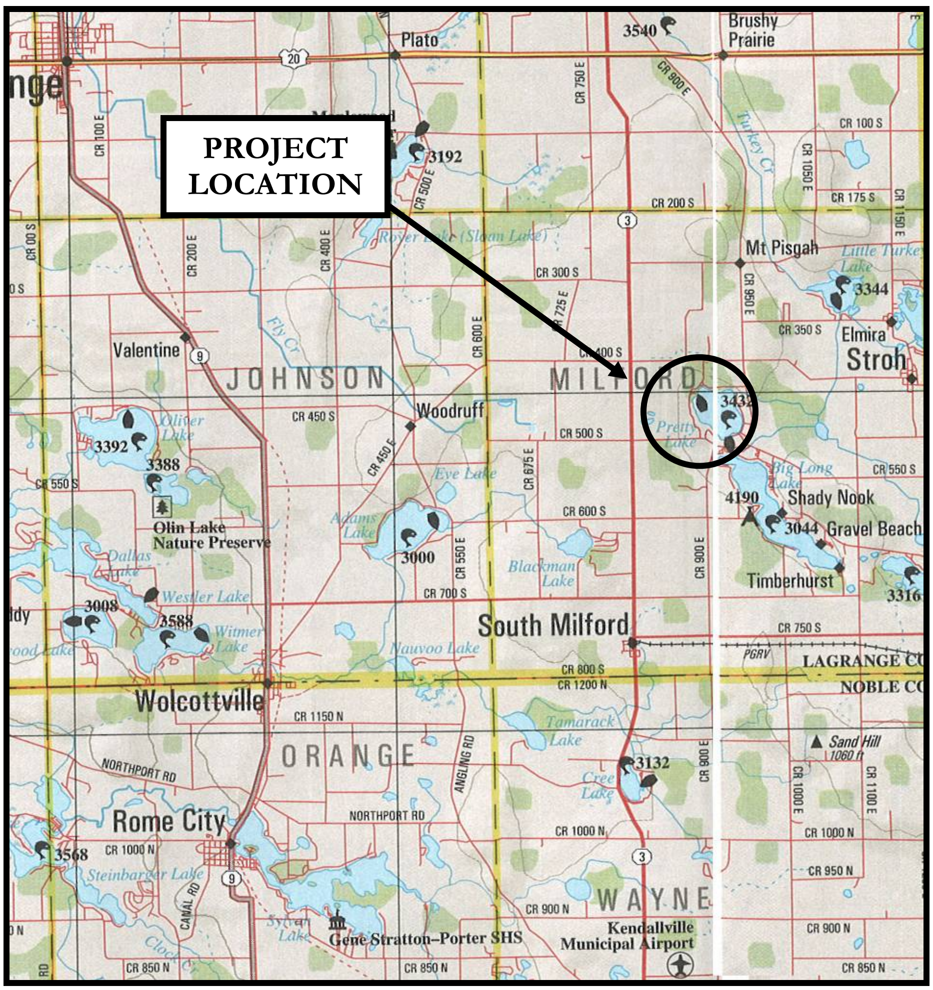

Figure 1. General location of the Pretty Lake watershed. Source: DeLorme, 1998.

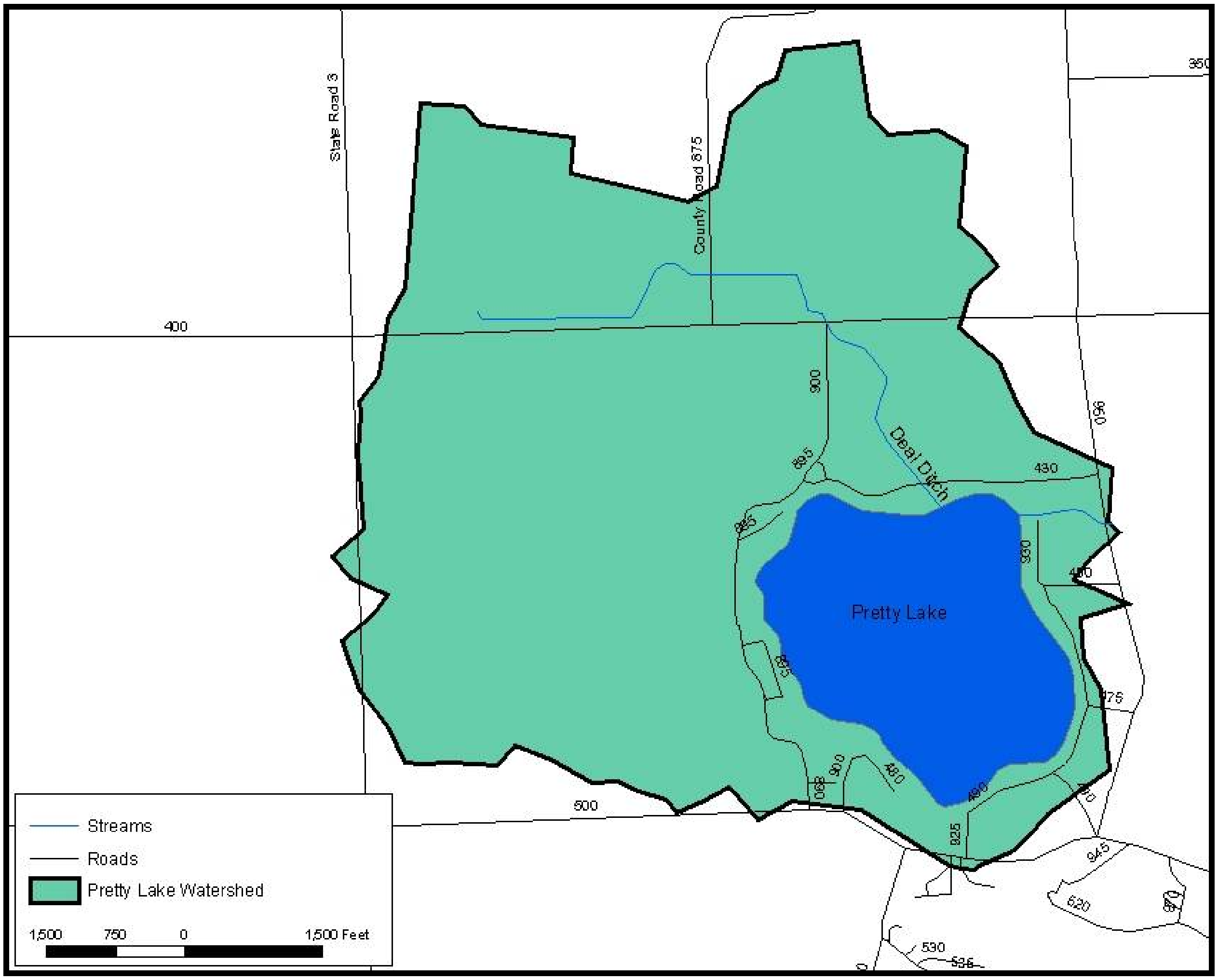

Figure 2. Pretty Lake watershed.

Pretty Lake has historically exhibited good water quality. The lake's water clarity is excellent compared to many other lakes in the region. Historical records from the past forty years show the lake's Secchi disk transparency (a measure of water clarity) has been consistently greater than 9 feet (2.7 m) compared to a regional median of less than 6.9 feet (2.1 m) (CLP, unpublished data). Pretty Lake's nutrient levels have similarly remained relatively low over the past 40 years. Total phosphorus concentrations are well below the state wide median value. Primary productivity of the lake (algae and plant growth) has been low as well. Chlorophyll *a* concentrations (an indicator of algae production) measured less than 3μg/L during all previous assessments.

In addition to exhibiting good water quality, Pretty Lake possesses and extremely diverse aquatic plant community and continues to be a good lake for fishing. More than 70 aquatic plant species were identified in the lake during the most recent assessment including more than 10 species of pondweeds. This is a reflection of Pretty Lake's good water clarity. However, four exotic species including Eurasian watermilfoil, curly-leaf pondweed, reed canary grass, and purple loosestrife were identified within the confines of Pretty Lake. Despite the presence of exotic species, the lake's excellent water quality is reflected in the fishery. Naturally-reproducing populations of largemouth bass and northern pike, a quality bluegill/redear sunfish combined fishery, and a successful walleye stocking program indicate that the lake is stable with excellent water quality. Although trout are no longer stocked in Pretty Lake, lack of angler interest probably played as large of a role in these management changes in summer habitat conditions (primarily water temperature). If water quality remains stable or continues to improve, there should be no significant change to the lake's aquatic plant community or its fishery. However, the introduction of exotic plant and animal species; changes in angler harvest or pressure, or global climate change could have a negative impact on a quality recreational fishery.

Despite the lake's excellent water quality and its ability to provide good fishing, lake residents, particularly long-time residents, have noticed changes in the lake over the past several years. Residents have observed a shift in the type of vegetation in the lake. Specifically, emergent vegetation beds have decreased in size, while more nuisance vegetation, including Eurasian watermilfoil, appears to have expanded its coverage in the lake. Residents have also noted a decrease in the lake's water clarity in some portions of the lake following large rain events. These changes have negatively impacted the residents' enjoyment of the lake and increased their desire to protect the lake's health and future.

Pretty Lake residents have been proactive in protecting their lake's health. For example, property owners throughout the watershed worked with the Natural Resources Conservation Service and Soil and Water Conservation District to implement several best management practices throughout the watershed to reduce erosion and improve water storage capacity. While these practices have slowed the import of sediment to Pretty Lake, lake residents and members of the Pretty Lake Conservation Club have identified additional areas of concerns including the elevated *E. coli* concentrations present in the lake's primary inlet stream, Deal Ditch. Lake residents have also expressed a desire to learn about practices that can be implemented on residential properties which might improve the lake's water quality. To achieve these goals, the Pretty Lake Conservation Club applied for and received funding from the IDNR Lake and River Enhancement Program (LARE) to complete a diagnostic study of the lake.

The purpose of the diagnostic study was to describe the conditions and trends in Pretty 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 lake 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 Pretty Lake and the water entering the lake, the diagnostic study included an examination of the lake and inlet 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 Topography and Physical Setting

Pretty Lake is a headwaters lake in the Great Lakes Basin. The lake and its 1,231-acre (497.7-ha) watershed lie north of the north-south continental divide. Similar to its more famous cousin, the east-west Continental Divide which divides the United States into two watersheds, one that drains to the Atlantic Ocean and one that drains to the Pacific Ocean, the north-south continental divide separates the Mississippi River Basin (land that drains south to the Mississippi River) from the Great Lakes Basin (land that drains north to the Great Lakes). As part of the St. Joseph River Basin, water exits Pretty Lake near the lake's northeast corner and flows east then north through Lagrange County as Turkey Creek. Turkey Creek combines with the Pigeon River south of Mongo, which eventually discharges into the St. Joseph River in Michigan directly north of Bristol, Indiana. The St. Joseph River flows northwest carrying water into Lake Michigan at St. Joseph/Benton Harbor.

The topography of the Pretty Lake watershed reflects the geological history of the watershed. The highest areas of the watershed lie along the watershed's southern and eastern edges, where the Erie Lobe of the last glacial age left end moraines. Along the watershed's northern boundary, the elevation nears 1030 feet (313.9 m) above mean sea level. The ridges along the watershed's southwestern boundary are nearly as high (1020 feet msl), and are equally as steep than the ridge along the northern watershed boundary. Deal Ditch, its floodplain, and Pretty Lake occupy a lower elevation valley in the watershed. Pretty Lake, elevation 964 feet (293.8 m) above mean sea level, is the lowest point in the watershed. This surface water elevation is one of the highest elevations for lakes in Lagrange County (Grant, 1989). Figure 3 presents a topographical relief map of the Pretty Lake watershed.

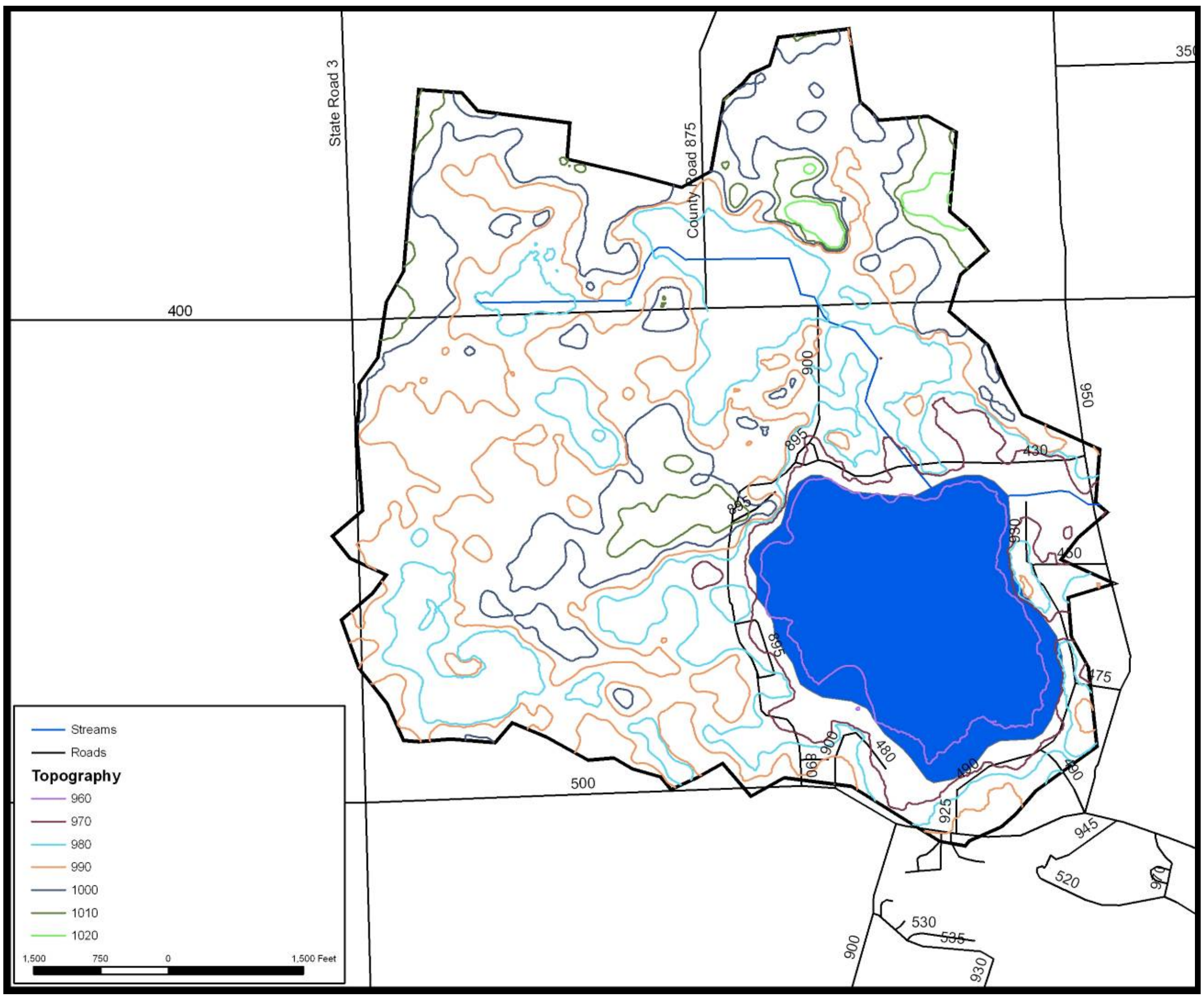

Figure 3. Topographical map of the Pretty Lake watershed.

2.1.1 Pretty Lake

Surface water drains to Pretty Lake via three primary routes: through Deal Ditch, through an unnamed tributary which enters near the public access site, and via direct drainage. Deal Ditch drains approximately 651 acres (263.5 ha or 53%) of the watershed north of Pretty Lake (Table 1). This stream empties into Pretty Lake in the lake's northeast corner. The drain was originally constructed as a tile drain in 1902 and was subsequently reconstructed in 1952 as a open drain (Rex Pranger, personal communication). This drain is a legal drain, which means that the drain is maintained by the drainage board. Furthermore, any activity in and around the drain must be approved by the drainage board prior the activity occurring. An unnamed tributary transports water to Pretty Lake from the watershed west of the lake emptying into the lake along its western boundary. In total, this tributary drains 160 acres (64.7 ha) of the Pretty Lake watershed. The remaining 19% of the land in the Pretty Lake watershed (236 acres or 95.5 ha) drains directly to Pretty Lake or via a series of small swales along the lake's western shoreline. Figure 4 illustrates the boundaries of each of these subwatersheds of Pretty Lake. McGinty (1966) noted that the main inlet to Pretty Lake (Deal Ditch) supplied 80% of the surface water to the lake. However, it should be noted that a majority of water likely enters Pretty Lake as groundwater. Historic fluctuations in surface water level typically occurred due to a large spring associated with the lake (McGinty, 1966).

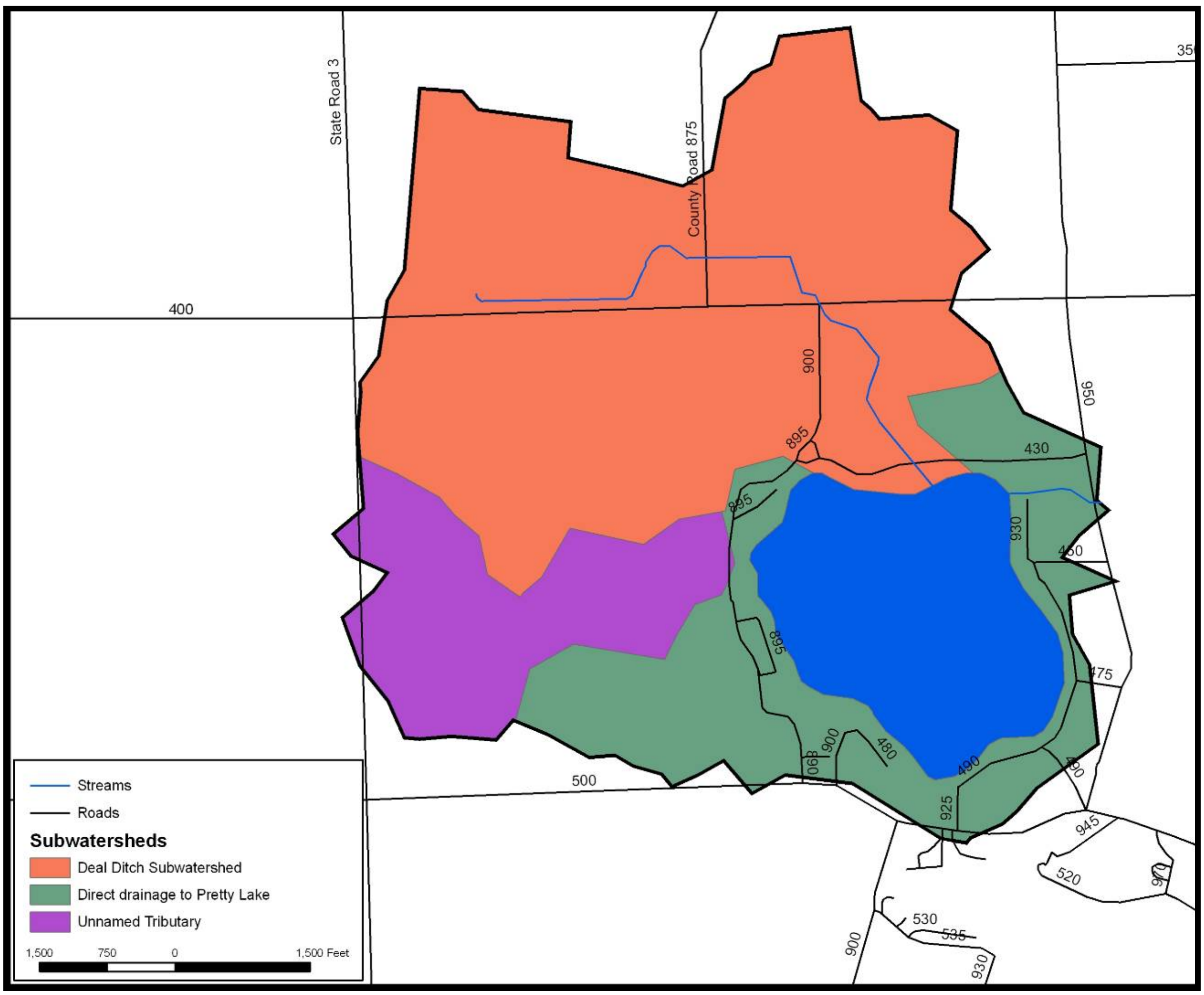

Figure 4. Pretty Lake subwatersheds.

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

Subwatershed/Lake	Area (acres)	Area (hectares)	Percent of Watershed
Deal Ditch	651	263.5	52.8%
Unnamed Tributary (West)	160	64.7	13.1%
Area draining directly to Pretty Lake	236	95.5	19.2%
Watershed Draining to Lake	**1,047**	**423.7**	**85.1%**
Pretty Lake	184	74.5	14.9%
Total Watershed	**1,231**	**498.2**	**100%**
Watershed to Lake Area Ratio	6.7:1		

Table 1 also provides the watershed area to lake area ratio for Pretty 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.

Pretty Lake possesses a watershed area to lake area ratio of approximately 6.7:1. This is a fairly low watershed area to lake area ratio for glacial lakes (Vant, 1987). This ratio is also relatively normal when compared to other lakes in northern Indiana. For example, Myers Lake in Marshall County, which is similarly in size to Pretty Lake, has a watershed area to lake area ratio of approximately 8:1. Conversely, Lake Tippecanoe, Ridinger Lake, and Smalley Lake, glacial lakes in the Upper Tippecanoe River watershed in Kosciusko, Noble, and Whitley Counties, possess watershed area to lake area ratios of 93:1, 165:1, and 248:1, respectively. All of these lakes have extensive watersheds compared to Pretty Lake. Pretty Lake's watershed area to lake area ratio is typical 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 (Vant, 1987).

In terms of lake management, Pretty Lake's watershed area to lake area ratio means that near lake (i.e. shoreline) and in-lake activities and processes can potentially exert a significant influence on the health of Pretty Lake. Consequently, implementing best management practices along the lake's shoreline, such as maintaining native, emergent vegetated buffers between the lakeside residences and the lake, should rank high when prioritizing management options. Similarly, in-lake management practices, should receive special attention. This does not mean that watershed or ravine management should be ignored. However, the relatively small watershed area to lake area ratio should be considered when prioritizing the use of limited funds for lake management.

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.

Pretty Lake Watershed Climate

The climate of the Pretty Lake watershed is characterized as having four well-defined seasons of the year. Winter temperatures average 27º F (-2.7º C), while summers are warm, with temperatures averaging 71º F (21.7º C). The growing season typically begins in early April and ends in September. Yearly annual rainfall averages 35.43 inches (97.8 cm). Winter snowfall averages about 33 inches (83.82 cm). During summers, relative humidity varies from about 65 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. Through 4 December 2006, almost 35.5 inches (90.2 cm) of precipitation (Table 2) was recorded at Prairie Heights High School in Lagrange County. This is slightly more than the average annual precipitation for Lagrange County. It is anticipated that once the remainder of the precipitation for the month of December is included, precipitation for 2006 will likely measure greater than one inch (2.54 cm) above the normal precipitation.

Table 2. Monthly rainfall data (in inches) for year 2006 as compared to average monthly rainfall.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2006	2.78	1.30	2.16	1.46	5.61	4.31	7.20	2.65	2.78	3.58	1.64	1.64*	35.47
Average	1.59	1.35	2.04	3.17	3.48	4.29	3.52	4.67	3.39	2.62	3.06	2.25	35.43

*December precipitation measured through 4 December 2006 only. Precipitation value will be updated in final report. All data were recorded at Prairie Heights High School in Lagrange County. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 at Prairie Heights High School (Purdue Applied Meteorology Group, 2006).

2.3 Geology

The advance and retreat of the glaciers in the last ice age (the Wisconsin 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 equals 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.

Pretty Lake is located within a series of kettle lakes that are generally oriented in a northwest-southeast direction. These lakes occur in line with a stress plain associated with the Saginaw Lobe. The movement and stagnation of the Saginaw and Erie Lobes of the Wisconsin glacial age shaped much of the Pretty Lake watershed. The Saginaw glacial lobe moved out of Canada to the south carrying a mixture of Canadian bedrock with it. The Packerton Moraine, an end moraine which marks the edge of the Saginaw Lobe's advance into Indiana, forms the southern boundary of Pretty Lake's watershed and the general boundary between the St. Joseph River Basin and the Wabash River Basin. The Packerton Moraine formed as remnant ice chunks from the Saginaw Lobe melted. However, some of these ice blocks remained when the Erie Lobe moved into Indiana from the northeast overriding the eastern edge of the Saginaw Lobe. Pretty Lake is located within the area where the Saginaw and Erie Lobes overlapped (Williams, 1974). Specifically, the lake is located within remnant Saginaw glacial drift (Hough, 1958).

The geology and resulting physiography of the Pretty Lake watershed typify the physiographic region in which the watershed lies. The Pretty Lake watershed lies within Malott's Steuben Morainal Lake Area. Schneider (1966) notes that the landforms common in this diverse physiographic region include till knobs and ice-contact sand and gravel kames, kettle holes and lakes, meltwater channels lined with outwash deposits or organic sediment, valley trains, outwash plains, and small lacustrine plains. Specifically, kames, kettle lakes, outwash plains, and meltwater channels exist within the Pretty Lake watershed and surrounding area (Williams, 1974). Many of these landforms are visible on the Pretty Lake watershed landscape. Pretty Lake is a good example of a deep (relative to many lakes in the region) kettle lake lying in an end moraine. It's part of the "knob and kettle" topography that is characteristic of end moraines. As Williams (1974) noted, the original ice block that formed as Pretty Lake has undergone some modifications as sediments accumulated within the glacial drift. Till knobs and kames occur along the watershed's southwestern edge. Many other reminders of the watershed's geologic history exist for those who look closely.

Surficial geology indicates that Pretty Lake lies within glacial till material. Glacial drift covers the Pretty Lake watershed to a depth of 300 to 400 feet (91.2 to 122 m; Wayne, 1966). The watershed's surficial geology originates from silty clay loam and clay loam till materials. The bedrock underlying the watershed's surficial geology includes rock from one period. Coldwater shale underlies the entire Pretty Lake watershed (Gray, 1989). Shale was laid to a depth of 90 and 350 feet (27.4 to 106.7 m). The underlying bedrock is a broad lowland which possesses moderate relief, the Dekalb Lowland. This lowland formed on Upper Devonian and Lower Mississippian shales (Wayne, 1966; Gutschick, 1966).

2.4 Soils

Before detailing the major soil associations covering the Pretty 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 eight to fifteen 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 Wawasee-Hillsdale-Conover soil association consists primarily of Wawasee fine sandy loam, Hillsdale sandy loam, and Conover loam.

One major soil association, the Wawasee-Hillsdale-Conover soil association, covers the Pretty Lake watershed. The following discussion on soil associations in the Pretty Lake watershed relies heavily on the *Soil Survey of Lagrange County* (Hillis, 1980). Readers should refer to this source for a more detailed discussion of soil associations covering Lagrange County.

The Wawasee-Hillsdale-Conover soil association covers the entirety of the Pretty Lake watershed. The Wawasee-Hillsdale-Conover soil association is the most plentiful association covering 34% of Lagrange County. Soils in this soil association developed from glacial till and occur on till plains and moraines. Thirty percent of the soil association consists of Wawasee soils, while Hillsdale soils cover 17% and Conover soils cover 14%. Wawasee soils are well drained and occur on knobs and breaks between drainageways. Hillsdale soils are also well drained soils; however, they are typically found on ridges between drainageways and on level till plains. Conover soils are typically located on broad flats or along drainageways and are somewhat poorly drained. Boyer loamy sand, Oshtemo loamy sand, Chelsea fine sand, Metea loamy sand, and Martinsville sandy loam soils are minor components of this association. Whitaker soils are common on low areas in the landscape, while Rensselaer soils are located in depressions and drainageways and Houghton soils are found in low-lying pockets and deep depressions.

Cultivated cropland, pasture, woodland, and housing or other urban uses are the typical uses for areas mapped in this association (Hillis, 1980). Soils in this association are well suited to crop production. However, erosion is a major hazard especially on the sloping, well-drained soils of this association. Low available water capacity limits Hillsdale soils, while Conover soils are limited by wetness. Many of the soils in the Wawasee-Hillsdale-Conover soil association have severe limitations when used as a septic tank absorption field. As a consequence, this soil association is not well suited for residential developments which utilize septic systems for wastewater treatment.

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 can 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 and Figure 5 displays the soil units in the Pretty Lake watershed that the NRCS considers to be highly erodible and potentially highly erodible.

Highly erodible (HES) and potentially highly erodible soil (PHES) units in the form of Boyer loamy sand, Chelsea fine sand, Hillsdale sandy loam, Metea loamy sand, Oshtemo loamy sand, and Wawasee fine sandy loam and loam soils cover much of the Pretty Lake watershed. Areas of the watershed that are mapped in these soil units and have gentle slopes are considered only slightly limited for agricultural production. As slope increases, the severity of the limitation increases. Some steeply sloped Oshtemo and Wawasee soils are considered unsuitable for agricultural production due to erosion hazard. The erosion hazard would also exist during residential development on these soils.

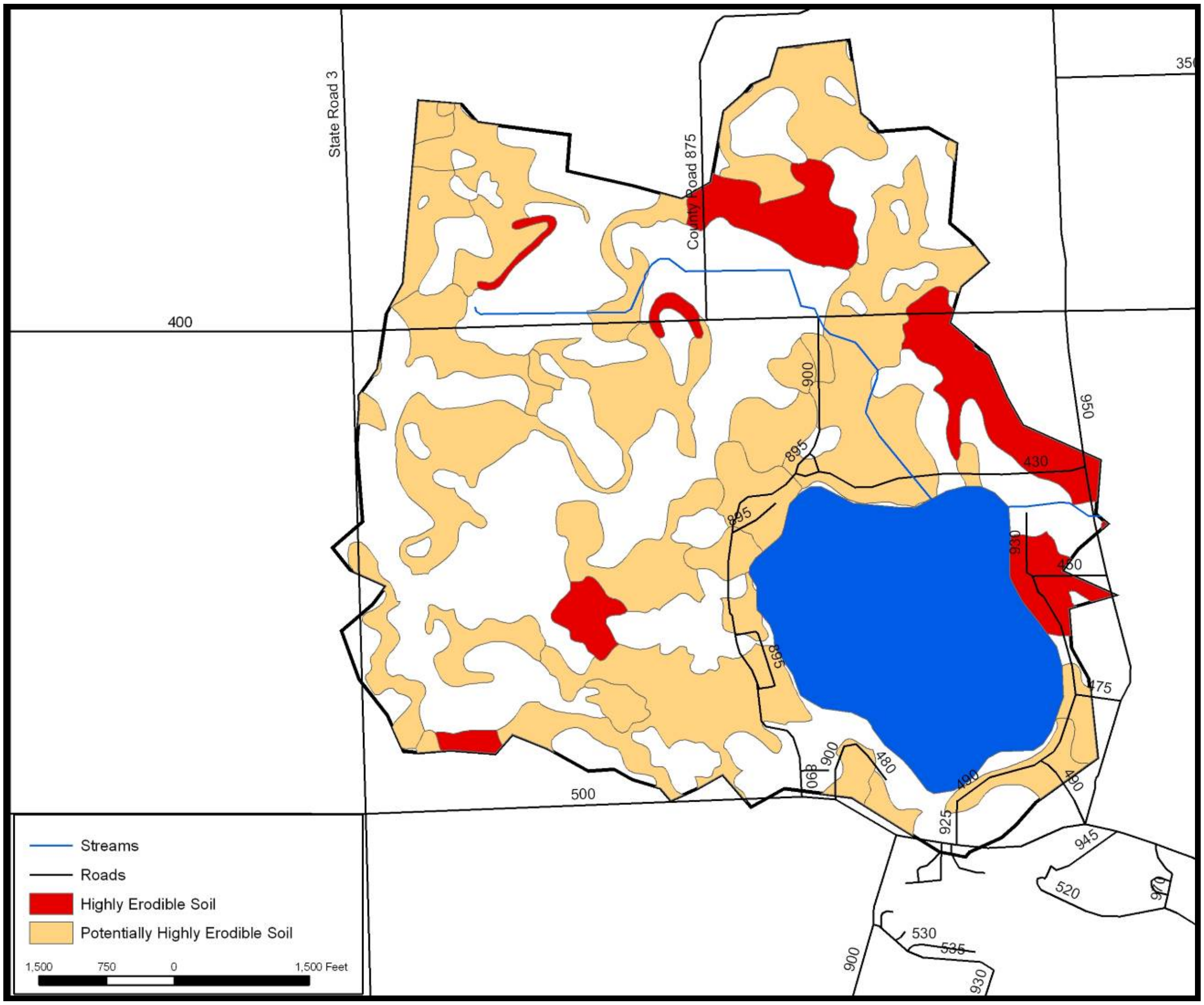

Figure 5. Highly erodible and potentially highly erodible soils within the Pretty Lake watershed.

Table 3. Highly erodible and potentially highly erodible soil units in the Pretty Lake watershed.

Soil Unit	Status	Soil Name	Soil Description
BoC	PHES	Boyer loamy sand	6-12% slopes
BoD	PHES	Boyer loamy sand	12-18% slopes
ChC	PHES	Chelsea fine sand	6-12% slopes
HdC	PHES	Hillsdale sandy loam	6-12% slopes
MeC	PHES	Metea loamy sand	6-12% slopes
OsC	PHES	Oshtemo loamy sand	6-12% slopes
WeC2	PHES	Wawasee fine sandy loam	6-12% slopes, eroded
WhC3	PHES	Wawasee loam	6-12% slopes, severely eroded
WhD3	HES	Wawasee loam	12-18% slopes, severely eroded

Note: PHES stands for potentially highly erodible soil and HES stands for highly erodible soil.

As Figure 5 indicates, erodible soils located on the most steeply sloped areas (HES) cover approximately 99 acres (40.1 ha) or 8% of the Pretty Lake watershed, while erodible soils on steep-sloped soils (PHES) cover approximately 450 acres (182.1 ha) or 36% of the watershed. Highly erodible and potentially highly erodible soils border nearly the entire shoreline of Pretty Lake and cover much of the watershed lying directly north and west of the lake. In 1987, EarthSource overlaid highly erodible soils with severely sloped areas (1991). This overlay identified 66 acres (26.7 ha) where highly erodible soils were mapped on severely sloped areas. EarthSource (1991) identified all of these areas as located adjacent to open drains or ditches and utilized for agricultural row crop production during the 1987 growing season.

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 throughout the Pretty Lake watershed. The shoreline of Pretty Lake is one exception to this. Wastewater from all of the residences directly adjacent to Pretty Lake is treated by a sewer system owned and operated by the Lagrange County Regional Sewer District. The sewer system treats wastewater from residences along the entire shoreline of Pretty Lake. Wastewater from the Lagrange County Regional Sewer District sewer is transported to the wastewater treatment plant. Once treated, effluent is discharged to Turkey Creek eventually reaching the Pigeon River. Much of the wastewater from the remainder of the Pretty Lake watershed is still primarily treated by private waste disposal systems. Private waste disposal systems rely 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 soil particle's surface; 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 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. Also, some sewage organisms only thrive under anaerobic conditions.

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 throughout 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, the NRCS ranks each soil series in the Pretty Lake watershed 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. Figure 6 displays the septic tank suitability of soils throughout the Pretty Lake watershed, while Table 4 lists the soils located within the watershed and their associated properties. Soils that are severely limited for use as septic systems cover 463 acres (187.3 ha or 37%) of the watershed. Severely limited soils cover the entire watershed east of Pretty Lake and are also located along the southwestern shoreline of the lake, in the southwest corner of the watershed, and along the length of the main inlet (Deal Ditch). Soils that are moderately limited cover an additional 34% or 422 acres (170.8 ha) of the Pretty Lake watershed. These soils border the remaining lakeshore including the western, northern, and southeastern shorelines. Soils that are rated as slightly limited for septic system usage (12%) or soils that are not rated at all (17%), including Pretty Lake, cover the remaining 29% of the watershed.

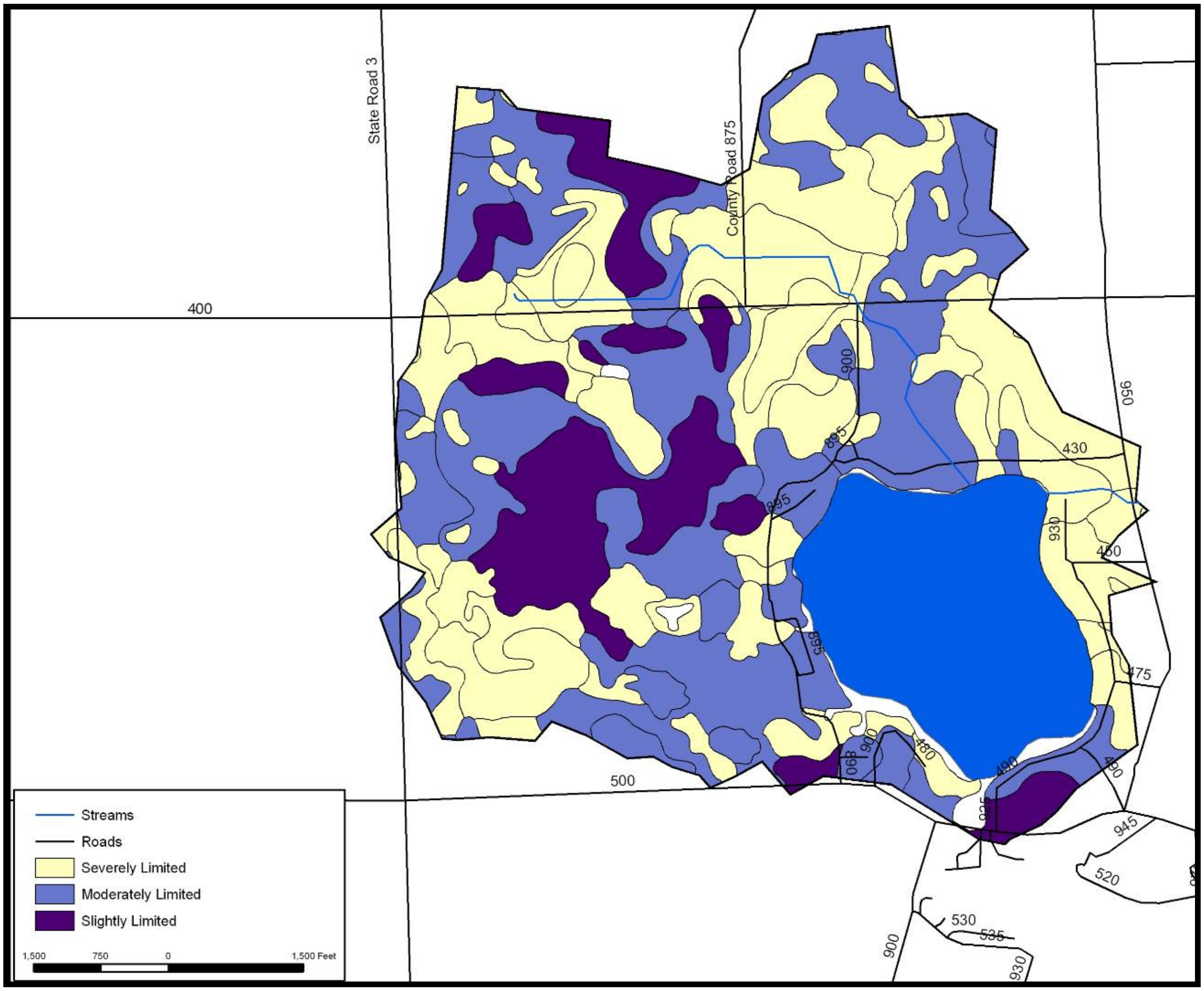

Figure 6. Soil septic tank suitability within the Pretty Lake watershed. Note: Residences directly adjacent to Pretty Lake's shoreline are treated by a sewer system maintained by the regional sewer district.

Table 4. Soil types in the Pretty Lake watershed and the features restrictive to their suitability to serve as a septic tank absorption field.

Soil Unit	Soil Name	Depth to High Water Table	Restrictive Features
BoB-BoD	Boyer loamy sand	>6 feet	Severe: poor filter
ChC	Chelsea fine sand	>6 feet	Severe: poor filter
CrA	Conover loam	1 to 2 feet	Severe: wetness, percs slowly
HdB-HdC	Hillsdale sandy loam	>6 feet	Moderate: percs slowly
Ht, Hw	Houghton muck	+0.5 to 1 feet	Severe: ponding, percs slowly
Hx	Houghton muck, ponded	+2 to 0.5 feet	Severe: ponding, percs slowly
Mc	Martisco muck	+0.5 to 0.5 feet	Severe: ponding, percs slowly
MeB	Metea loamy sand	>6 feet	Moderate: percs slowly
MeC	Metea loamy sand	>6 feet	Moderate: slope, percs slowly
OsC	Oshtemo loamy sand	>6 feet	Severe: poor filter
Pv	Pits, gravel	--	--
Rb	Rensselaer loam	+0.5 to 1 feet	Severe: ponding, percs slowly
Ud	Udorthents	--	--
Wa	Wallkill silt loam	+0.5 to 0.5 feet	Severe: ponding
WeB	Wawasee fine sandy loam	>6 feet	Slight
WeC2	Wawasee fine sandy loam	>6 feet	Moderate: percs slowly, slope
WeD2	Wawasee fine sandy loam	>6 feet	Severe: slope
WhC3	Wawasee loam	>6 feet	Moderate: percs slowly, slope
WhD3	Wawasee loam	>6 feet	Severe: slope

2.5 Natural History

Geographic location, climate, topography, geology, soils, and other factors play a role in shaping the native floral and faunal communities in a particular area. Various ecologists (Deam, 1921; Petty and Jackson, 1966; Homoya et al., 1985; Omernik and Gallant, 1988) have divided Indiana into several natural regions or ecoregions, each with similar geographic history, climate, topography, and soils. Because the groupings are based on factors that ultimately influence the type of vegetation present in an area, these natural areas or ecoregions tend to support distinctive native floral and faunal communities. The Pretty Lake watershed lies in the northeastern part of Homoya's Northern Lakes Natural Region, near its transition with the Bluffton Till Plain Section of the Central Till Plain Natural Region. Similarly, the Pretty Lake watershed lies in the southeastern portion of Omernik and Gallant's Southern Michigan/Northern Indiana Till Plains Ecoregion, near its transition with the Eastern Corn Belt Plains Ecoregion (Omernik and Gallant, 1988). The Pretty Lake watershed also lies within the Oak-Hickory Climax Forest Association near the transition zone between Petty and Jackson's Oak-Hickory and Beech-Maple Climax Forest Associations (Petty and Jackson, 1966). As a result, the native floral community of the Pretty Lake watershed likely consisted of components of neighboring natural areas and ecoregions in addition to components characteristic of the natural area and ecoregion in which it is mapped.

Homoya et al. (1985) noted that 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. 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. Omernik and Gallant (1988) describe the region as consisting mostly of cropland agriculture, with remnants of natural forest cover. Mesic forests are dominated by American beech and sugar maple, with a significant component of white oak, black oak, northern red oak, yellow poplar, hickory, white ash, and black walnut. Petty and Jackson (1966) list pussy toes, common cinquefoil, wild licorice, tick clover, blue phlox, waterleaf, bloodroot, Joe-pye-weed, woodland asters, goldenrods, wild geranium, and bellwort as common components of the forest under story in the watershed's region. Historically, Milford Township was covered by swamps and forests (Historical Landmarks Foundation, 2002). Historical records support the observation that prior to European settlement of Milford Township dense oak-hickory forests covered the Pretty Lake watershed (Petty and Jackson, 1966). White oak was the dominant component of the heavily timbered areas with shagbark hickory, maple, beech, elm, walnut, butternut, and red and black oak as subdominants (Petty and Jackson, 1966; Omernik and Gallant, 1988; Historic Landmarks Foundation, 2002). Williams (1974) noted that in the 1970s, patches of uncleared woodlots were dominated by northern red, white, scarlet, and black oak; shagbark hickory; silver maple; cottonwood; sycamore; hackberry; sassafras; box elder; American elm; and flowering dogwood.

Historically, wet habitat (ponds, swamps, marshes, and bogs) intermingled with the upland habitat throughout the Pretty Lake watershed. The hydric soils map and an 1876 map of Lagrange County indicate that wetland habitat existed throughout the Pretty Lake watershed including areas north and west of the lake. These wet habitats supported very different vegetative communities than the drier portions of the landscape (Homoya et. al, 1985). Sycamore, American elm, red elm, green ash, silver maple, red maple, cottonwood, hackberry, and honey locust likely dominated the floodplain forests. Swamp communities bordering lakes typically consisted of red maple, silver maple, green ash, American elm, black ash, and yellow birch. Marshes associated with lake communities typically contained swamp loosestrife, cattails, bulrush, marsh fern, marsh cinquefoil, and sedges. Aquatic species within the lake community included spatterdock, water shield, fragrant water lily, pickerel weed, hornwort, wild celery, pondweeds, Virginia arrow arum, and sedges.

2.6 Land Use

Just as soils, climate, and geology shape the native communities within the watershed, how the land in a watershed is used can impact the water quality of a waterbody. Different land uses have the potential to contribute different amounts of nutrients, sediment, and toxins to receiving water bodies. For example, Reckhow and Simpson (1980) compiled phosphorus export coefficients (amount of phosphorus lost per unit of land area) for various land uses by examining the rate at which phosphorus loss occurred on various types of land. (The Phosphorus Modeling Section of the report contains more detailed information on this work and its impact on Pretty Lake and its watershed.) Several researchers have also examined the impact of specific urban and suburban land uses on water quality (Bannerman et. al, 1992; Steuer et al., 1997; Waschbusch et al., 2000). Bannerman et al. (1992) and Steuer et al. (1997) found high mean phosphorus concentrations in runoff from residential lawns (2.33 to 2.67 mg/L) and residential streets (0.14 to 1.31 mg/L). These concentrations are well above the threshold at which lakes might begin to experience algae blooms. (Lakes with total phosphorus concentrations greater than 0.03 mg/L will likely experience algae blooms.) Finally, the Center for Watershed Protection has estimated the association of increased levels of impervious surface in a watershed with increased delivery of phosphorus to receiving waterbodies (Caraco and Brown, 2001). Land use directly affects the amount of impervious surface in a watershed. Because of the effect watershed land use has on water quality of the receiving lakes, mapping and understanding a watershed's land use is critical in directing water quality improvement efforts.

2.6.1 Pretty Lake Watershed

Figure 7 and Table 5 present current land use information for the Pretty Lake watershed. (Land use data from the U.S. Geological Survey (USGS) form the basis of Figure 7.) Like many Indiana watersheds, agricultural land use dominates the Pretty Lake watershed, accounting for approximately 67% of the watershed. Row crop agriculture makes up the greatest percentage of agricultural land use at 50.2%, while pastures or hay vegetate another 16.8%. Most of the agricultural land in the Pretty Lake watershed and throughout Lagrange County (USDA, 2002) is used for growing soybeans and corn. Lagrange County ranks the highest of all 92 state counties for forage (land used for hay, haylage, grass silage, and greenchop) production and sales of donkeys, ponies, mules, burrows, and horses and also cattle sales. County-wide tillage transect data for Lagrange County provide an estimate for the portion of cropland in conservation tillage for the Pretty Lake watershed. In Lagrange County, soybean producers utilize no-till methods on 64% of soybean fields and some form of reduced tillage on 28% of soybean fields (IDNR, 2004b). Lagrange County corn producers used no-till methods on 14% of corn fields and some form of reduced tillage on 24% of corn fields in production (IDNR, 2004a). Overall, Lagrange County ranked 56th for usage of no-till on corn fields and 46th for use of no-till on soybean fields. The percentages of fields on which no-till methods were used in Lagrange County were above the statewide median percentage for soybean production, but below the median percentage for corn production.

Land uses other than agriculture account for the remaining 33% of the watershed. Natural landscapes, including forests and wetland, cover approximately 17% of the watershed. Most of the natural acreage in the watershed is associated with the forested and emergent and woody wetland area north of Pretty Lake. Additional smaller tracts are located near the headwaters of Deal Ditch, in the northeastern corner of the watershed, and adjacent to the pond in the watershed's southwestern corner. These natural areas consist of small tracts of wooded or emergent wetlands or deciduous forest, and are scattered along the shoreline. Open water, including Pretty Lake and several small ponds, accounts for another 15% of the watershed. Most of the remaining 1.3% of the watershed is occupied by low intensity residential land, with less than 1% of high intensity residential or commercial land. Much of the residential land lies directly adjacent to Pretty Lake.

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

Land Use	Area (acres)	Area (hectares)	% of Watershed
Row Crops	618.1	250.3	50.2%
Pasture/Hay	207.0	83.8	16.8%
Open Water	187.2	75.8	15.2%
Deciduous Forest	155.5	63.0	12.6%
Woody Wetlands	37.6	15.2	3.1%
Low Intensity Residential	14.7	6.0	1.2%
Emergent Herbaceous Wetlands	8.3	3.4	0.7%
Evergreen Forest	1.1	0.4	0.1%
High Intensity Commercial	0.9	0.4	0.1%
High Intensity Residential	0.7	0.3	0.1%
Mixed Forest	0.2	0.1	<0.1%
Entire Watershed	**1,231.3**	**498.5**	**100.0%**

Source: USGS EROS, 1998.

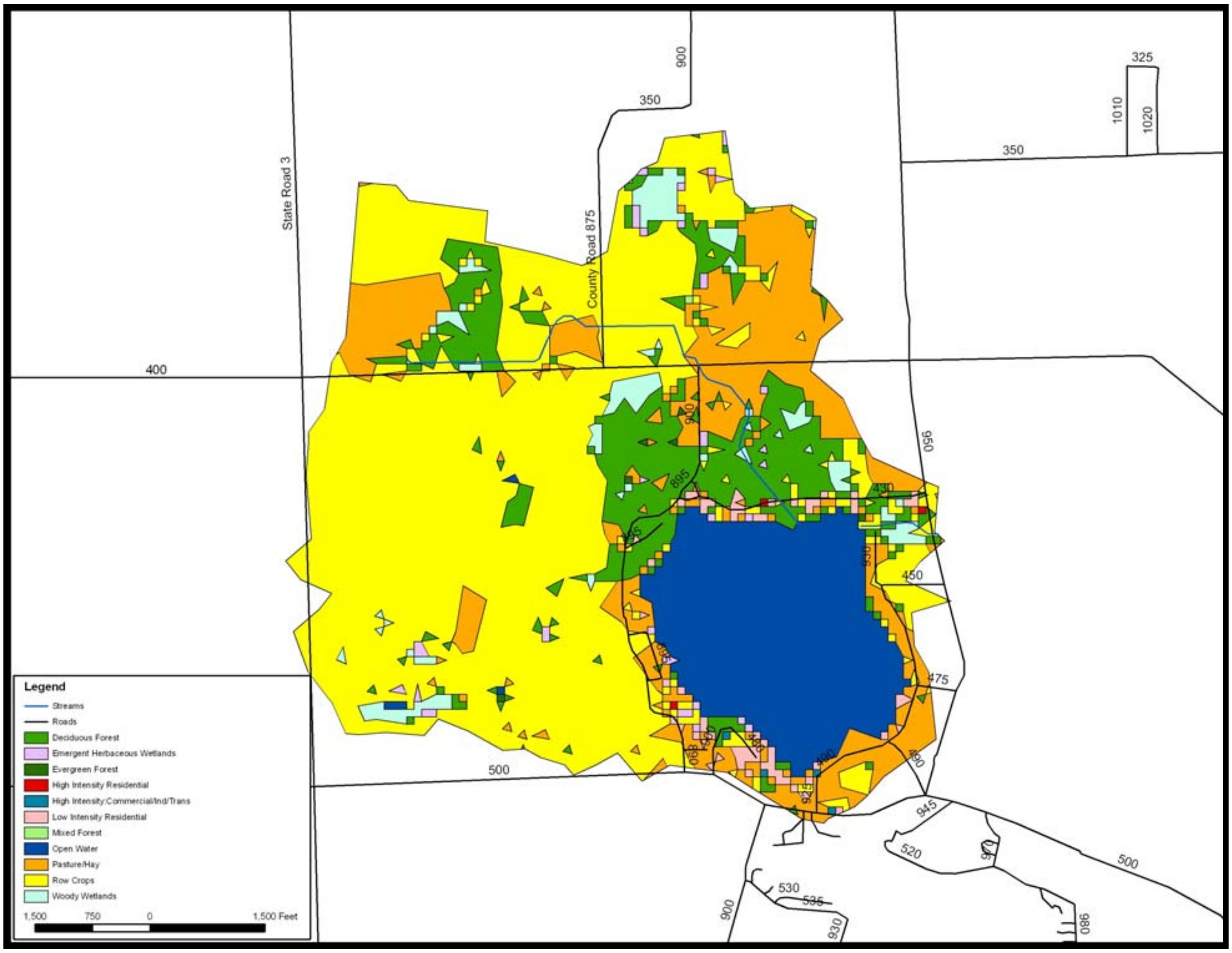

Figure 7. Land use in the Pretty Lake watershed.
Source: USGS EROS, 1998.

Impervious surface coverage was calculated by using adapted impervious values for selected land used in Lee and Toonkel (2003), but does not include road surfaces. Impervious surfaces cover approximately 1.6% of the watershed. This estimate of impervious surface coverage is below the threshold (10%) at which the Center for Watershed Protection has found an associated decline in water quality. The land uses contributing to the impervious surface coverage in the Pretty Lake watershed are agricultural (1.3%), residential (0.2%), and commercial (0.1%).

2.7 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.

The United States Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) Map (Figure 8) shows that wetlands cover approximately 27% of the Pretty Lake watershed. (Table 6 presents the acreage of wetlands by type according to the National Wetland Inventory.) Pretty Lake itself accounts for most (15% of the total 27% of the watershed) of this wetland acreage. Forested, shrub-scrub, and herbaceous wetlands cover approximately 11% of the watershed. The largest contiguous tracts of wetland habitat lie in the north of Pretty Lake, in the watershed's northeast and southwest corners, and adjacent to the headwaters of Deal. Two ponds account for the remaining wetland acreage (0.8%). Nearly 55% of the wetlands present in the Pretty Lake watershed possess seasonal water regimes (EarthSource, 1991). Additionally, 88% of the wetlands present in the watershed are less than 10 acres (4 ha) in size (EarthSource, 1991).

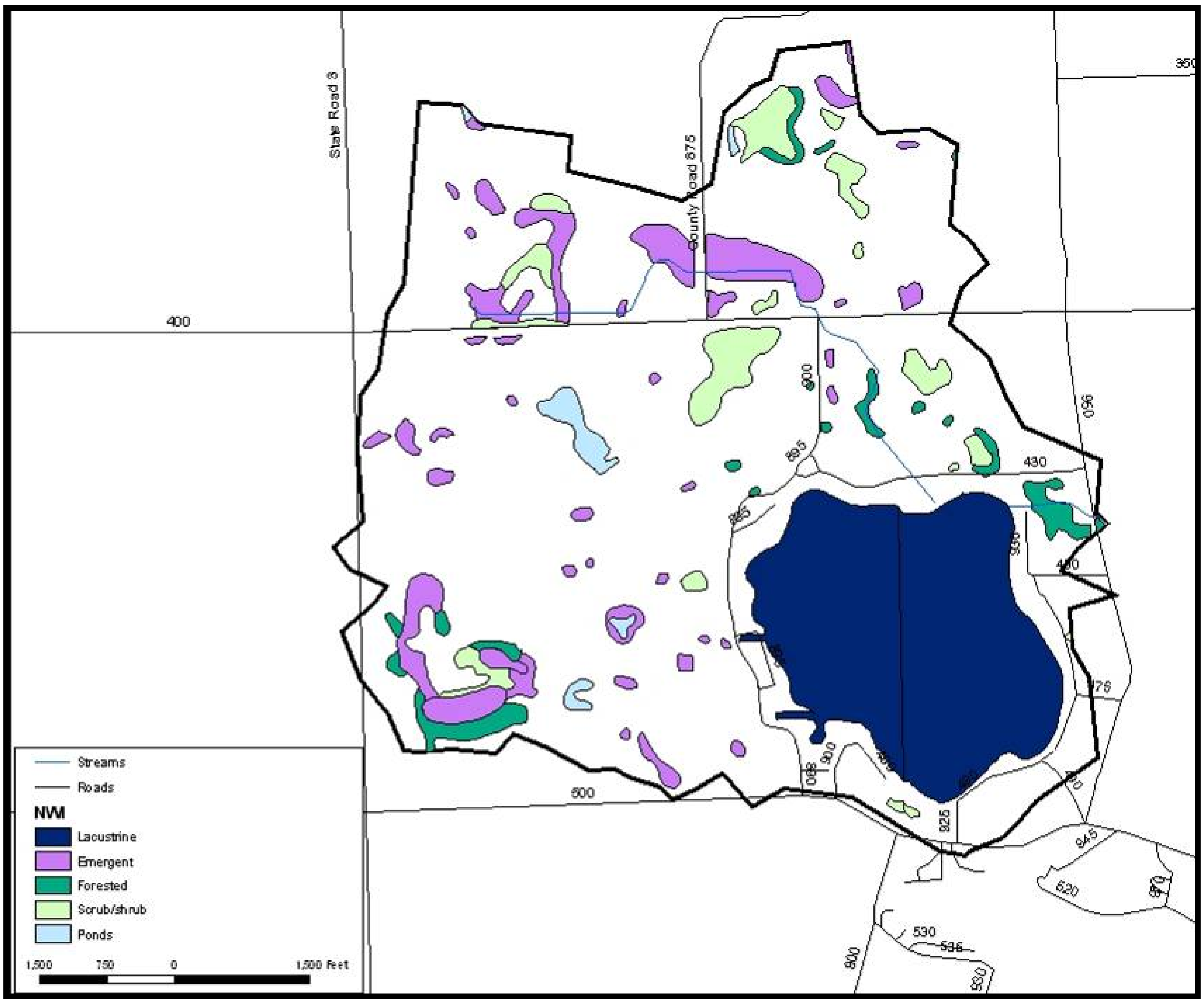

Figure 8. National wetland inventory wetlands in the Pretty Lake watershed.

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

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed
Lacustrine	189.9	76.9	15.4%
Palustrine emergent	68.3	27.7	5.6%
Palustrine forested	24.0	9.7	1.9%
Palustrine scrub/shrub	42.8	17.3	3.5%
Ponds	10.0	4.1	0.8%
Total	**335.1**	**135.7**	**27.2%**

Source: National Wetlands Inventory.

The USFWS NWI data differ in their estimate of wetland habitat acreage in the watershed from the USGS data presented in Table 5 and Figure 7. The USGS Land Cover Data Set suggests that wetlands cover approximately 3.7% of the Pretty Lake watershed and open water covers an additional 15.2% of the watershed (Table 5). The primary difference between the two data sets is the acreage of emergent wetland. The USFWS reports over 68 acres of emergent wetland habitat exists in the Pretty Lake watershed compared to slightly more than 8 acres of emergent wetland habitat reported by the USGS. Additionally, the USFWS reports nearly 68 acres of shrub-scrub and forested wetlands, while the USGS reports only 37.6 acres of woody wetland. The differences in reported wetland acreage in the Pretty Lake watershed reflect the differences in project goals and methodology used by the different agencies to collect land use data.

The U.S. Fish and Wildlife Service estimates an average of 2.6% of the nation's wetlands were lost annually from 1986 to 1997 (Zinn and Copeland, 2005). The IDNR estimates that approximately 85% of the state's wetlands have been filled (IDNR, 1996). The greatest loss has occurred in the northern counties of the state such as Lagrange County. 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. Hamilton (1965) estimated that nearly 71% of the wetlands within the Lake Michigan Basin in Indiana have been lost (cited in EarthSource, 1991).

Development within the Pretty Lake watershed has undoubtedly reduced wetland acreage in the watershed as well. Hydric soil, which formed under wetland conditions, cover nearly the entire length of Deal Ditch, are scattered along the southern watershed boundary, and cover the northeastern shoreline of Pretty Lake (Figure 9). Areas mapped in the wettest of hydric soils, such as Houghton muck, Rensselaer loam, and Wallkill silt loam, have largely remained undeveloped. Overall, hydric soils cover approximately 253 acres (102.3 ha or 20%) of the Pretty Lake watershed. When compared to the acreage of wetland mapped by the USFWS NWI map (145.2 acres or 58.8 ha), more than 57% of wetlands remain in the Pretty Lake watershed.

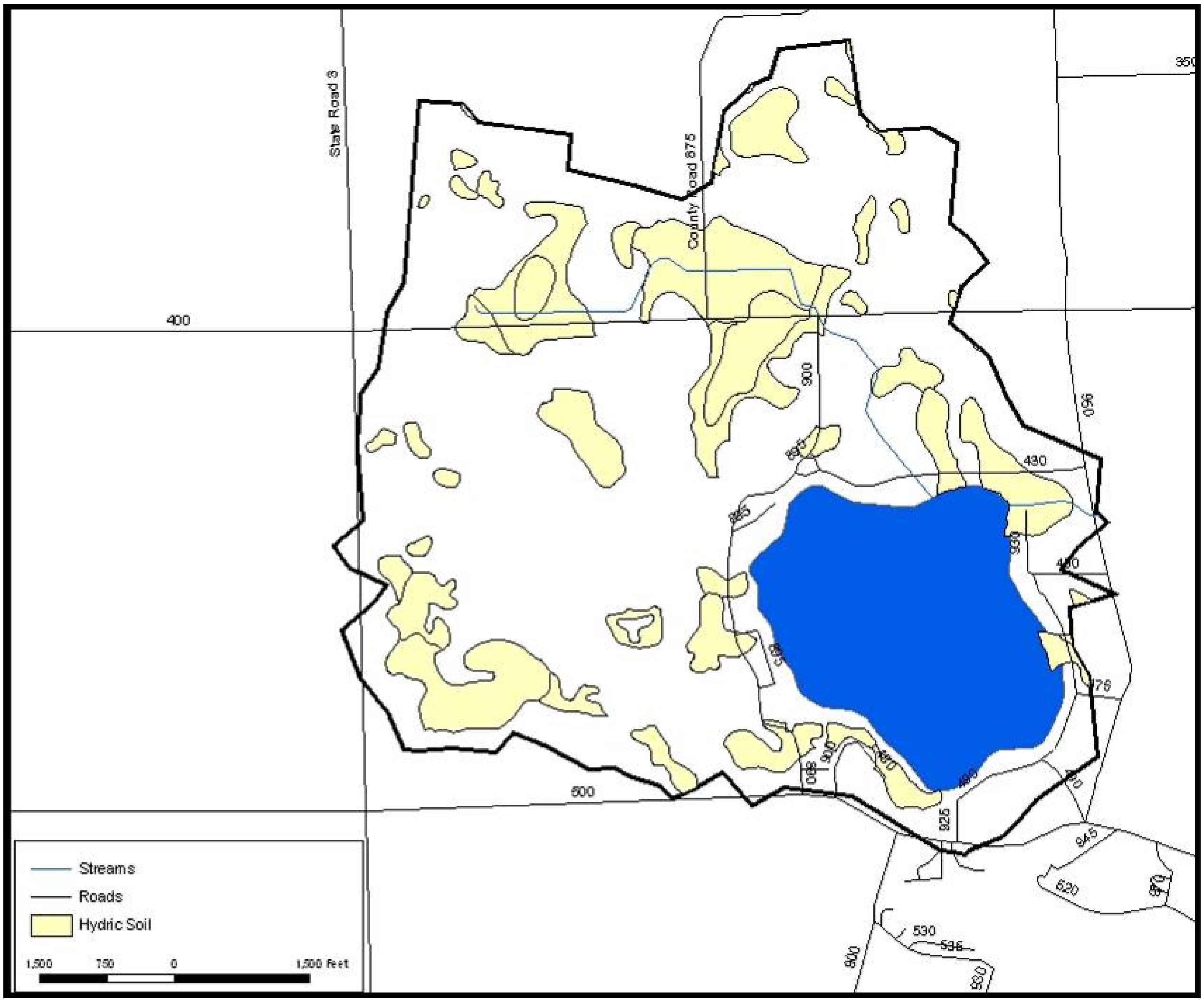

Figure 9. Hydric soils in the Pretty Lake watershed.

2.8 Natural Communities and Endangered, Threatened, and Rare 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 A presents the results from the database search for the Pretty Lake watershed. (For additional reference, Appendix B provides a listing of endangered, threatened, and rare species (ETR) documented in Lagrange County.) No federally listed endangered, threatened, and rare species are known to exist in the watershed. One state protected animal inhabits the Pretty Lake watershed. The state of Indiana uses the following definitions when listing species:

- *Endangered*: Any species whose prospects for survival or recruitment with the state are in immediate jeopardy and are in danger of disappearing from the state. This includes all species classified as endangered by the federal government which occur in Indiana. Plants known to occur currently on five or fewer sites in the state are considered endangered.
- *Threatened*: Any species likely to become endangered within the foreseeable future. This includes all species classified as threatened by the federal government which occur in Indiana. Plants known to occur currently on six to ten sites in the state are considered endangered.
- *Rare*: Plants and insects known to occur currently on from eleven to twenty sites.

The Indiana Natural Heritage Data Center database contains only one record for the area encompassed by the Pretty Lake watershed. In 1983 and 1989, the state non-game protected American badger was found north and west of Pretty Lake.

No other records exist for the Pretty Lake watershed; however, Lagrange County supports a variety of endangered, threatened, and rare animals and plants as detailed by the Indiana Natural Heritage database listing for Lagrange County, which was last updated in 2005. The listed animals include four freshwater mussels (slippershell mussel, snuffbox, ellipse, and rayed bean), three amphibians (northern leopard frog, four-toed salamander, and blue-spotted salamander), four reptiles (spotted turtle, Blanding's turtle, copperbelly water snake, and eastern massasauga), and two fish (cisco and greater redhorse). More than fifty insects, more than twenty-five birds, and six mammals (star-nosed mole, northern river otter, bobcat, least weasel, Indiana bat, and American badger) have been documented in Lagrange County. More than eighty plant species, many of which are hydrophytic (wetland or aquatic species), are also included in the database for Lagrange County. The county also supports fifteen high quality communities.

3.0 STREAM ASSESSMENT

3.1 Stream Assessment Introduction

To better understand the transport of nutrients and other pollutants to Pretty Lake from its watershed, this study included an evaluation of the water quality of Deal Ditch, which is the main inlet stream, and the outlet stream. The water quality evaluation consisted of the collection of water samples from the streams. These samples were analyzed for an array of physical and chemical parameters and results of the analysis were compared to historical data, state standards (if available), and other known measures of stream water quality.

The biological communities of Deal Ditch and the outlet stream were also assessed to supplement the findings from the physical and chemical parameter analysis. A stream's biological communities (fish, macroinvertebrates, and periphyton communities) tend to reflect the stream's long-term water quality. For example, streams that carry significant sediment loads on a regular basis tend to support few or no stoneflies, since stoneflies are sediment-intolerant organisms. Evaluating the biological community characteristics, such as species diversity and composition, helps understand the stream's water quality over a longer term than can be assessed with the collection of only grab samples.

While a stream's biota serve as a useful means for assessing the stream's water quality, it is important to remember that water quality is not the only factor that shapes a stream's biological community. Habitat quality, energy source, flow regime, and biological pressures (predation, parasitism, competition, etc.) also affect a stream's biological community composition (Karr et al., 1986). For example, a stream fish community dominated by very tolerant fish does not necessarily mean the water quality is very poor. Lack of appropriate spawning habitat or changes in the stream's hydrological regime could play a larger role in shaping the stream's fish community than water quality in some instances.

To provide a complete assessment of water quality within the inlet stream, the study included the collection of water chemistry and biological (macroinvertebrate) samples. Water quality samples were collected twice, once during base flow or normal conditions and once following a storm event, at the location indicated in Figure 10. The biological community of Deal Ditch was sampled during base flow conditions as required by standard protocol. Sampling occurred in mid-summer to avoid the May and October macroinvertebrate diversity peaks. The in-stream and riparian habitat along all stream reach was also evaluated to help in isolating which factors are responsible for shaping the creek's biotic communities. The following section outlines the stream sampling methods in greater detail.

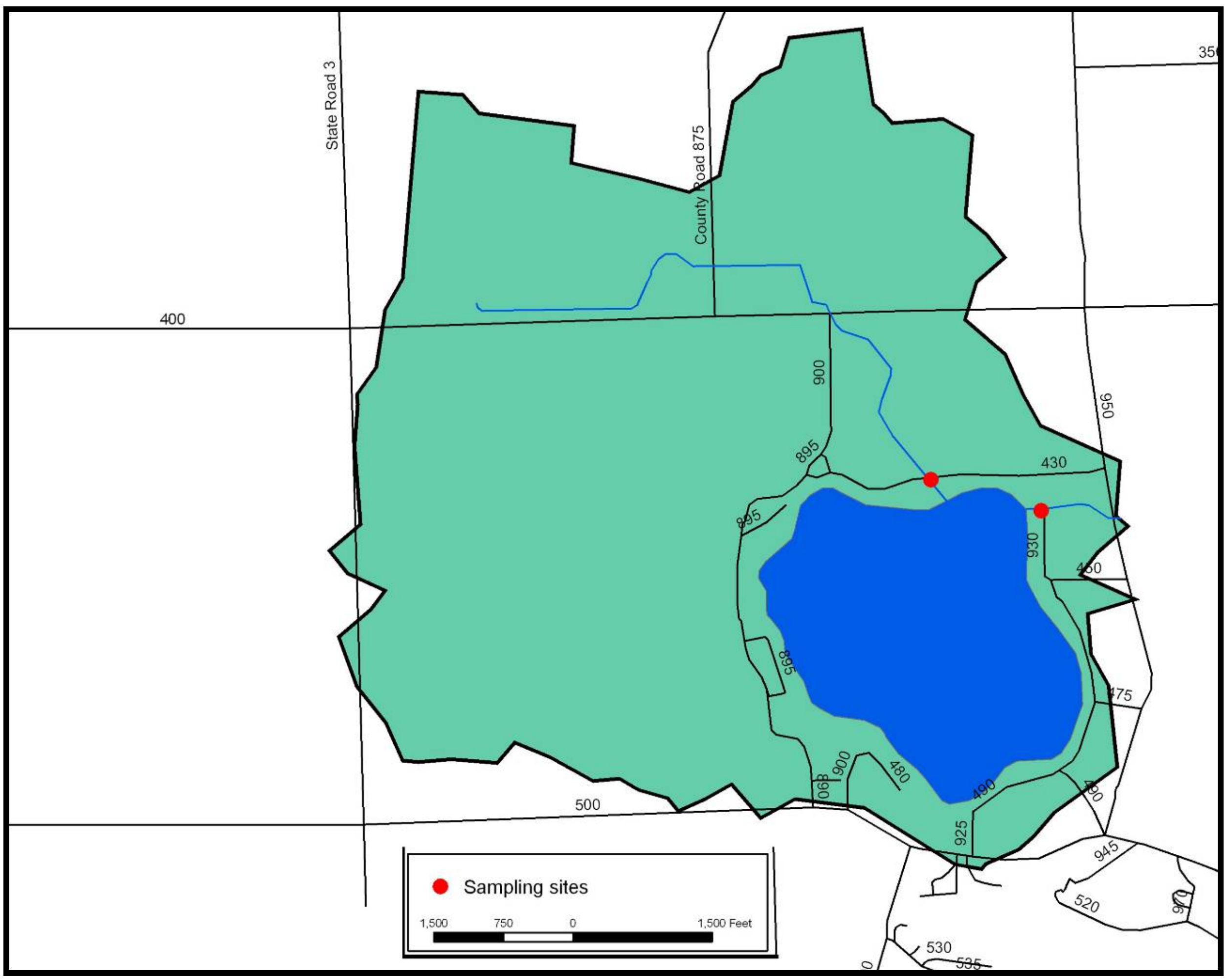

Figure 10. Stream sampling locations.

3.2 Stream Assessment Methods

3.2.1 Water Chemistry

Water samples were collected and analyzed for various parameters from the main inlet (Deal Ditch) and outlet streams within the Pretty Lake watershed (Table 7 and Figure 10). 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 11, 2006, following more than 2 inches (5 cm) of rain. (The Purdue Agricultural Service field gauge at Prairie Heights High School reported 2.5 inches of rain on July 10 and 11, 2005.) Base flow samples were collected on July 27, 2006 following a period of little precipitation.

Table 7. Location of stream sampling sites.

Site	Stream Name	Sampling Location	Latitude	Longitude
1	Deal Ditch	County Road 340 South	N 41° 34.811'	W 85° 14.981'
2	Outlet Stream	County Road 930 East	N 41° 34.754'	W 85° 14.690'

During the current assessment, stream water chemistry samples were analyzed for pH, 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* 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 was measured and discharge calculated by multiplying water velocity by the cross-sectional area.

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). Additional E. coli samples were collected by the Pretty Lake Conservation Club and delivered to Indiana University-Purdue University Fort Wayne for source tracking purposes. The methods of this particular assessment are included with the entire report in Appendix C.

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. Water temperature also governs species composition and activity of aquatic biological communities. 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 according to the time of year. For example, temperatures during the summer months should not exceed 90 °F (32.2 °C).

Dissolved Oxygen (DO). DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3 to 5 mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The Indiana Administrative Code (IAC) sets minimum DO concentrations at 4 mg/L, but all waters must have a daily average of 5 mg/L. DO 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 DO. 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 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 IAC 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. Water's pH 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.

Nutrients. Scientists 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. Scientists commonly measure nutrient concentrations in aquatic ecosystem evaluations to determine the potential for such nuisance growth.

Nutrients themselves, as well as the primary producers (algae and plants) they feed, can also affect the composition of secondary producer communities such as macroinvertebrates and fish. Changes in secondary producer communities can, in turn, impact the way chemical constituents in the water are processed. This is an additional reason for examining nutrient levels in an aquatic ecosystem.

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, 2000b). 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 0.076 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 0.08 mg/L in headwater 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. 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 and have a different criterion.) While the entire length of Deal Ditch within the Pretty Lake watershed may not fit the WWH definition, 0.08 to 0.1 mg/L is a good goal for the streams.

The USEPA sets aggressive nitrogen criteria recommendations for streams compared to the Ohio EPA. The USEPA's recommended criteria for nitrate-nitrogen and total Kjeldahl nitrogen concentrations for streams in Aggregate Nutrient Ecoregion VII are 0.633 mg/L and 0.591 mg/L, respectively (USEPA, 2000b). In contrast, the Ohio EPA suggests using nitrate-nitrogen criteria of 1.0 mg/L in WWH wadeable and headwater streams and MWH headwater streams 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 streams in the Pretty Lake watershed. 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 draft 2006 303(d) list of impaired waterbodies listing criteria indicates that the IDEM will include waterbodies with total phosphorus concentrations greater than 0.3 mg/L on subsequent lists of impaired waterbodies (IDEM, 2006).

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 to 17.5 NTU (Crighton and Hosier, 2004). 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 concentration of *E. coli* 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.

3.2.2 Macroinvertebrates

Aquatic macroinvertebrates are important indicators of environmental change. Numerous studies have shown that different macroinvertebrate orders and families react differently to pollution sources. Additionally, aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995). Thus, a stream's insect community composition provides a long term reflection of the stream's water quality.

To help evaluate the water quality flowing into Pretty Lake, macroinvertebrates were collected during base flow conditions on July 27, 2006 from Deal Ditch and the lake's outlet stream using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). Organisms were identified to the family level. Peckarsky et al., 1990 was used for identification purposes. All nomenclature follows Peckarsky et al. 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; and 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). Voucher specimens are maintained on file in the Indiana University laboratory and were not forwarded to Purdue University.

The benthic community in the streams was evaluated using IDEM's macroinvertebrate Index of Biotic Integrity (mIBI). The mIBI is a multi-metric index that combines several aspects of the benthic community composition. As such, it is 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 8) 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 or family level biotic index; Hilsenhoff, 1988), 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 mIBI at each site was calculated without the protocol dependent metrics of the mIBI (number of individuals and number of individuals to number of squares sorted). (Protocol dependent methods were defined by Steve Newhouse, IDEM, in personal correspondence.) 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 8. 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, the 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 2006 303(d) listing methodology, the IDEM suggests that those waterbodies with mIBI scores less than 1.4 when using the multi-habitat approach are considered non-supporting for aquatic life use. Similarly, waterbodies with mIBI scores greater than 1.4 when assessed using the multi-habitat approach are considered fully supporting for aquatic life use (IDEM, 2006). 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.

3.2.3 Habitat

The physical habitat at the sampling sites for each of the streams 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 rocks (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 rock substrate 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 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 the 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 higher QHEI scores represents more diverse habitat for colonization by macroinvertebrates. Scores below 51 suggest that poor habitat may be limiting biota within the associated stream.

3.3 Stream Assessment Results and Discussion

3.3.1 Water Chemistry

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling of the Pretty Lake watershed streams are presented in Table 9. Stream discharges measured during base and storm flow conditions are shown in Figure 11. As indicated in Table 9 and Figure 11, the lake discharged a larger volume of water during base flow than the volume of water entering the lake during the same time period. This greater discharge out of the lake versus the flow into the lake could be due to the lake releasing water from a previous storm event. Alternately, ground water or springs may be a large source of water to Pretty Lake. Neither of these were measured during this assessment. Stream cross-sections, which were determined while measuring discharge, are shown in Figure 12. The cross sections indicate that all of the stream sites possess extremely straight stream banks as is typical of drainage ditches that have not recovered from channelization and dredging.

Table 9. Physical characteristics of the Pretty Lake watershed streams May 11, 2006 (storm flow) and July 27, 2006 (base flow).

Site	Date	Timing	Flow (cfs)	Temp (°C)	DO (mg/L)	% Sat.	Cond (μmhos)	pH	Alk (mg/L)	TSS (mg/L)
Deal Ditch (1)	5/11/06	Storm	1.18	11.8	8.0	74.6	575	7.6	214	12.22
	7/27/06	Base	0.50	19.3	7.2	75.4	648	--	--	1.83
Outlet (2)	5/11/06	Storm	1.17	13.7	6.5	63.5	418	7.6	152	3.63
	7/27/06	Base	1.58	26.2	8.3	102	376	--	--	1.26

IAC Standards: DO > 5mg/L; Temperature: < 26.7° C (May), < 32.2° C (July); 6<pH<9; Conductivity < 1050

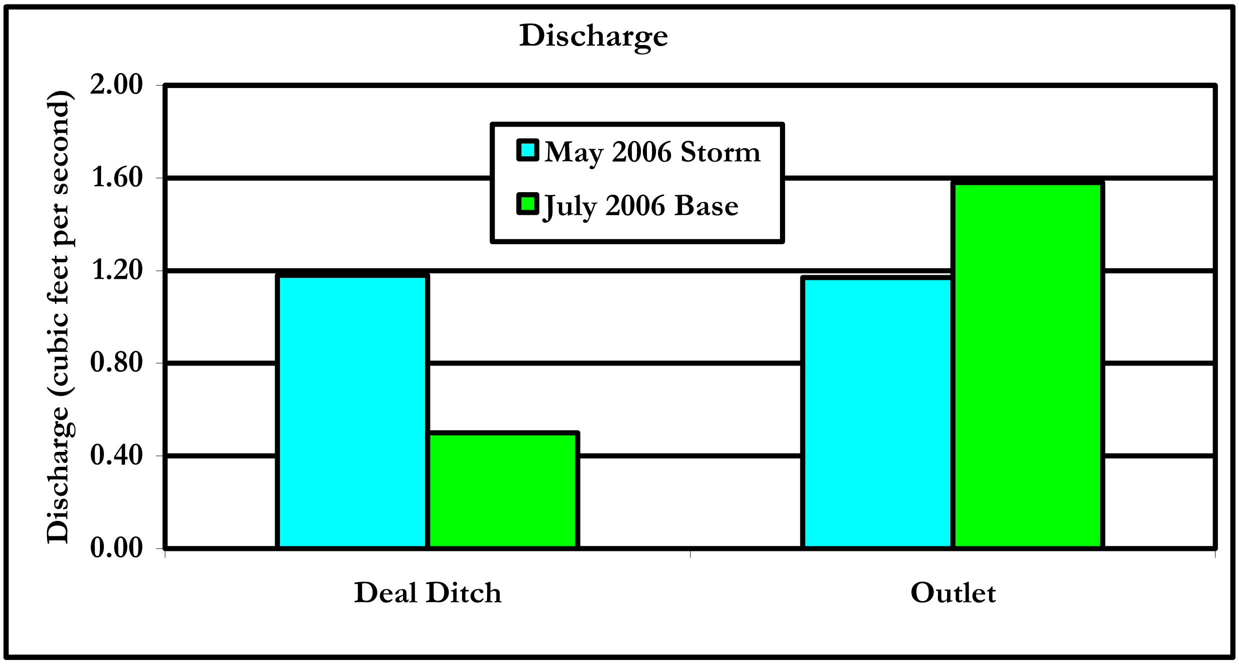

Figure 11. Discharge measurements during base flow and storm flow sampling of Pretty Lake watershed streams.

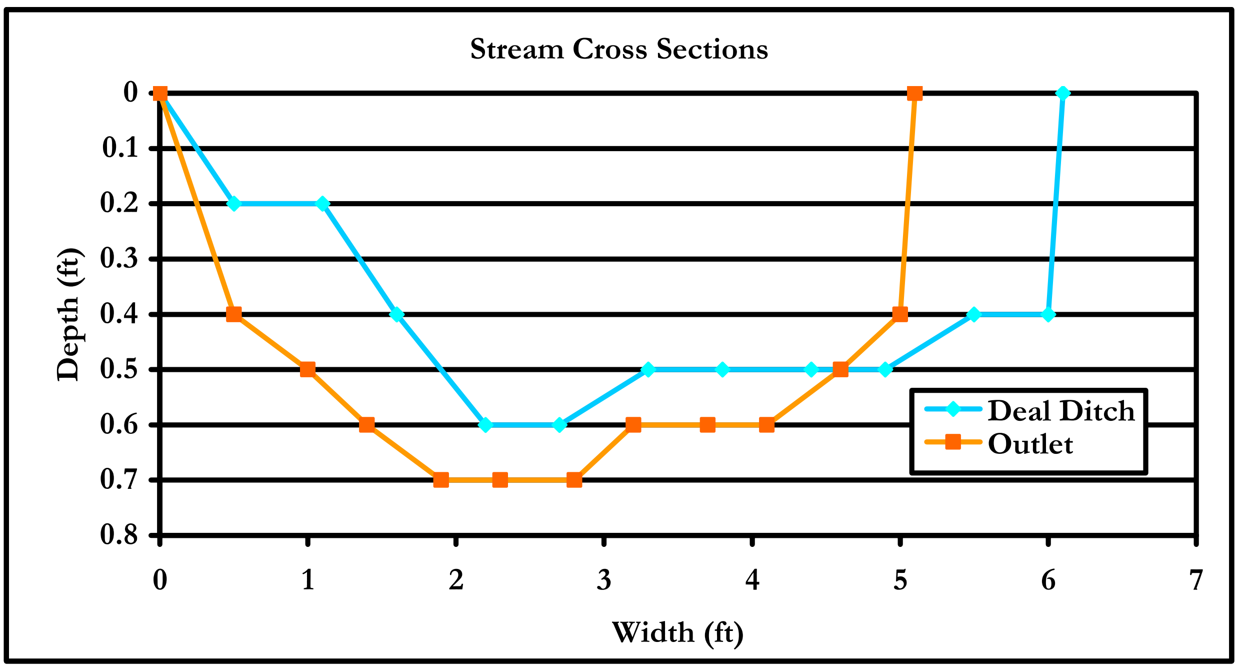

Figure 12. Physical dimensions at the sampling locations of Pretty Lake watershed streams.

Alkalinity, pH, and conductivity values were within normal ranges for Indiana streams. Alkalinity concentrations were typical of well-buffered streams, suggesting the presence of carbonates and other alkalinity-producing materials in the watershed's bedrock. Alkalinity ranged from 152 mg/L in the outlet stream during storm flow conditions to 214 mg/L in Deal Ditch during storm flow. No base flow measurements were collected for alkalinity. The watershed streams' pH values were somewhat alkaline measuring 7.6 at both sites during storm flow. All of the pH values were within the range that is appropriate for supporting aquatic life. Conductivity values ranged from 376 μmhos in the outlet stream during base flow conditions to 648 μmhos in Deal Ditch during base flow. Conductivity measurements were higher in Deal Ditch during both assessments than concentrations measured in the lake's outlet stream. None of the conductivity values exceeded the Indiana state water quality standard.

Water temperatures in the Pretty Lake watershed streams varied slightly between storm and base flow sampling events. Generally, stream temperatures in Deal Ditch were lower than those measured in the outlet stream. These lower temperatures present in Deal Ditch reflect the influence of groundwater, which is typically cooler than surface water, in maintaining flow within Deal Ditch. In contrast, most of the water flowing through the outlet stream originates from surface water from Pretty Lake itself. None of the observed water temperatures exceeded the Indiana Administrative Code standard for the protection of aquatic life.

Base flow dissolved oxygen concentrations in the Pretty Lake watershed streams ranged from 6.5 mg/L in the outlet stream during storm flow to 8.0 mg/L in the outlet stream during base flow. All of the streams during both base and storm flow sampling events possessed dissolved oxygen levels above the minimum IAC level of 5 mg/L set to protect aquatic life. DO saturation refers to the amount of oxygen dissolved in water compared to the total amount possible when equilibrium between the stream water and the atmosphere is maximized. When a stream is less than 100% saturated with oxygen, decomposition processes within the stream may be consuming oxygen more quickly than it can be replaced and/or flow in the stream is not turbulent enough to entrain sufficient oxygen. In the case of the Pretty Lake watershed streams, both streams experienced low saturations levels during the storm flow sampling event, while Deal Ditch's saturation was low during base flow as well. None of these saturations levels were low enough to warrant concern over low oxygen levels.

Both Deal Ditch and the outlet stream possessed relatively low total suspended solids concentrations during base and storm flow events. During the storm flow sampling event, Deal Ditch exhibited a TSS concentration more than four times greater than its base flow concentration (Figure 13). Storm flow TSS concentrations are typically higher than base flow TSS concentrations since during storm events, soil and other particles erode from the watershed and are transported to streams in overland flow. Additionally, storm flows scour stream beds and banks releasing sediment into the water.

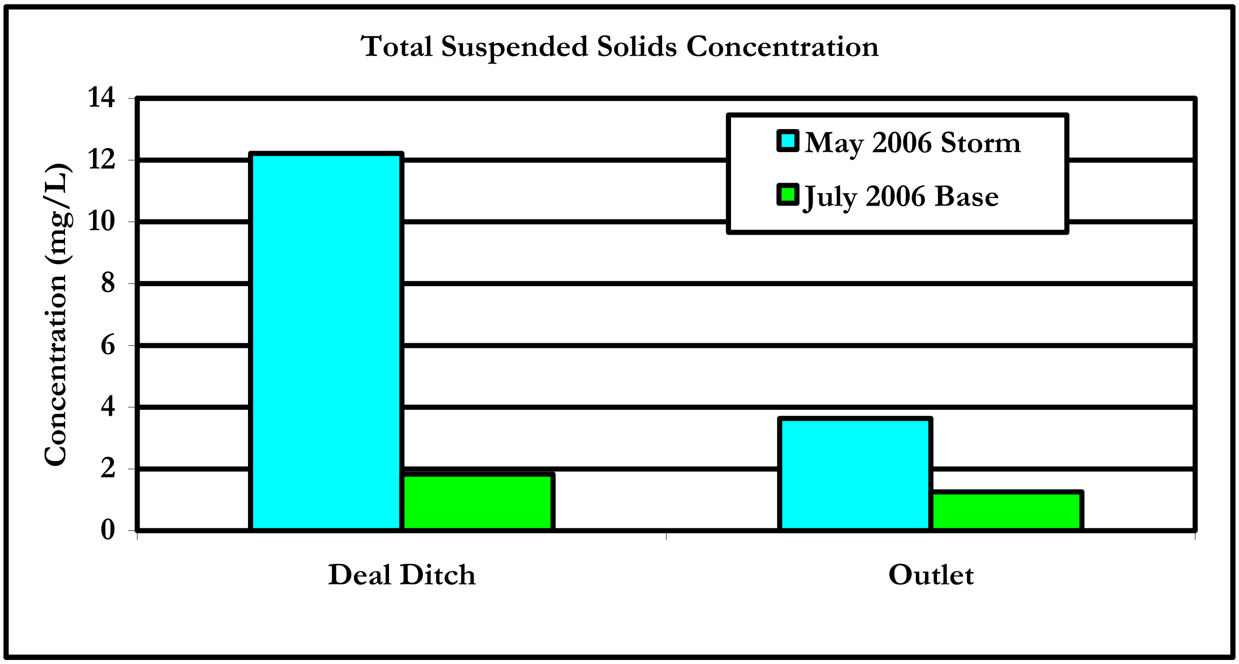

Figure 13. Total suspended solids measurements in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

Chemical and Bacterial Characteristics

The chemical and bacterial characteristics of the Pretty Lake watershed streams during base and storm flow conditions are shown in Table 10. 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 in the Pretty Lake streams exceeded most of these median concentrations. All other parameters that are in excess of the median concentrations occur by less than an order of magnitude.

Table 10. Chemical and bacterial characteristics of the Pretty Lake watershed streams on July 27, 2006 (base flow) and August 11, 2006 (storm flow).

Site	Date	Timing	Nitrate (mg/L)	Ammonia (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	*E. coli* (#/100mL)
Deal Ditch (1)	5/11/06	Storm	1.521	0.100	2.147	0.029	0.146	1,240
	5/11/06	Base	1.235	0.091	1.117	0.043	0.076	890
Outlet (2)	7/27/06	Storm	0.013*	0.018*	0.777	0.023	0.055	520
	7/27/06	Base	0.020	0.018*	0.703	0.010	0.024	950

*Method detection level. IAC Standards: NO_3 < 10 mg/L; NH_3-temp & pH dependent; *E. coli* < 235.

Nitrate-nitrogen concentrations in Deal Ditch were elevated for Indiana streams; however, concentrations in the outlet stream were relatively low (Figure 14). Concentrations ranged from below the detection limit (0.013 mg/L) to 0.020 mg/L in the outlet stream and from 1.2 mg/L to 1.5 mg/L during base and storm flow, respectively within Deal Ditch. Deal Ditch possessed nitrate-nitrogen concentrations in excess of the productive to highly-productive threshold (1.5 mg/L) identified by Dodd et al. (1998). However, it did not exhibit nitrate-nitrogen concentrations above the level recommended by the Ohio EPA (1.6 mg/L) for the protection of aquatic biota in a modified warmwater habitat stream.

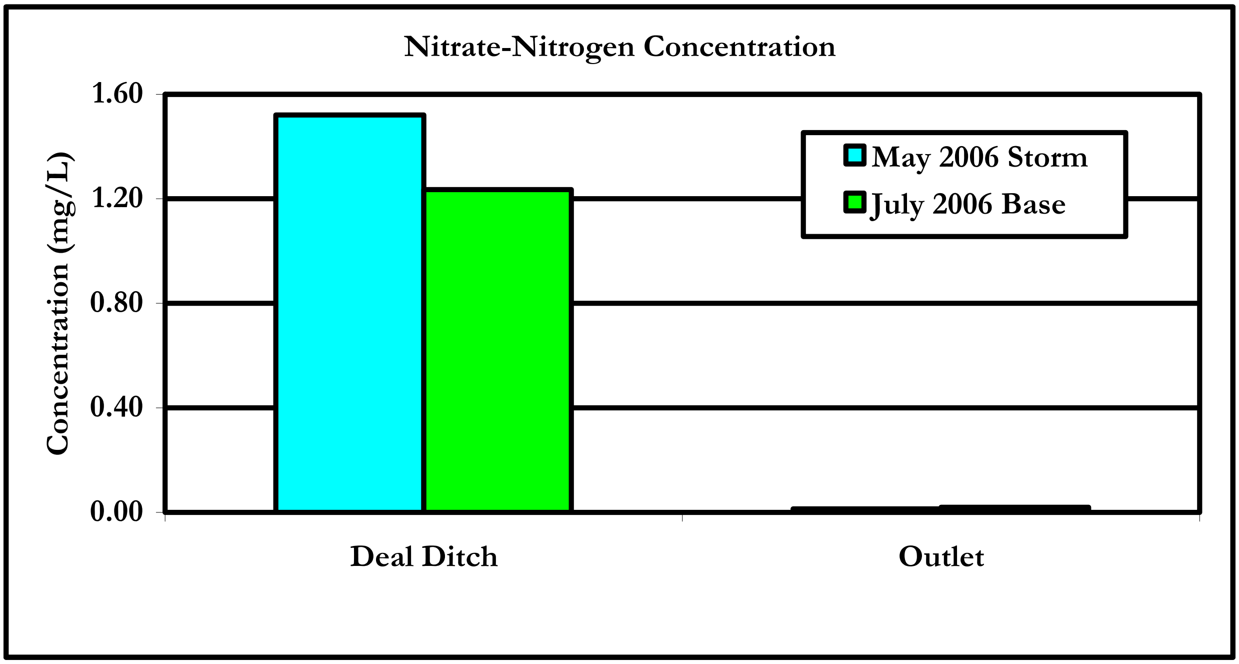

Figure 14. Nitrate-nitrogen concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow). Detection limit is 0.013 mg/L.

Like nitrate-nitrogen, ammonia-nitrogen concentrations were below the detection level in the outlet stream. Concentrations within Deal Ditch were somewhat elevated during both the base and storm flow assessment (0.091 mg/L and 0.100 mg/L, respectively; Figure 15). Ammonia is a by-product of decomposition and therefore streams with high levels of organic material, like Deal Ditch, are expected to have higher ammonia concentrations. Deal Ditch also possessed high total phosphorus and total Kjeldahl nitrogen concentrations (Figure 16) during the same sampling event that they registered elevated high ammonia concentrations, especially during the storm event. High total phosphorus concentrations are indicative of high levels of organic matter. Deal Ditch's substrate is composed largely of muck and silty organic matter, so the high ammonia concentration in that stream is not surprising. Relatively high TKN concentrations were also observed in Deal Ditch during both base and storm flow conditions. 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 existed within Deal Ditch resulting in nearly a storm flow concentration nearly double that observed during base flow. Both the inlet and outlet streams possessed TKN concentrations greater than the target concentration of 0.591 mg/L recommended by the USEPA (2000b). TKN and ammonia-nitrogen concentrations were much lower in the outlet stream than the concentrations measured in the inlet stream. There are several plausible explanations for this occurrence including the fact that Deal Ditch is likely closer to the source of the organic nitrogen than the outlet stream. Additionally in lake systems, ammonia-nitrogen is typically converted to nitrate-nitrogen via oxidation. This would result in lower ammonia-nitrogen and TKN concentrations in the lake and therefore in the lake's outlet compared to its inlet.

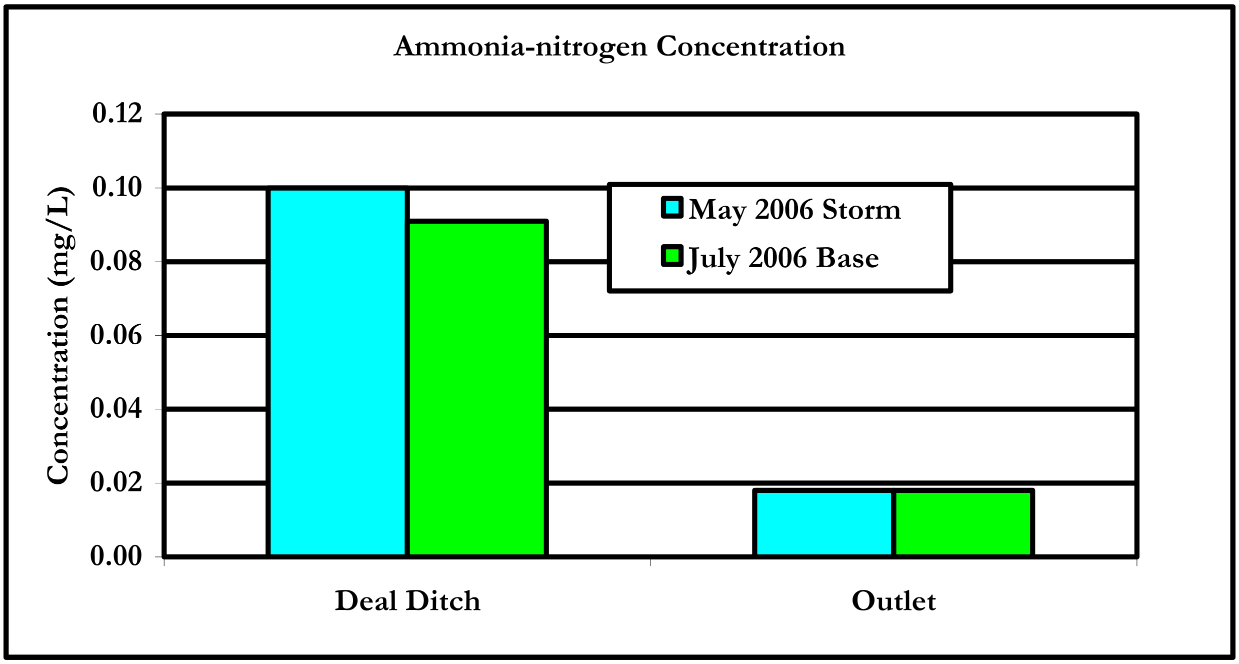

Figure 15. Ammonia-nitrogen concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

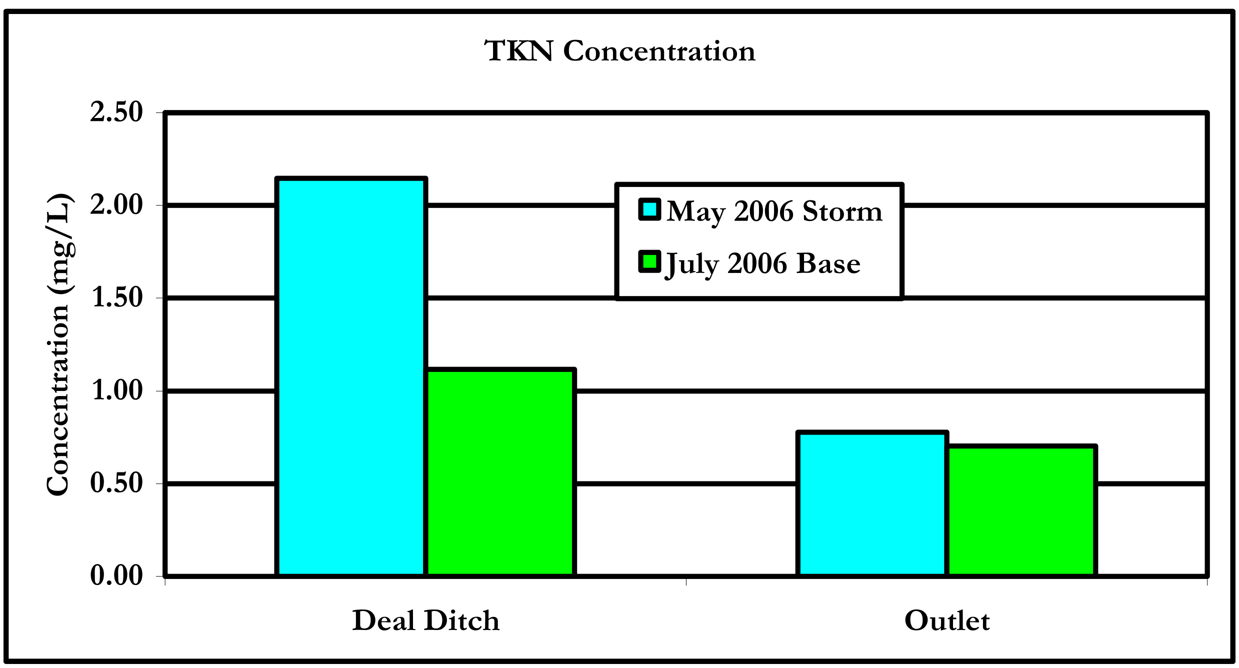

Figure 16. Total Kjeldahl nitrogen concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

Soluble reactive phosphorus (SRP) is the dissolved component of total phosphorus. Understanding what portion of the total phosphorus concentration is dissolved aids in directing management efforts. Dissolved phosphorus usually comes from fertilizer and waste (wildlife and human). Chemical reactions within the stream can also contribute to the dissolved phosphorus levels in the stream. SRP concentrations in the Pretty Lake watershed streams were higher than desired for headwater streams (Figure 17). SRP concentrations in the Pretty Lake watershed streams ranged from 0.010 mg/L in the outlet stream during base flow to 0.043 mg/L in Deal Ditch during base flow. Even though concentrations within Deal Ditch are higher than optimal, SRP concentrations measured at these sites did not exceed the phosphorus concentration (0.1 mg/L) recommended by the Ohio EPA for the protection of aquatic biota. However, elevated *E. coli* concentrations observed at these sites suggests that waste (wildlife and/or human) may be increasing the SRP concentrations in these streams. Management efforts should focus on reducing the waste reaching these streams. Nutrient (fertilizer) management should also be a priority on agricultural and residential land in these subwatersheds.

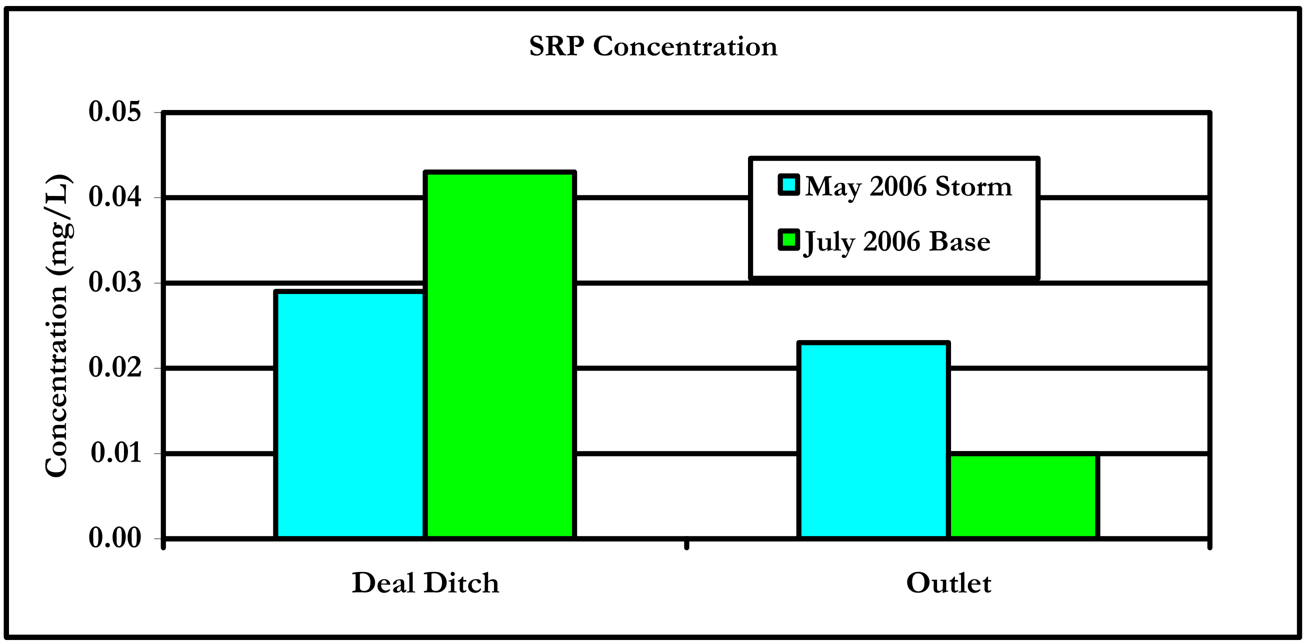

Figure 17. Soluble reactive phosphorus concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

Like the TKN levels, total phosphorus concentrations in the Pretty Lake watershed streams were high for northern Indiana streams (Figure 18). Total phosphorus concentrations ranged from 0.024 mg/L in the outlet stream during base flow to 0.146 mg/L in Deal Ditch during storm flow. Based on the elevated total phosphorus concentration present in Deal Ditch, this stream is a fairly productive stream. Furthermore, this high productivity has the potential to impair the streams' biotic communities. Deal Ditch possessed base and storm flow total phosphorus concentrations that would place the streams in the eutrophic, or highly productive, category using Dodd et al.'s (1998) criteria. Total phosphorus concentrations in Deal Ditch under base and storm flow conditions exceeded the USEPA recommended target criterion of 0.076 mg/L (USEPA, 2000b). Similarly, total phosphorus concentrations in Deal Ditch during storm flow exceeded the Ohio EPA's recommended total phosphorus criterion to protect aquatic life (0.1 mg/L) in wadeable warmwater habitat streams (Ohio EPA, 1999). The high total phosphorus concentration observed in Deal Ditch may be impairing the stream's biotic communities.

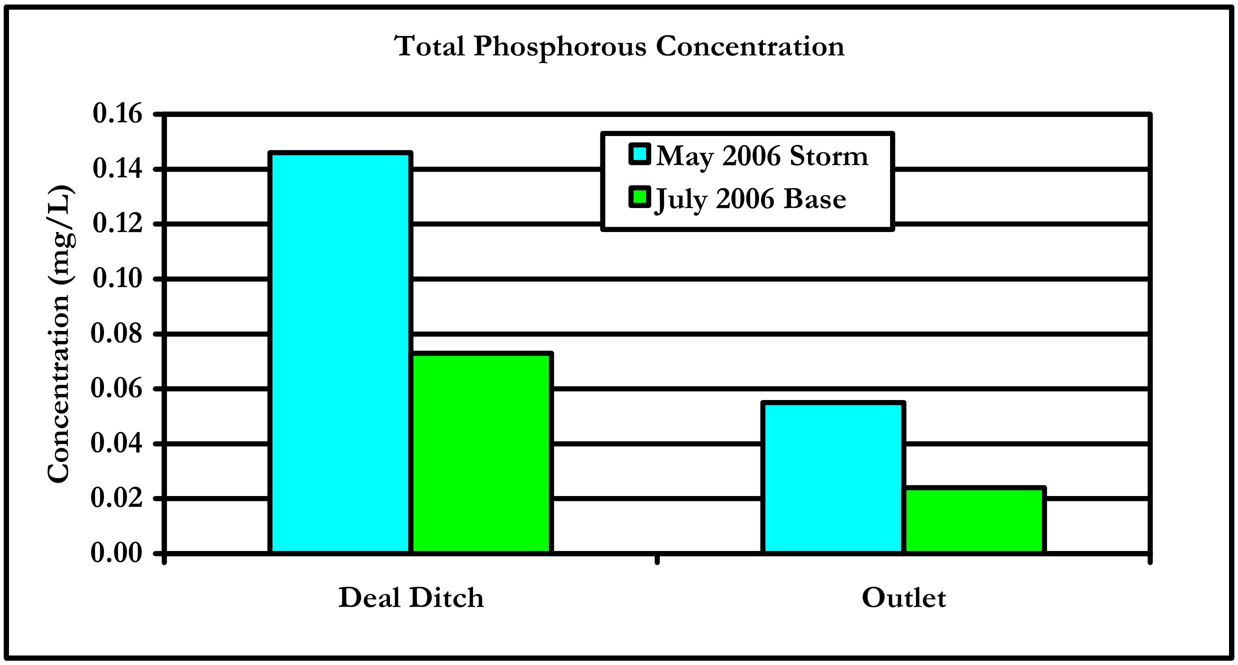

Figure 18. Total phosphorus concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow). Detection limit is 0.010 mg/L.

E. coli concentrations in the Pretty Lake watershed streams were elevated, but are relatively normal when compared with concentrations measured in other Indiana streams. All of the concentrations measured in the Pretty Lake watershed streams contained *E. coli* concentrations that violated state water quality standards (Figure 19). In addition to violating the state standard, *E. coli* concentrations during three of the four sampling events (base at Deal Ditch and storm at both sites) were above the average *E. coli* concentration of 650 col/100mL found in Indiana waters (White, unpublished data). *E. coli* concentrations in the Pretty Lake watershed streams ranged from 520 col/100mL in the outlet stream during storm flow and 1240 col/100 mL during storm flow in Deal Ditch. Because *E. coli* is killed by UV light, it is not unusual to observe low *E. coli* concentration downstream of lakes, particularly under normal or base flow conditions. Water in lakes is exposed to light for a prolonged period. This phenomenon is exhibited in part in the outlet stream: concentrations are lower here than in Deal Ditch. However, concentrations still exceed the Indiana state standard.

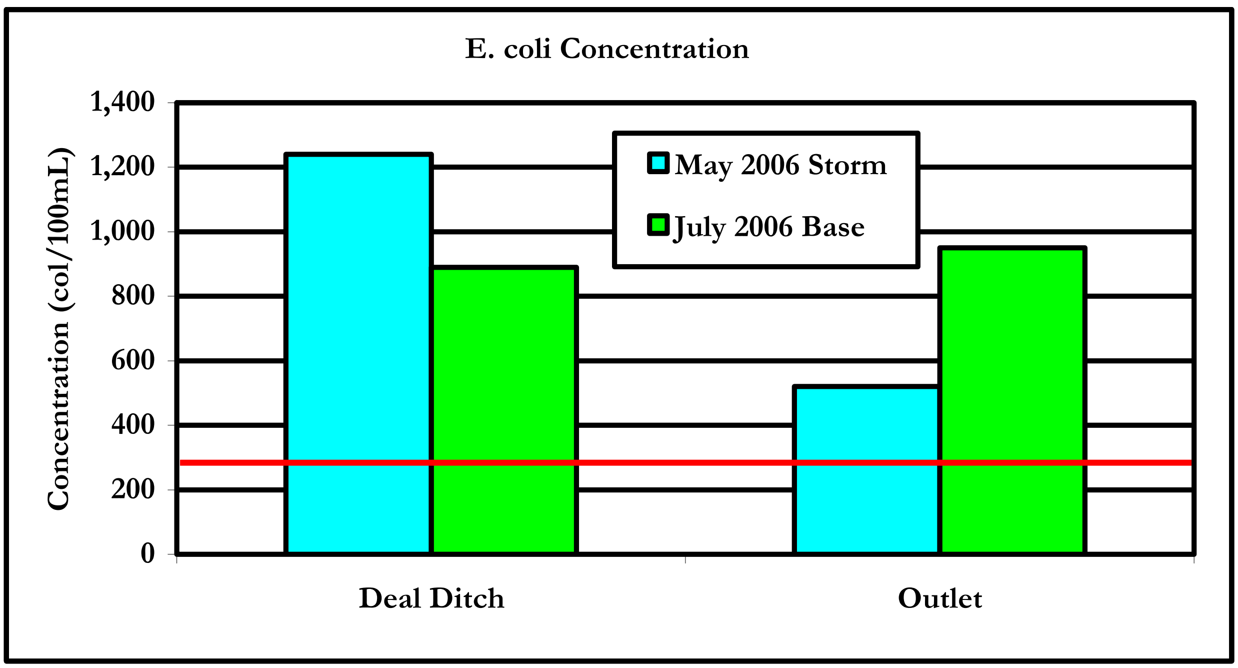

Figure 19. *E. coli* concentrations in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow). The red line indicates the Indiana state standard (235 colonies/100 mL).

This data corresponds with data historically collected in the watershed by the Pretty Lake Conservation Club. The PLCC collected *E. coli* samples from ten locations throughout the watershed from 1997 to 2006 (Figure 20). Table 11 details the sampling locations; resultant concentrations; and minimum, median, and maximum concentrations within the watershed sampling sites. Median concentrations measured at all but two of the sites exceeded the state standard (235 col/100 mL). Maximum concentrations exceeded the state standard at each of the ten sites ranging from 900 col/100 mL at Site 12 (the outlet) to 60,000 col/100 mL at Site 11 (the inlet tile adjacent to the boat ramp in 2002. Issues at this site have been addressed since the 2002 assessment. The resultant decline in *E. coli* concentration details this change in watershed land practices. Concentrations ranged from 10 to 100 col/100 mL during all assessments at this site since 2002.

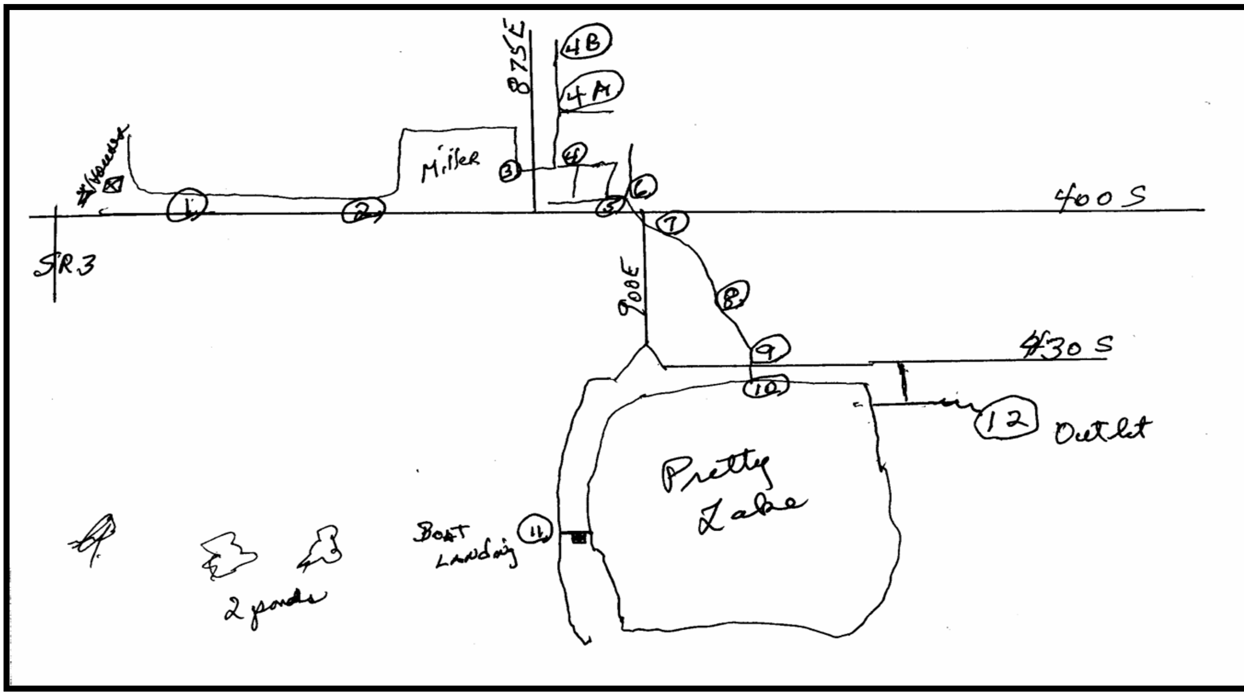

Figure 20. Locations where *E. coli* samples have historically been collected within the Pretty Lake watershed.

Table 11. *E. coli* concentrations measured in watershed streams by the Pretty Lake Conservation Club from 1997 to 2006.

Date	1	2	3	4	5	6	7	10	11	12
6/5/97	--	130	700	--	--	--	--	210	20	--
8/22/97	--	240	260	--	--	--	--	100	1,130	--
7/7/98	--	239	698	--	--	--	--	341	350	--
10/17/98	--	20	380	--	--	--	--	38,000	20	--
6/12/00	600	10	--	3,000	--	--	--	--	60,000	--
6/26/00	11,000	60	--	1,000	--	--	--	--	13,000	--
7/11/00	1,000	60	--	2,000	--	--	--	--	100	--
6/14/01	--	<1,000	--	<1,000	--	--	--	1,390	<10	--
5/28/02	--	130	--	80	--	--	90	50	10	--
5/28/02	--	130	--	80	--	--	90	50	10	--
10/10/02	--	190	--	190	--	--	1,000	1,000	10	--
6/27/03	--	--	--	>1,000	>1,000	--	--	1,000	140	900
7/12/03	--	--	--	>1,000	1,000	--	--	950	--	460
3/16/06	--	2,500	3,600	--	--	--	900	1,400	--	--
minimum	600	10	260	80	1,000	1,000	90	50	20	460
median	1,000	130	698	595	1,000	1,000	495	950	100	680
maximum	11,000	2,500	3,600	3,000	1,000	1,000	1,000	38,000	60,000	900

In order to identify sources of *E. coli* within the watershed streams, a series of five samples were collected in sterile containers and delivered to Indiana University-Purdue University. (Details of analytical methods are detailed in Appendix C.) Samples were collected from five locations along the length of Deal Ditch including: upstream of a hog farm on CR 400 South (Site 2), downstream of a hog farm on CR 400 South (Site 3), within the stream south of CR 400 South (Site 7), within the natural area between CR 400 and 430 South (Site 8), and at CR 430 South (Site 9). Sample sites correspond with historical *E. coli* sampling sites utilized by the Pretty Lake Conservation Club. These samples were analyzed to determine their antibiotic resistance to a series of antibiotics including tetracycline, amoxicillin, streptomycin, and others. As livestock, swine, pets, wildlife, human, and horses all react differently to antibiotics, *E. coli* from these sources also react differently. There is, however, some overlap between human and horse antibiotic resistance patterns which makes source determination a bit more difficult in the case of these two species. Based on discussions with watershed stakeholders regarding the limited horse population present within the watershed, all horse sources were reclassified to human sources.

Based on the above stated data transformation, humans account for the largest percentage of *E. coli* present within the samples (Figure 21). Swine antibiotic resistance patterns are present at Site 3 (downstream of the hog farm north of CR 400 South). Pets account for more than 10% of the population at all sites except Site 8 (natural area). Additionally, fecal enterococci, or bacteria that are typically present in the intestine of warm-blooded mammals, were tabulated during this assessment. Concentrations ranged from 220 col/100 mL at Site 7 (downstream of CR 400 South) to 2,920 col/100 mL at Site 3 (downstream of farm). Fecal enterococci cannot be substituted for *E. coli*. They are, however, indicative of relative levels of fecal contamination with Sites 3, 8, and 9 possessing the highest concentrations (Ross, 2006).

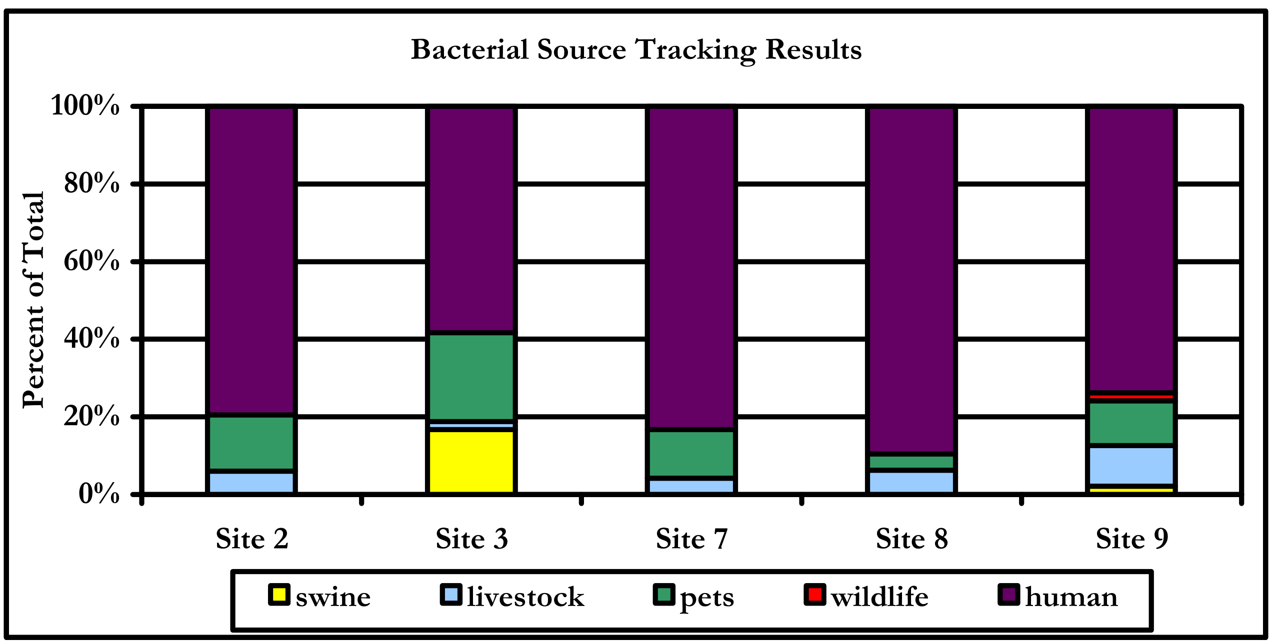

Figure 21. *E. coli* source tracking determination for the five samples collected from Pretty Lake watershed streams July 10, 2006.

Chemical and Sediment Loading

While pollutant concentration data provides an understanding of the water quality at a given time and the conditions to which stream biota are subjected, pollutant loading data provides an understanding of how much actual pollutant (mass) is delivered to a downstream waterbody per unit of time. For example, an inlet stream that has high pollutant concentrations does not necessarily contribute the greatest amount of pollutants to its downstream lake. If the inlet stream possesses a very low discharge (i.e. water flow), it likely does not transport as much pollution to the lake as other inlets to the lake that have higher discharge levels might. Thus, is it important to evaluate inlet streams' pollutant loading rates to fully understand which inlet is contributing the greatest amount of pollutants to a lake. This information is essential to prioritizing watershed management.

Table 12 lists the chemical and sediment loading data for the Pretty Lake watershed sites. Figures 22 to 27 present mass loading information graphically. As expected, the nutrient and sediment loading rates entering the lake exceed those rates exiting the lake. Additionally, loading rates were typically higher during storm flow than during base flow conditions. This is to be expected as both concentrations and water volume typically increase as overland flow increases.

Table 12. Chemical and sediment load characteristics of the Pretty Lake watershed streams on July 27, 2006 (base flow) and May 11, 2006 (storm flow).

Site	Date	Timing	Nitrate Load (kg/d)	Ammonia Load (kg/d)	TKN Load (kg/d)	SRP Load (kg/d)	TP Load (kg/d)	TSS Load (kg/d)
Deal Ditch (1)	5/11/06	Storm	4.39	0.29	6.19	0.08	0.42	35.26
	5/11/06	Base	1.51	0.11	1.37	0.05	0.09	2.24
Outlet (2)	7/27/06	Storm	0.04	0.05	2.22	0.07	0.16	10.38
	7/27/06	Base	0.08	0.07	2.72	0.04	0.09	4.85

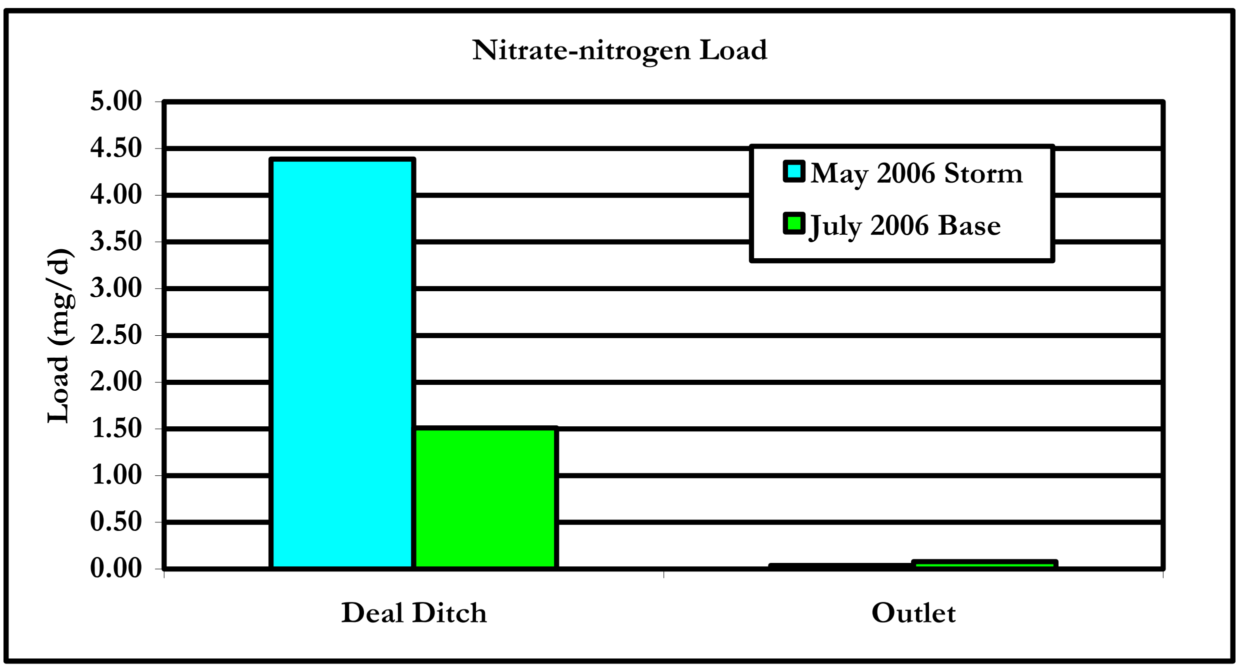

Figure 22. Nitrate-nitrogen loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

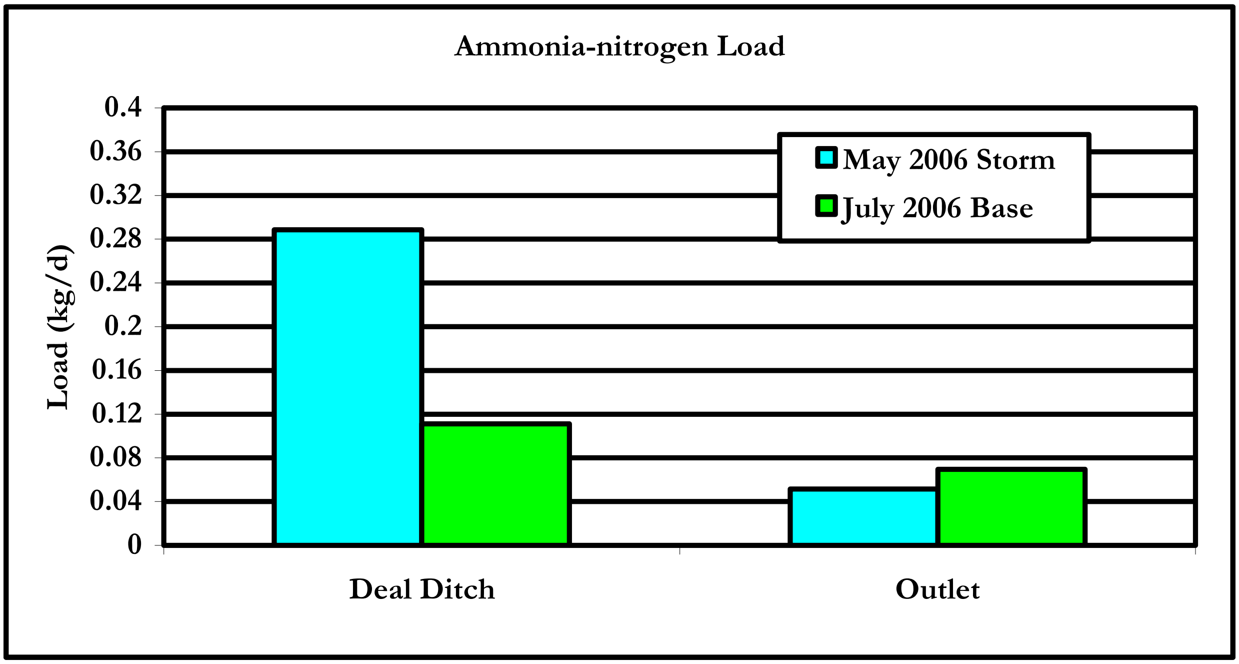

Figure 23. Ammonia-nitrogen loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

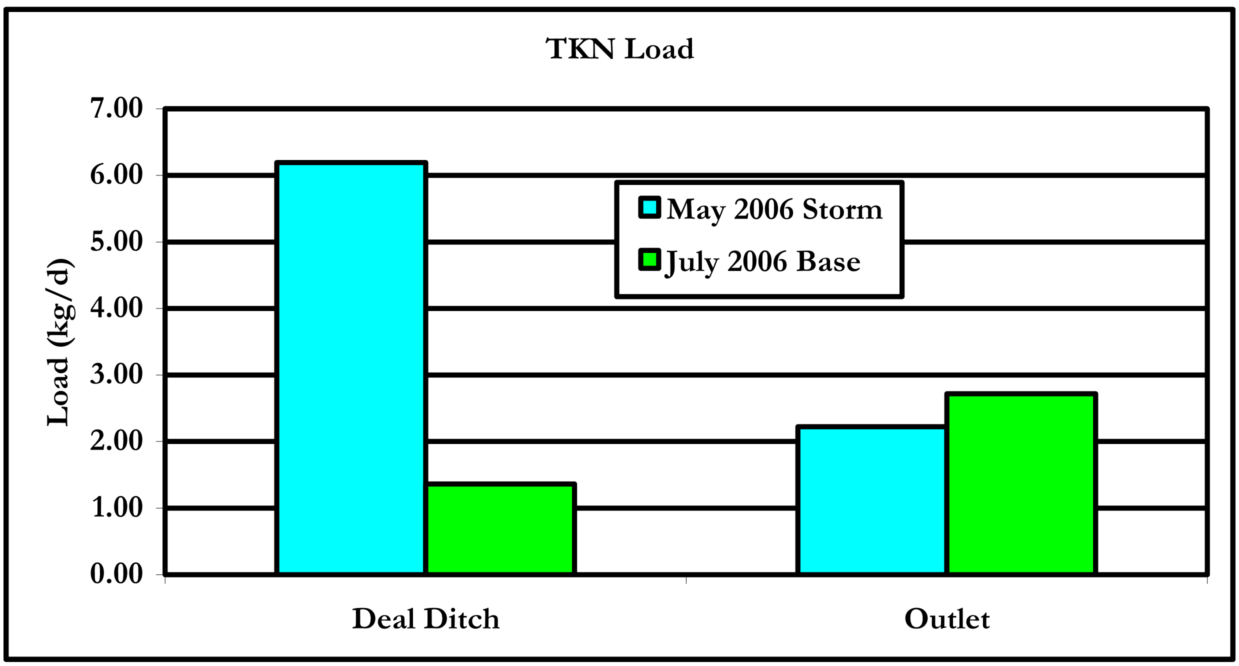

Figure 24. Total Kjeldahl nitrogen loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

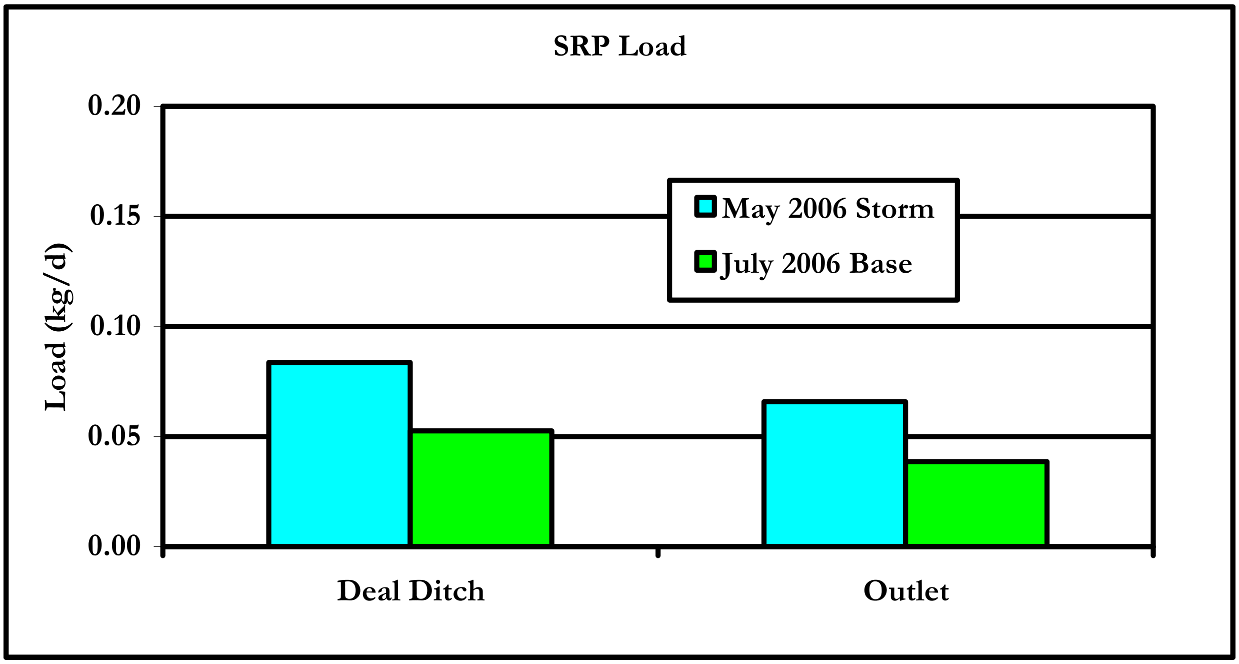

Figure 25. Soluble reactive phosphorus loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

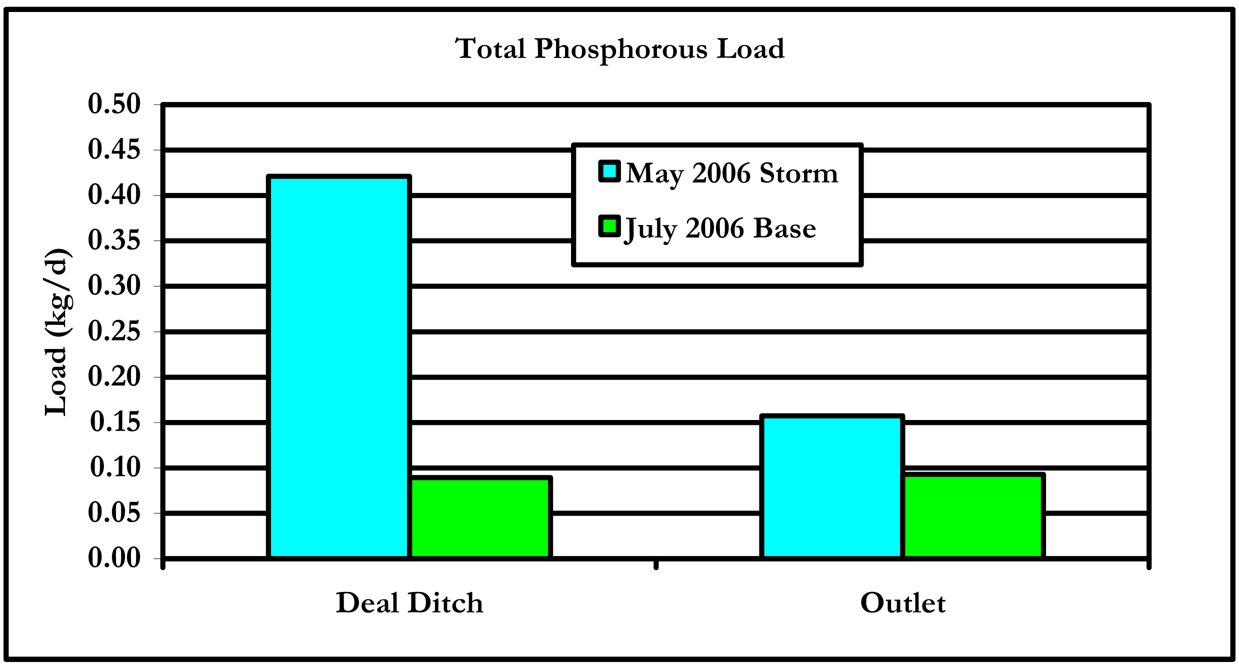

Figure 26. Total phosphorus loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

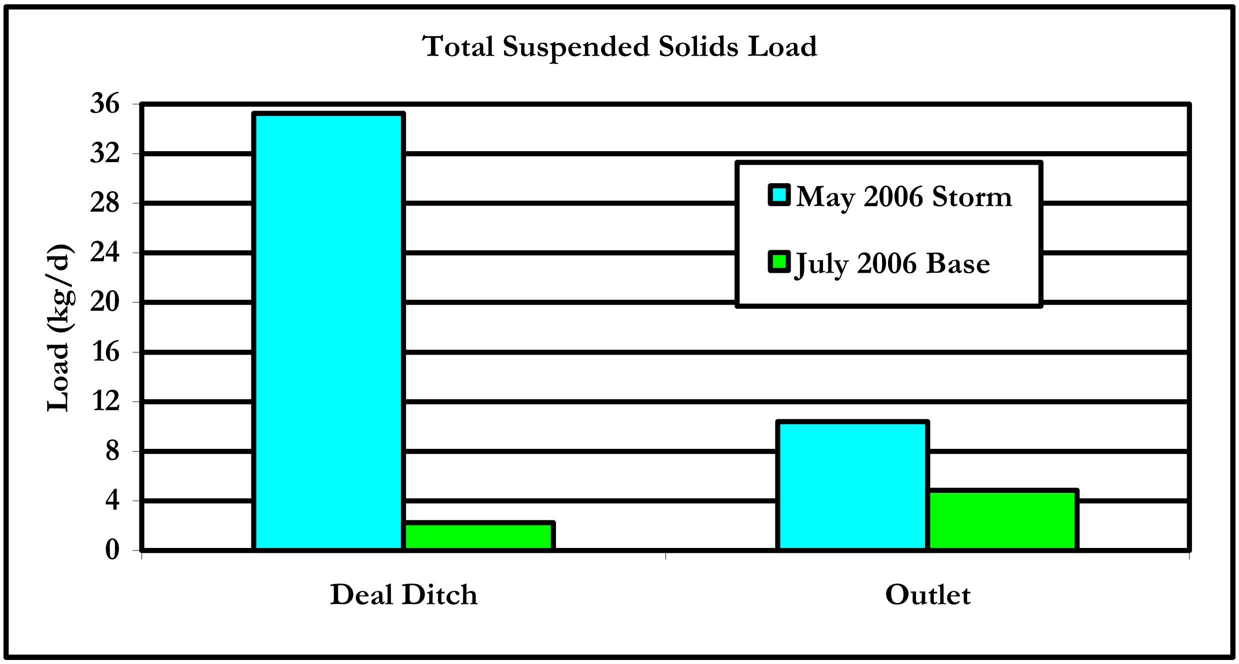

Figure 27. Total suspended solids loads in Pretty Lake watershed streams as sampled July 27, 2006 (base flow) and May 11, 2006 (storm flow).

3.3.2 Macroinvertebrates

Table 13 presents the results of the macroinvertebrate sampling of Deal Ditch, while Table 14 details macroinvertebrate sampling results for the lake's outlet stream. (Appendix D includes a complete list of macroinvertebrates found in Deal Ditch and the outlet stream.) Overall, Deal Ditch possessed an mIBI score of 3.3 suggesting that the stream's biotic community is moderately impaired. The stream supports average species richness and the dominant taxa accounts for 35% of the community composition. Many of the taxa exhibited moderate tolerance to pollutants. This is reflected in the relatively low HBI score of 4.6. A community dominated by extremely pollution tolerant taxa would have a much higher (poorer) HBI score. Finally, very few members of the *Chironomidae* family were observed in Deal Ditch. A dominance of members of the *Chironomidae* family is typically associated with degraded water quality.

Deal Ditch's biotic community also exhibited some negative attributes. For example, the stream possessed only two taxa from the more sensitive *Ephemeroptera*, *Plecoptera*, and *Trichoptera* or EPT orders. The two taxa observed were part of the *Baetidae* and *Hydropsychidae* families, tend to be much more tolerant of pollution compared to other members of the EPT orders. No stoneflies were observed in Deal Ditch. Stoneflies are arguably the most sensitive to pollution. Finally, while reflecting moderate taxa richness, four taxa comprised nearly 75% of the sample.

Despite these negative attributes, Deal Ditch's overall mIBI indicates that water quality is relatively good, particularly in comparison to many other northern Indiana streams in agricultural settings. While the mIBI score places the stream's biotic community in the moderately impaired category, this would be sufficient for IDEM to consider Deal Ditch as meeting the requirements of the Clean Water Act (IDEM, 2006).

Table 13. Classification scores and mIBI scores for Deal Ditch, July 27, 2006.

mIBI Metric		Metric Score
HBI	4.64	4
Number of Taxa (family)	12	4
Total Count (Number of individuals)	69	0
Percent Dominant Taxa	34.8	4
EPT Index (Number of families)	2	0
EPT Count (Number of individuals)	25	2
EPT Count/Total Count	0.36	4
EPT Abundance/Chironomid Abundance	3.13	4
Chironomid Count	8	8
mIBI Score		3.3

Table 14 details macroinvertebrate sampling results for the lake's outlet stream. The outlet stream rated an mIBI score of 4.4 suggesting that the stream's biotic community is slightly impaired. The stream supports average species richness and the dominant taxa accounts for 15% of the community composition. Many of the taxa exhibited moderate to high tolerance to pollutants. This is reflected in the moderate HBI score of 5.5. A community dominated by extremely pollution tolerant taxa would have a much higher (poorer) HBI score. Finally, like in Deal Ditch, very few members of the *Chironomidae* family were observed in the outlet stream.

The outlet stream possessed higher density and diversity in EPT taxa; however, these metrics still scored relatively low. The outlet stream contained four taxa from the EPT orders all of which represented moderately to highly tolerant members of the EPT orders. No stoneflies were observed in the outlet stream. Additionally, the outlet stream contained low densities of macroinvertebrates. Only 72 individuals were collected. Despite these negative attributes, the outlet stream's overall mIBI indicates that water quality is relatively good, particularly in comparison to Deal Ditch and many other northern Indiana streams in agricultural settings. While the mIBI score places the stream's biotic community in the slightly impaired category, this would be sufficient for IDEM to consider this stream as meeting the requirements of the Clean Water Act (IDEM, 2006).

Table 14. Classification scores and mIBI scores for Pretty Lake's outlet stream, July 27, 2006.

mIBI Metric		Metric Score
HBI	5.53	2
Number of Taxa (family)	18	8
Total Count (Number of individuals)	72	0
Percent Dominant Taxa	15.3	8
EPT Index (Number of families)	4	4
EPT Count (Number of individuals)	29	2
EPT Count/Total Count	0.40	4
EPT Abundance/Chironomid Abundance	2.90	4
Chironomid Count	10	8
mIBI Score		4.4

3.3.3 Habitat

In addition to a stream's water chemistry, habitat quality also influences the quality of the biotic community inhabiting the streams. Thus, it is useful to examine the habitat quality of the streams in the Pretty Lake watershed. Table 15 presents the results of the QHEI calculated at Deal Ditch and the outlet stream. (Appendix E presents the QHEI data sheets for these assessments.) Deal Ditch's QHEI score was relatively low (39). The Indiana Department of Environmental Management characterizes QHEI scores less than 51 as poor habitat. The low QHEI score is due in large part to the stream's history. Judging by the straight profile (Figure 12) and the prevalence of hydric soils within and along the stream's corridor, Deal Ditch was likely dug through historic wetlands to facilitate drainage for agricultural purposes. The stream's straight profile and corridor's lack of gradient limit the development of pool/riffle sequences, contribute to low channel development, and result in poor substrate (Figure 28). Combined, these characteristics help to reduce the stream's QHEI score. Conversely, the outlet stream possesses relatively good habitat. Gravel and cobble cover the stream channel, which contains relatively good sinuosity, and a wide riparian buffer. The stream's gradient also contributes to the development of riffles; however, no pools were present within the stream reach (Figure 29).

Table 15. QHEI scores for Deal Ditch and Pretty Lake's outlet stream, July 27, 2006.

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**
Deal Ditch	4	15	6	6	0	0	8	**39**
Outlet Stream	14	12	14	8.5	0	5	8	**61.5**

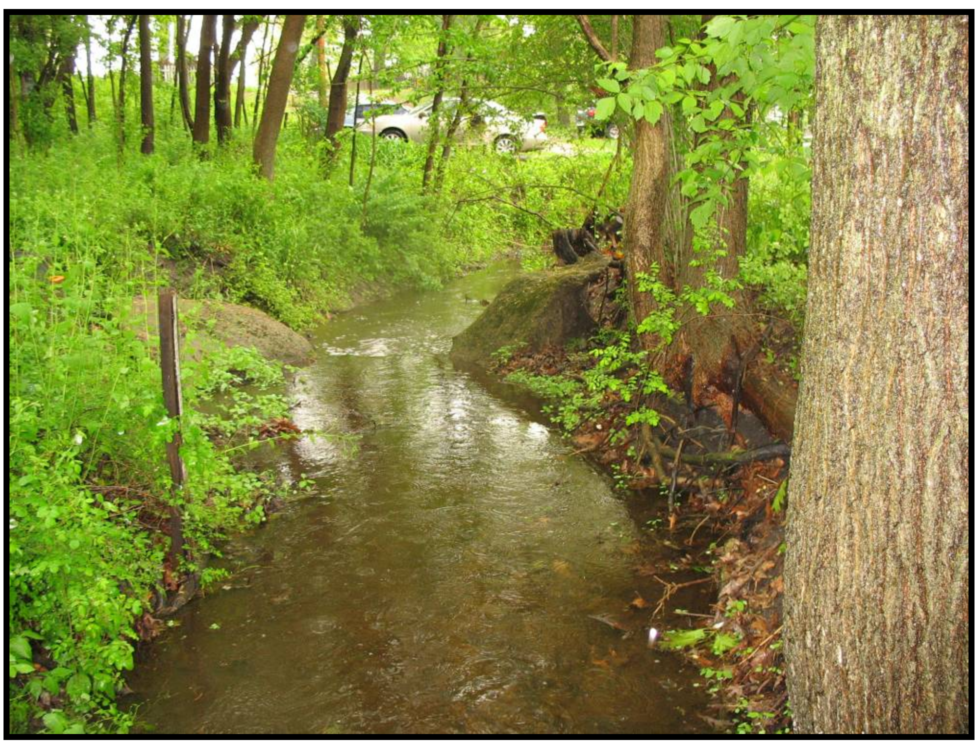

Figure 28. Deal Ditch sampling site, July 27, 2006.

Figure 29. Pretty Lake's outlet stream sampling site, July 27, 2006.

Due to Deal Ditch's relatively poor habitat score, it is difficult to determine with any certainty whether the moderate impairment of the stream's biotic community is due to water quality or some other reason. The stream's QHEI score suggests that the habitat may be contributing to the observed impairment of the biotic community. At the same time, total phosphorus and nitrate-nitrogen concentrations observed during base flow were elevated but were not above the threshold at which the Ohio EPA found to impair a stream's biotic community. Thus, it is possible that both poor habitat and water quality are impairing the stream's biotic community.

4.0 LAKE ASSESSMENT

4.1 Morphology

Figure 30 presents Pretty Lake's moderately complex morphology. The lake consists of two deep holes surrounded by shallower water. The lake's deepest point lies slightly west of the center of the 184-acre (34-ha) lake. Here, the lake extends to it maximum depth of 82 feet (25 m; Table 16). One shallower hole lies in the southeastern portion of the lake reaching a maximum depth of 50 feet (15.2 m). Water as shallow as 30 feet (9.1 m) separates these holes from the other parts of the lake. The lake also contains two shallow islands, one along the western shoreline north of the public access site (3 feet or 0.9 m) and one in the northeast corner the lake which is commonly known as Job's Hole (4 feet or 1.2 m)

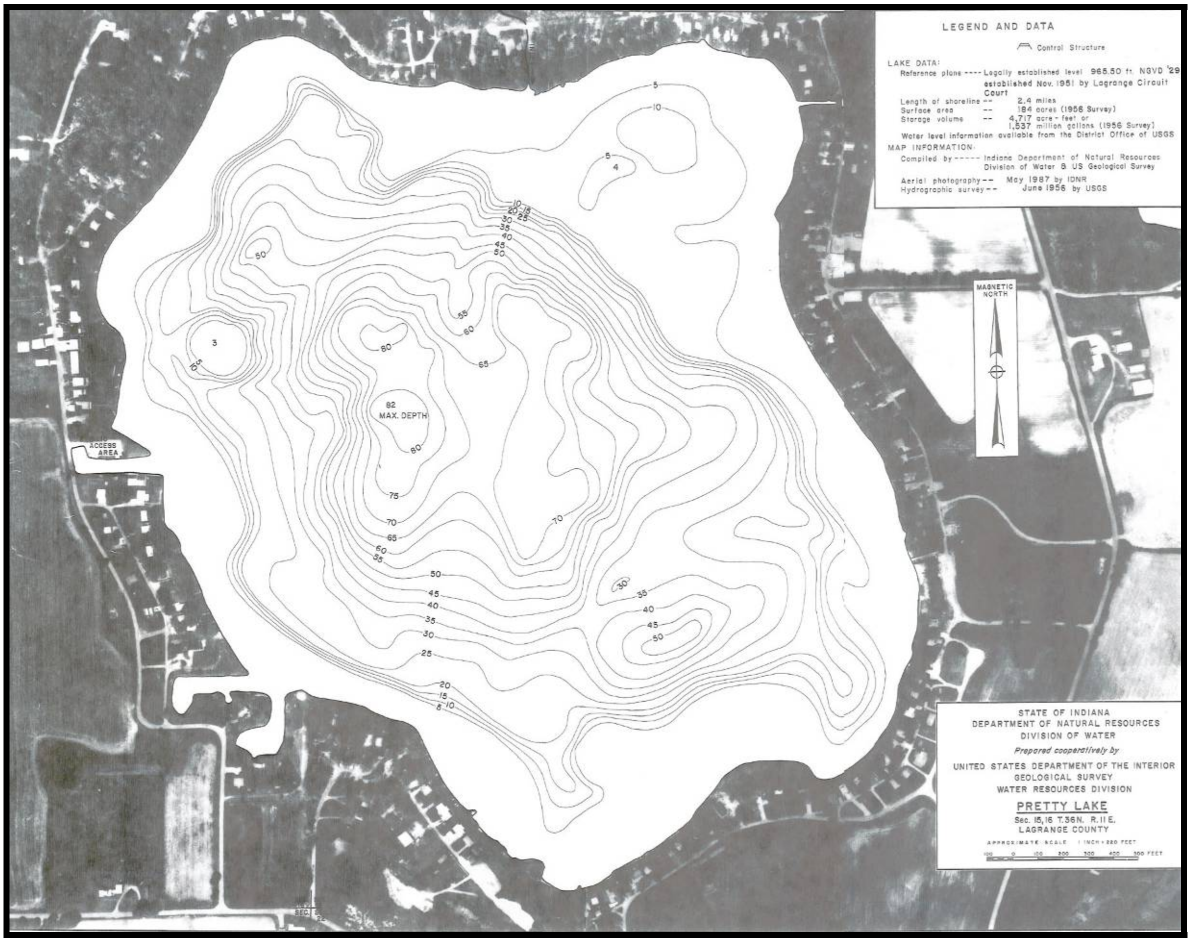

Figure 30. Pretty Lake bathymetric map. Source: IDNR, 1956.

Table 16. Morphological characteristics of Pretty Lake.

Characteristic	Value
Surface Area	184 acres (34 ha)
Volume	4,717 acre-feet (5,818,178 m^3)
Maximum Depth	82 feet (25 m)
Mean Depth	25.6 feet (7.8 m)
Shallowness Ratio	0.32
Shoalness Ratio	0.48
Shoreline Length	13,472 feet (4,106 m)
Shoreline Development Ratio	1.34

Pretty Lake possesses limited expanses of shallow water. According to its depth-area curve (Figure 31), nearly 60 acres (24.3 ha) of the lake is covered by water less than 5 feet (1.5 m) deep, while nearly 92 acres (37 ha) is covered by water less than 20 feet (6.1 m) deep. This translates into a very low shallowness ratio of 0.32 (ratio of area less than 5 feet (1.5 m) deep to total lake area) and a moderately high shoalness ratio of 0.48 (ratio of area less than 20 feet (6.1 m) deep to total lake area) (Table 16), as defined by Wagner (1990). A large portion of the lake's acreage (approximately 46 acres or 32.5 ha) covers the water deeper than 40 feet (12.1 m). The lake's area gradually increases with depth to a water depth of about 10 feet (3 m) before the rate of change increases. This rate (slope of lake bottom) continues to the lakes maximum depth (82 feet or 25 m).

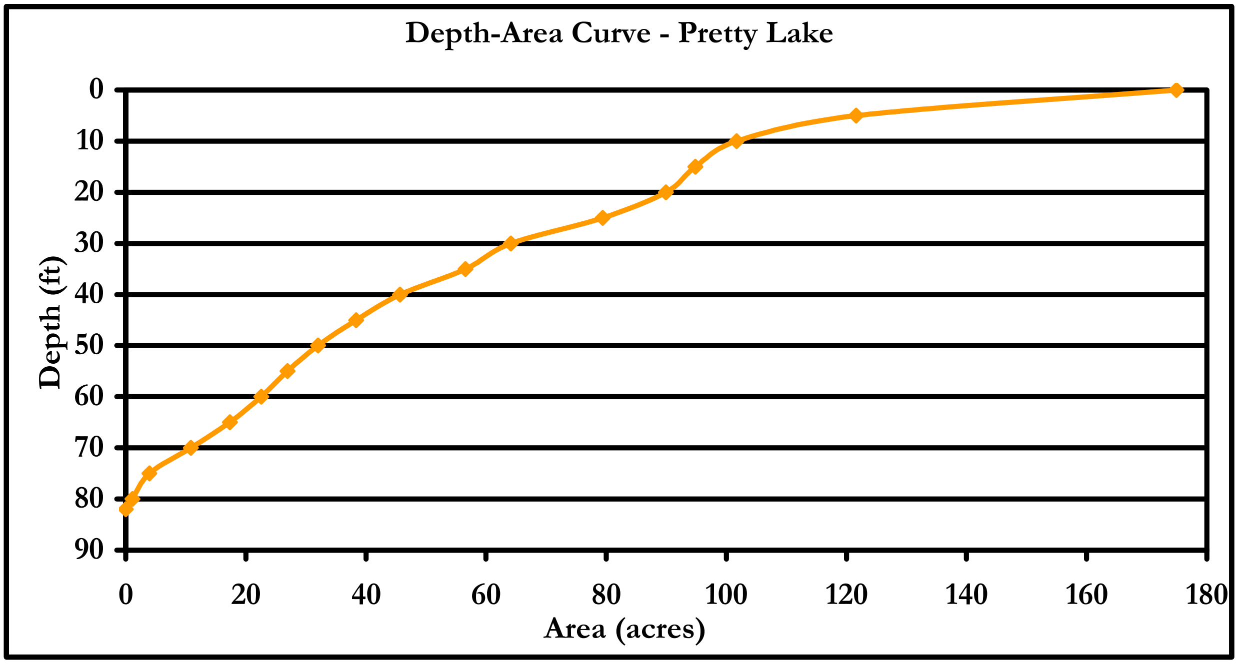

Figure 31. Depth-area curve for Pretty Lake.

Pretty Lake holds approximately 4,717 acre-feet (5,818,178 m^3) of water. As illustrated in the depth-volume curve (Figure 32), most of the lake's volume is contained in the shallower areas of the lake. More than 75% of the lake's volume is contained in water that is less than 35 feet (10.7 m) deep. The lake's volume gradually increases with depth to a water depth of about 50 feet (15.2 m) before the rate of change increases. Below 50 feet (15.2 m), the steep curve indicates a greater change in depth per unit volume. This rate continues to the lakes maximum depth (82 feet or 25 m). The importance of this rate of increase will be discussed with regard to light penetration and the planktonic community in the Results Section.

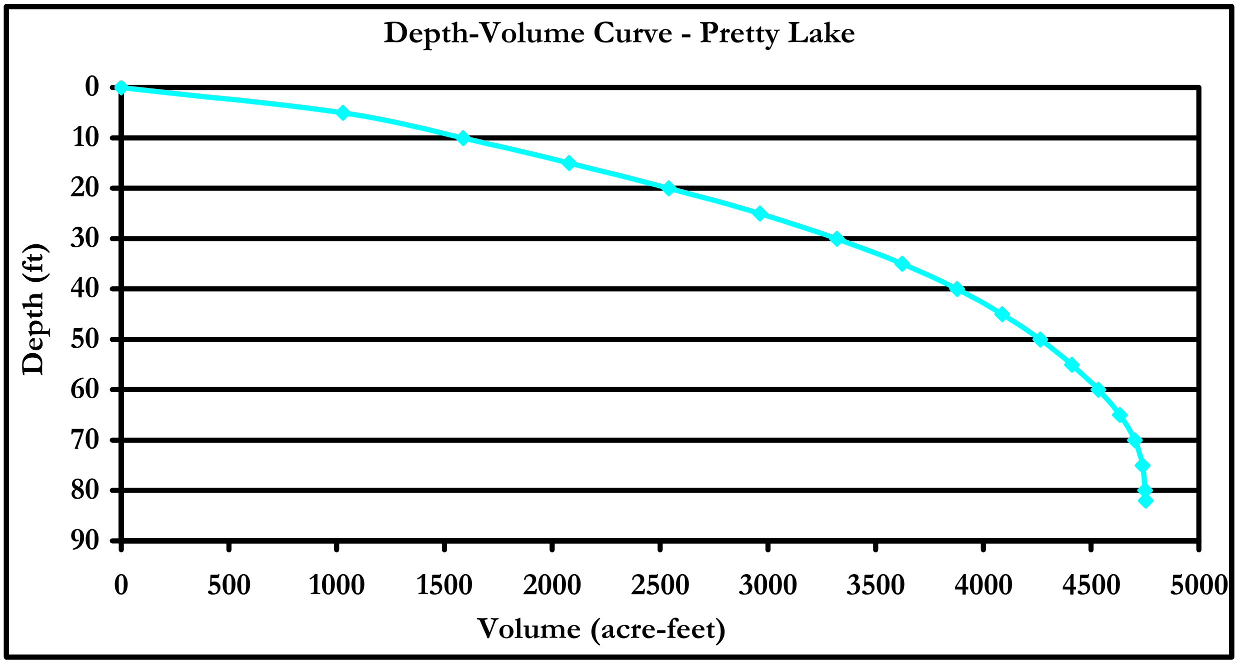

Figure 32. Depth-volume curve for Pretty Lake.

Historically, water level fluctuations caused large changes in the surface area of Pretty Lake. Horn (1951) noted that Pretty Lake covered 227 acres (91.9 ha) with a maximum depth of 102 feet (31.1 m) in the early 1950s. This is nearly 23 acres (9.3 ha) larger and 18 feet (5.4 m) deeper than the lake's current size and depth. Additionally, Horn (1951) detailed the outlet structure as a tunnel flowing underground towards Big Long Lake which was constructed to furnish water power to a mill on the shores of Big Long Lake. McGinty's accounts of water level fluctuation correspond with this greater than present depth and area for Pretty Lake. He noted that a water control structure was installed in the mid-1950s to limit water level fluctuations due to a large underground spring (McGinty, 1966). The installation of the public access ramp in 1949, construction of channels at the lake's southwest corner around 1952, and deepening of the southeast corner of the lake between 1957 and 1960 all shaped the current morphology of Pretty Lake (McGinty, 1966; Figure 33).

A lake's morphology can play a role in shaping the lake's biotic communities. For example, Pretty Lake's moderately sized shallow area and wide, shallow shelf around much of the perimeter of the lake coupled with its moderate clarity suggests the lake is capable of supporting a quality rooted plant community. Based on the lake's clarity, Pretty Lake's littoral zone (or the zone capable of supporting aquatic rooted plants) extends from the shoreline to the point where water depths are approximately 35.5 feet (10.8 m). Referring to Pretty Lake's depth-area curve (Figure 31), this means that the lake's littoral zone is approximately 130 acres (52.6 ha) in size or approximately 70% of the lake. The lake's 1% light level (or the depth at which only 1% of available surface light penetrates) is less than the littoral zone calculated by multiplying the transparency by a factor of three. Using the second method, Pretty Lake's littoral zone reaches a depth of 23 feet (7 m) and covers 101 acres (40.9 h) or 55% of the lakes surface area. This size littoral zone can impact other biotic communities in the lake such as fish that use the plant community for forage, spawning, cover, and resting habitat.

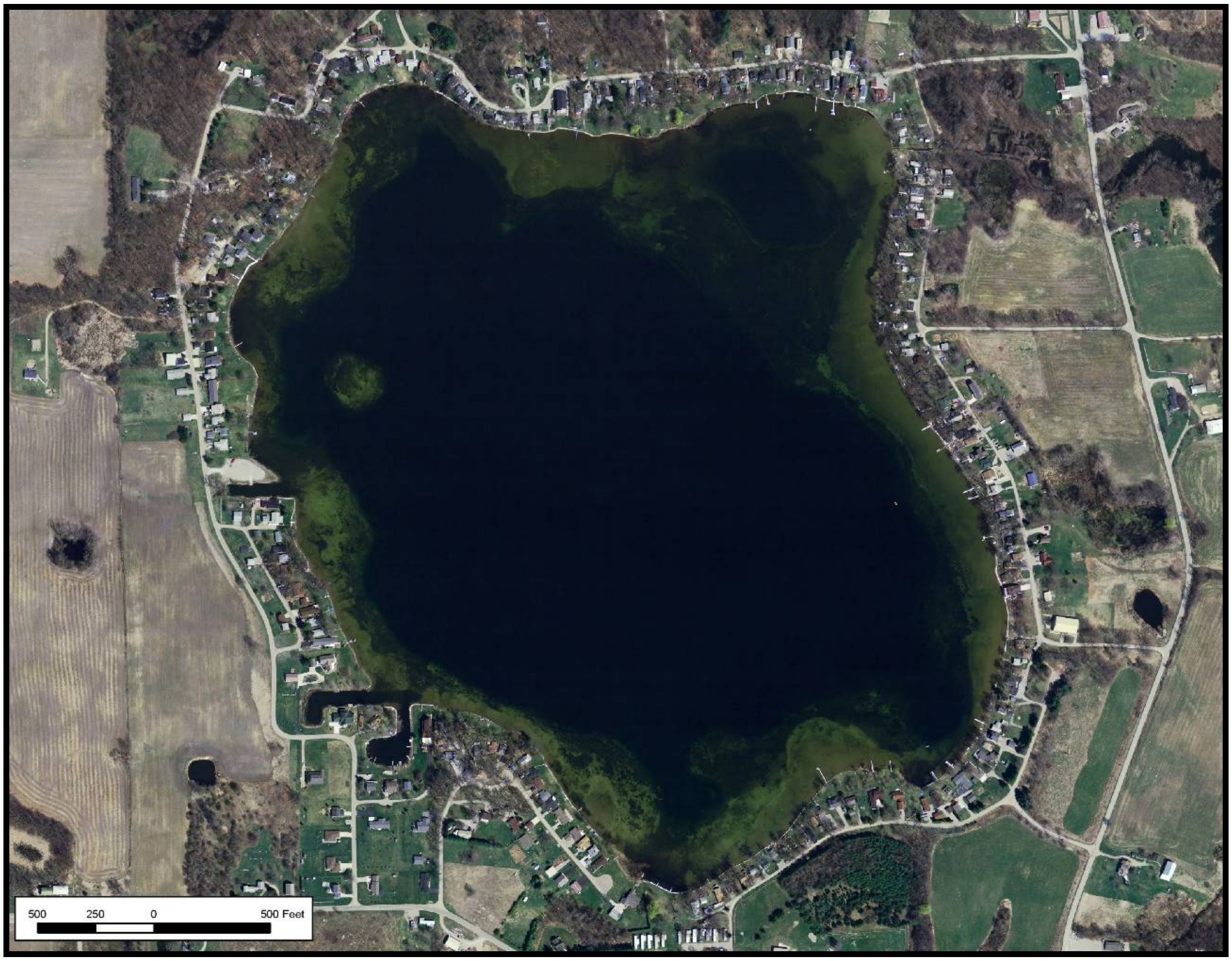

Figure 33. Aerial photograph of Pretty Lake circa spring 2005.

A lake's morphology can indirectly influence water quality by shaping the human communities around the lake. The shoreline development ratio is a measure of the development potential of a lake. It is calculated by dividing a lake's 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 Pretty Lake (184 acres or 34 ha) would have a circumference of 10,036 feet (3,059 m). Dividing Pretty Lake's shoreline length (13,472 feet or 4,106 m) by 10,036 feet yields a ratio of 1.34:1. This ratio is relatively low. Pretty Lake is relatively round and lacks extensive shoreline channeling observed on other popular Indiana lakes such as lakes in the Barbee Chain and Lake Tippecanoe in Kosciusko County. Given the immense popularity of lakes in northern Indiana, lakes with high shoreline development ratios are often highly developed. Increased development around lakes often leads to decreased water quality.

In 1989, EarthSource developed a new bathymetric map for Pretty Lake (Figure 34). Based on their estimates, the 0-5 foot contour covered the largest portion of the lake (68 acres or 27.5 ha). Water depths gradually increased to a depth of 82 feet which covered less than 2 acres (0.8 ha) of the lake's surface area. EarthSource determined that major changes in the lake's morphology occurred at the 0-5 and 5-10 foot depth intervals with the 0-5 foot interval increased by approximately 10% of the lake's surface area and the 5-10 foot decreased by approximately the same amount. In both of these contours, lake fill from sediment was apparent at the mouths of the main inlet (Deal Ditch) in the lake's northeast corner and along the western shoreline of the lake near the tile drain inlet.

EarthSource (1991) stated that most of the sediment that accumulated in Pretty Lake from 1956 to 1989 resulted from watershed erosion.

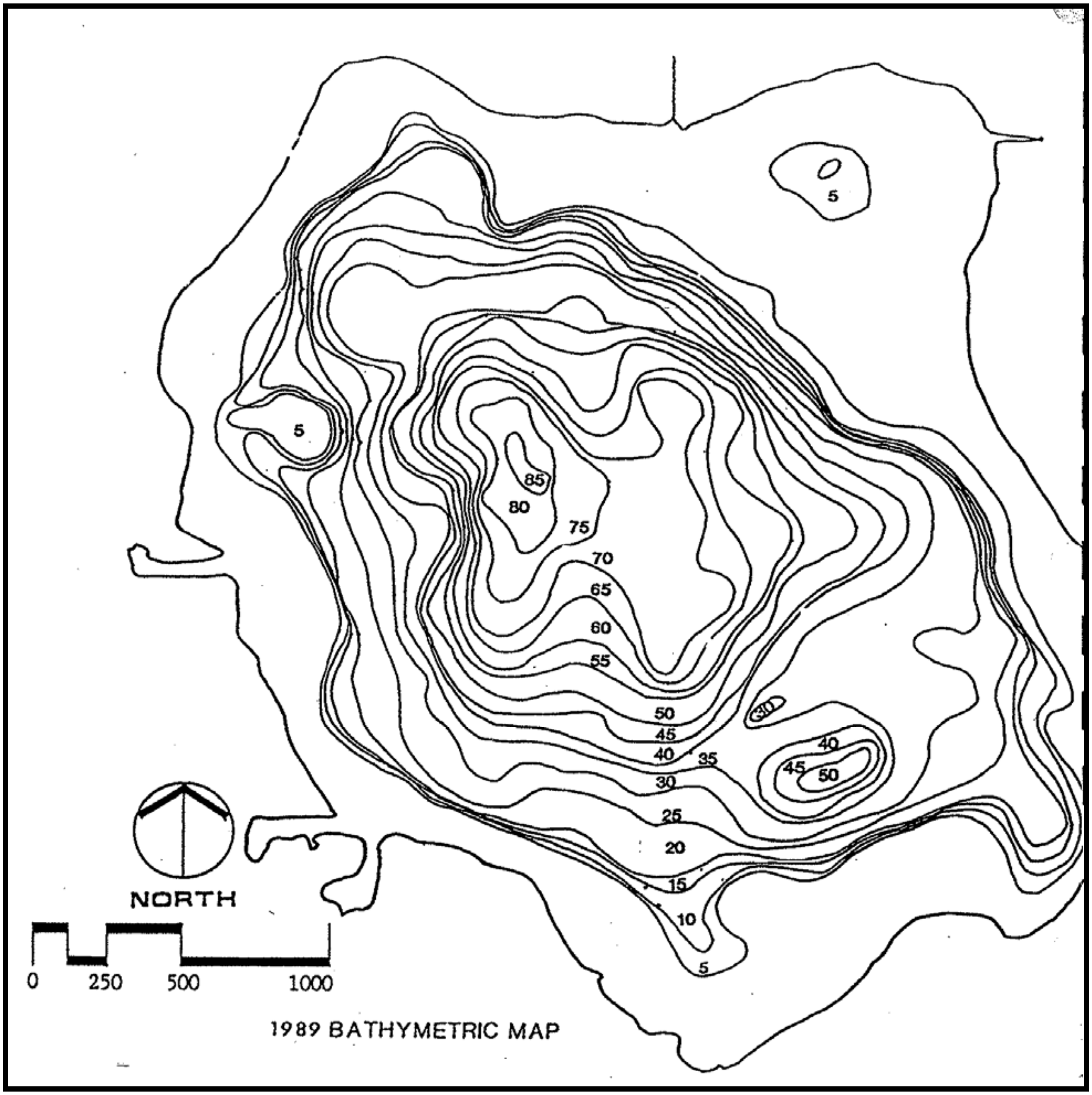

Figure 34. Bathymetric map created by EarthSource using data collected in 1989.

4.2 Shoreline Development

Development around Pretty Lake began early and by 1938, approximately 60 cottages were located along Pretty Lake's shoreline (Grant, 1989). Most of the houses were scattered around the lake with the exception of the western shoreline, which remained largely undeveloped. Over the next 25 years, development around the shores of Pretty Lake increased. In 1964, McGinty noted the presence of 159 cottages and 3 trailers. Individual residents owned 226 boats and 18 pontoons, many of which were housed at 4 boat liveries. By 1965, nearly the entire shoreline was developed. Cottages and trailer courts ringed much of Pretty Lake. The wetland buffers that were previously present adjacent to Pretty Lake were filled and developed (Grant, 1989). By the 1970s, development covered similar areas as those observed in1964. Residential and boat densities remained the same as determine by Peterson (1974) who noted 153 homes and 245 boats present along 95% of the shoreline in 1973. Aerial photographs from 1972 confirm the presence of houses scattered along nearly the entirety of Pretty Lake's shoreline with these houses present in similar densities to those present in both the 1930s and today.

Given the plethora of houses along Pretty Lake's shoreline, it is not surprising that nearly 92% of Pretty Lake's shoreline has been altered in some form. Along much of Pretty Lake's shoreline (64%; 8,735 feet or 2,662 m), trees and emergent vegetation have been thinned; however, these areas possess at least a narrow band of emergent plants. These areas are mapped as modified natural shoreline because they still possess at least a small portion of all these strata (submerged, emergent, and floating). Other portions of the shoreline that are also mapped as modified natural include those areas where individuals removed only the portion of the shoreline vegetation required to view or access the lake such as the property depicted in Figure 35. Figure 36 displays the portion of shoreline possessing modified natural characteristics.

Figure 35. Modified natural shoreline present within Pretty Lake. Note that vegetation was removed in areas required to place the dock for access to the lake. The remaining vegetation along the shoreline acts as a natural buffer.

Figure 36. Shoreline surface type observed at Pretty Lake, August 2, 2006.

Approximately 26% of Pretty Lake's shoreline has been largely altered from its natural state (Figure 36). Along these portions of Pretty Lake's shoreline emergent and floating rooted vegetation has been completely removed from adjacent to the shoreline. This leaves exposed soils or mowed, residential lawns exposed to wave action. In some areas wooden railroad timbers, concrete seawalls, glacial stone, or riprap cover the shoreline. This type of shoreline is especially prevalent in the lake's northeastern corner where wind and wave energy is higher than other areas of the lake (Figure 37). This area of the lake is subject to higher wave energy due to prevailing winds and possessing the highest ***fetch*** (longest distance that the wind travels without touching land) of anywhere on the lake.

Figure 37. Modified shoreline present along Pretty Lake's northeastern shoreline. Note the higher wave energy present within this portion of the lake due to the prevailing wind pattern and increased fetch.

Natural shoreline remains along approximately 8% of Pretty Lake's shoreline where bands of plants like those described by McGinty (1965) are present with trees, emergent vegetation, floating vegetation, and submerged vegetation located in distinct zones along the lakeshore (Figure 38). In these areas, the submerged, floating, emergent, and shoreline canopy layers all remain intact.

Figure 38. Natural shoreline present along Pretty Lake's southern shoreline.

The shoreline surface becomes especially important in and adjacent to shallow portions of Pretty Lake. In areas where concrete seawalls are present, wave energy from wind and boats strike the flat surface and reflect back into the lake. This creates an almost continuous turbulence in the shallow areas of the lake. At points where the waves reflect back into the lake and meet incoming waves, the wave height increases resulting in additional in-lake turbulence. This turbulence resuspends bottom sediments thereby increasing the transfer of nutrients from the sediment-water interface to the water column. Continuous disturbance in shallow areas can also encourage the growth of disturbance-oriented plants.

In contrast, shorelines vegetated with emergent or rooted floating vegetation or those areas covered by sand will absorb more of the wave energy created by wind or boats. In these locations, wave energy will dissipate along the shoreline each time a wave meets the shoreline surface. Similarly, stone seawalls or those covered by wood can decrease shallow water turbulence and lakeward wave energy reflection while still providing shoreline stabilization.

4.3 Historical Water Quality

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana State Pollution Control Board, the Indiana Clean Lakes Program (CLP), the Lagrange County Health Department (LCHD), EarthSource, and Volunteer Monitors have conducted various water quality tests on Pretty Lake. Table 17 presents some selected water quality parameters for these assessments of Pretty Lake.

Table 17. Summary of historic data for Pretty Lake.

Date	Secchi (ft)	Percent Oxic	epi pH	Mean TP (mg/L)	Plankton Density (#/L)	TSI Score (based on means)	Data Source
8/1/30	--	36.3%	--	--	--	--	Scott, 1930
8/1/63	--	37.5%	--	--	--	--	Wetzel, 1966
9/1/63	--	35.0%	--	--	--	--	Wetzel, 1966
10/1/63	--	47.5%	--	--	--	--	Wetzel, 1966
11/1/63	--	48.8%	--	--	--	--	Wetzel, 1966
6/22/64	10.8	100.0%	--	--	--	--	McGinty, 1966
7/1970	--	32.5%	--	--	--	--	Peterson, 1974
8/31/72	10.0	31.3%	--	0.300*	--	25^{δ}	IDEM, 1986
7/31/73	11.0	56.3%	9.00	--	--	--	Peterson, 1974
1/1/74	--	--	8.10	0.040	--	--	Peterson, 1974
8/6/79	18.5	75.0%	9.00	--	--	--	IDNR, 1980
9/1/83	12.6	36.3%	9.20	--	--	--	Peterson, 1984
8/7/85	17.0	50.0%	9.00	--	--	--	Ledet, 1986
7/1/88	14.8	48.8%	8.50	--	--	--	CLP, 1988
8/22/88	9.0	48.8%	--	0.005	--	--	Grant, 1989
7/25/89	9.2	95.5%	--	0.013	2,806	7	CLP, 1989
9/15/89	12.4	32.8%	--	0.680*	--	13	EarthSource, 1991
10/5/89	13.1	32.8%	--	0.190*	--	13	EarthSource, 1991
7/27/93	11.5	65.9%	8.50	0.070	4,437	22	CLP, 1993
6/17/96	19.0	100.0%	9.20	--	--	--	Ledet, 1998
8/26/97	11.2	32.0%	8.61	0.043	7,483	21	CLP, 1997
5/21/00	17.0	--	--	--	--	--	Volunteer monitor
6/17/00	17.0	--	--	--	--	--	Volunteer monitor
5/19/01	16.5	--	--	--	--	--	Volunteer monitor
6/23/01	13.5	--	--	--	--	--	Volunteer monitor
8/29/01	12.5	--	--	--	--	--	Volunteer monitor
9/12/01	11.0	--	--	--	--	--	Volunteer monitor
10/4/01	16.0	--	--	--	--	--	Volunteer monitor
7/5/02	14.0	--	--	--	--	--	Volunteer monitor
7/14/02	14.8	--	--	--	--	--	Volunteer monitor
8/3/02	14.5	--	--	--	--	--	Volunteer monitor
8/12/02	15.8	78.7%	8.35	0.026	8,983	16	CLP, 2002
8/29/02	16.5	--	--	--	--	--	Volunteer monitor
9/30/02	12.9	--	--	--	--	--	Volunteer monitor
7/2/03	14.8	--	--	--	--	--	Volunteer monitor
6/15/04	13.6	--	--	--	--	--	Volunteer monitor
6/19/04	14.2	--	--	--	--	--	Volunteer monitor
7/13/04	14.5	--	--	--	--	--	Volunteer monitor

Date	Secchi (ft)	Percent Oxic	epi pH	Mean TP (mg/L)	Plankton Density (#/L)	TSI Score (based on means)	Data Source
7/4/05	15.5	--	--	--	--	--	Volunteer monitor
7/27/06	11.5	83.0%	8.7	0.019	901	15	Current Study

*Water column average; all other values are means of epilimnion and hypolimnion values.
$^{\delta}$Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.

Based on the data presented in Table 17, water quality in Pretty Lake has remained stable or even improved slightly over the past 50 years. Water clarity is relatively good for the region. Since 1964, Secchi disk transparency (a measure of water clarity) has ranged from 9 feet (2.7 m) in August 1988 to 19 feet (5.8 m) in June 1996. These measurements follow a pattern typically observed in Indiana lakes. Water clarity is generally better during the spring, early summer, and fall than clarity measurements that occur during the middle of the summer and early fall (July to September). This trend is more apparent when individual monthly median and average Secchi disk transparencies are observed (Table 18). The best (highest) monthly average and median transparencies occur during May (16.8 feet or 5.1 m), while the poorest (lowest) average and median transparencies occur during September (12.2 feet (3.7 m) and 12.5 feet (3.8 m), respectively). Water clarity has been variable over the years with no distinct trend toward increasing or decreasing water clarity. Data collected by a citizen volunteer and other organization on the lake confirms that clarity has remained relatively stable or even improved slightly over the past 40 years (Figure 39).

Table 18. Median and average transparencies measured in Pretty Lake from 1965 to 2005.

Month	Average Transparency (feet)	Median Transparency (feet)	Count
May	16.8	16.8	2
June	14.7	13.9	6
July	13.3	14.5	9
August	13.9	14.5	9
September	12.2	12.5	4
October	14.6	14.6	2
Overall	**13.9**	**14.1**	**32**

Source: McGinty, 1966; Grant, 1989; EarthSource, 1991; Ledet, 1984, 1998; Peterson, 1974, 1980; CLP, 1989, 1993, 1997, and 2002; Volunteer Monitors 2000-2005.

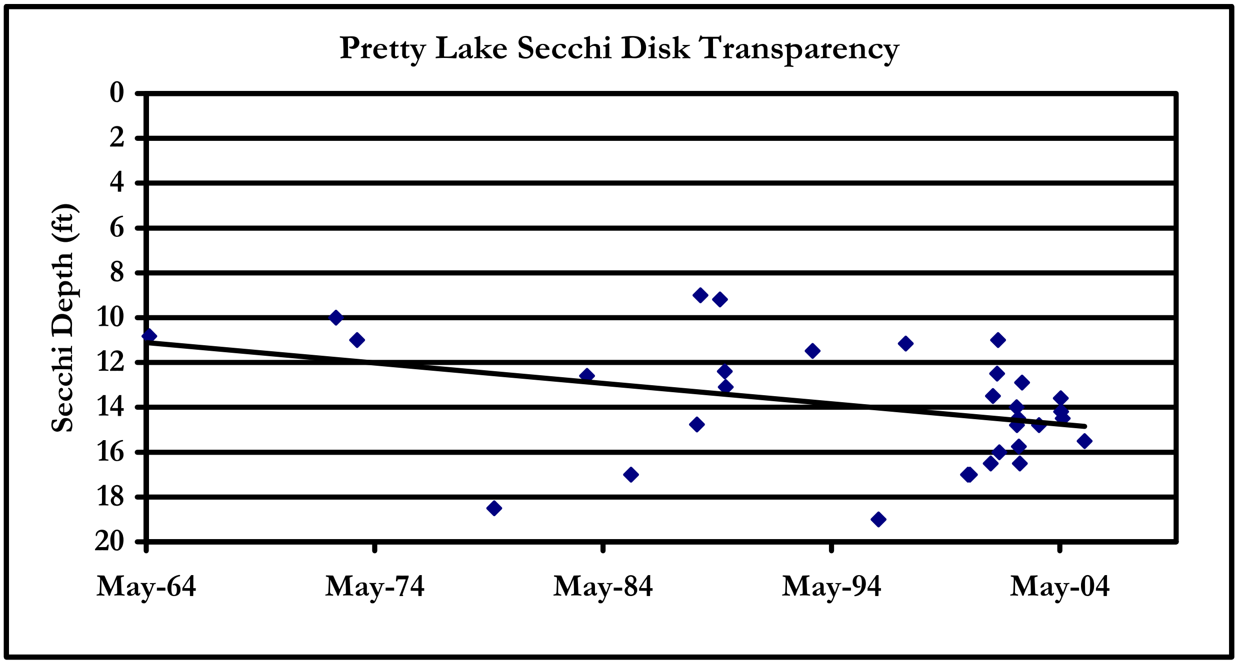

Figure 39. Historic Secchi disk transparency data for Pretty Lake.
Source: McGinty, 1966; Grant, 1989; EarthSource, 1991; Ledet, 1984, 1998; Peterson, 1974, 1980; CLP, 1989, 1993, 1997, and 2002; Volunteer Monitors 2000-2005.

Total phosphorus concentrations have generally remained low within Pretty Lake with three notable exceptions. Total phosphorus concentrations ranged from 0.005 mg/L in August 1988 (Grant, 1989) to 0.680 mg/L in September 1989 (EarthSource, 1991). Three of the concentrations measured in total phosphorus samples collected in the previous 35 years are relatively high compared with other total phosphorus concentrations measured in Pretty Lake. All three of these, 0.3 mg/L in 1972 (IDEM, 1986) and 0.19 mg/L and 0.68 mg/L in 1989 (EarthSource, 1991) are water column composite samples rather than surface water (epilimnetic) and bottom water (hypolimnetic) samples. All three samples exceeded the median total phosphorus concentration measured in most Indiana lakes (0.17 mg/L). These data appear to be outliers as all other total phosphorus concentrations are relatively low (Figure 40).

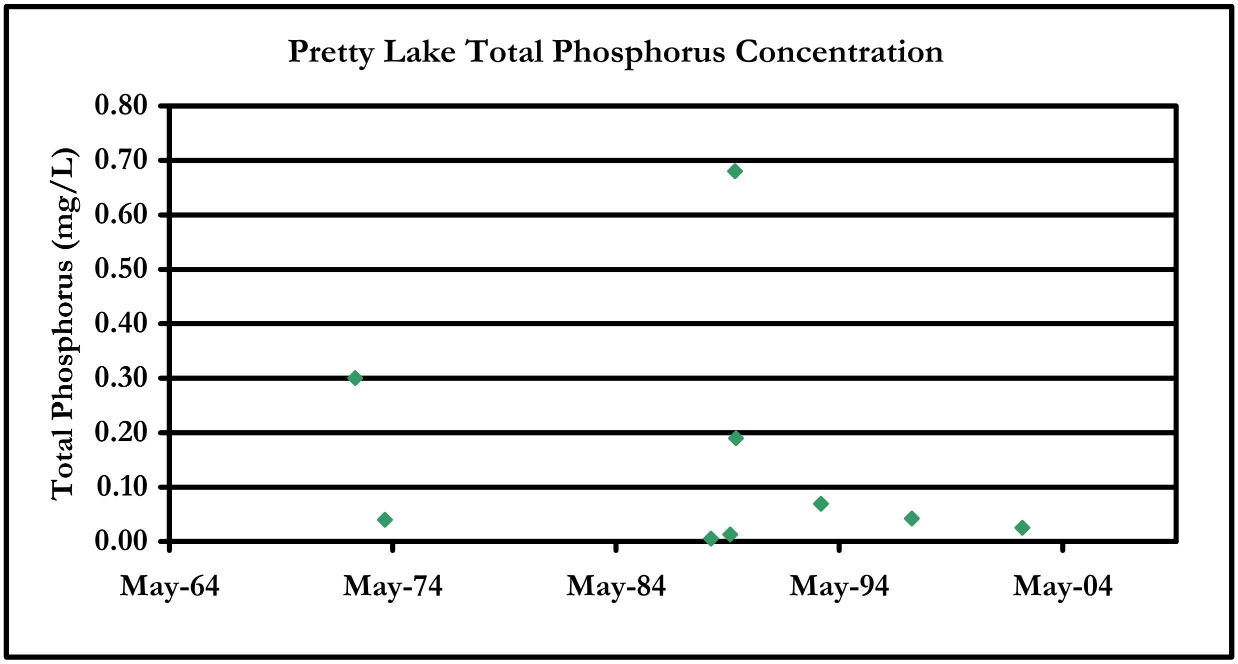

Figure 40. Historic total phosphorus concentrations measured in Pretty Lake.
Source: Grant, 1989; EarthSource, 1991; CLP, 1989, 1993, 1997, and 2002.

The lake's algae (plankton) density reflects the relatively low nutrient levels typically present in Pretty Lake. Nutrients (nitrogen and phosphorus) promote the growth of algae and/or rooted plant populations. Thus, lakes with high nutrient levels are expected to support dense algae and/or rooted plants. Plankton densities are relatively low within Pretty Lake, reflecting the relatively low nutrient concentrations present within the lake. The lowest plankton density coincides with the lowest total phosphorus concentration measured in the lake; however, this relationship does not hold true for the other three plankton densities. This is likely due to the overall low density present in Pretty Lake. Low chlorophyll *a* concentrations also reflect the relatively low plankton densities and total phosphorus concentrations found in the lake. None of the chlorophyll *a* concentrations exceed the median concentration measured in Indiana lakes (12.9 μg/L; Tables 20-22). The lake's overall trophic index (TSI) score ranged from 25 in 1972 to 7 in 1989 before rising again to 22 in 1993. The TSI remained in this range during the 1997 assessment. Since 1997, TSI scores calculated for Pretty Lake ranged from 15 to 16. All of these scores suggest that the lake is oligotrophic to slightly mesotrophic. (Please see the following sections for more detailed discussion of lake water quality parameters and trophic state indices.)

Figure 41 displays the temperature profiles recorded during IDNR fisheries surveys and Indiana CLP assessments. All of the temperature profiles show that Pretty Lake was stratified. The developed hypolimnion present during the surveys is very typical of Indiana lakes.

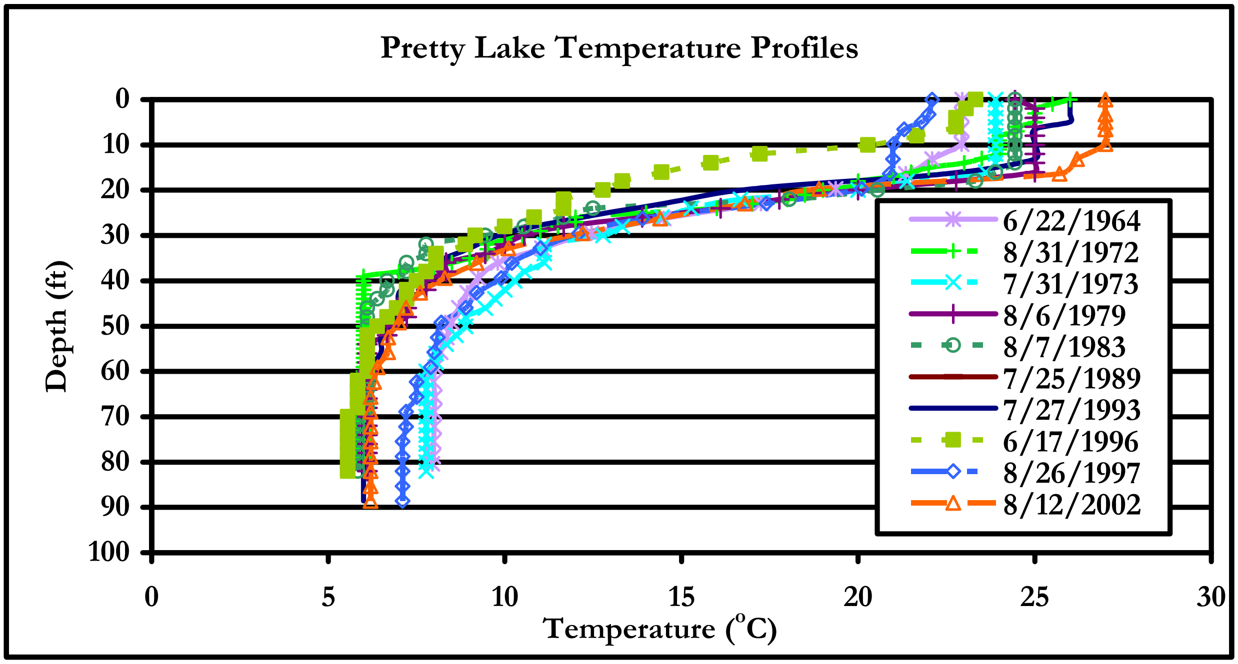

Figure 41. Historical temperature profiles for Pretty Lake.
Source: McGinty, 1966; Grant, 1989; EarthSource, 1991; Ledet, 1984, 1998; Peterson, 1974, 1980; CLP, 1989, 1993, 1997, and 2002.

While much of the data presented above suggest that Pretty Lake is only moderately productive, the historical percent oxic results (Table 17) and dissolved oxygen profiles (Figure 42) are more typical of a eutrophic (productive) lake. Dissolved oxygen data indicate that the lake possessed dissolved oxygen greater than 1 mg/L in less than 40% of the water column (Figure 42). This decline in dissolved oxygen limits the availability of habitat for the lake's inhabitants and increases the potential for nutrient release from the lake's bottom sediments. The 1964, 1979, and 1993 sampling profiles illustrate different conditions than those observed during the other assessments. For example in the 1979 dissolved oxygen profile, there is a sharp increase in dissolved oxygen in the lake's metalimnion. This results in a positive-heterograde profile. Positive-heterograde profiles are characterized by a peak in oxygen concentration at a depth below the water surface, such as the peak in the 1979 profile beginning at 15 feet (4.6 m) below the water's surface. The peak is likely associated with a higher concentration in phytoplankton at that particular depth layer. Called a ***metalimnetic oxygen maximum***, the peak 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 a peak in oxygen at that level. The 1964, 1993, and 1996 assessments profiles are also examples of metalimnetic oxygen maxima, although in all of these cases, the peaks are much smaller than that present during the 1979 assessment.

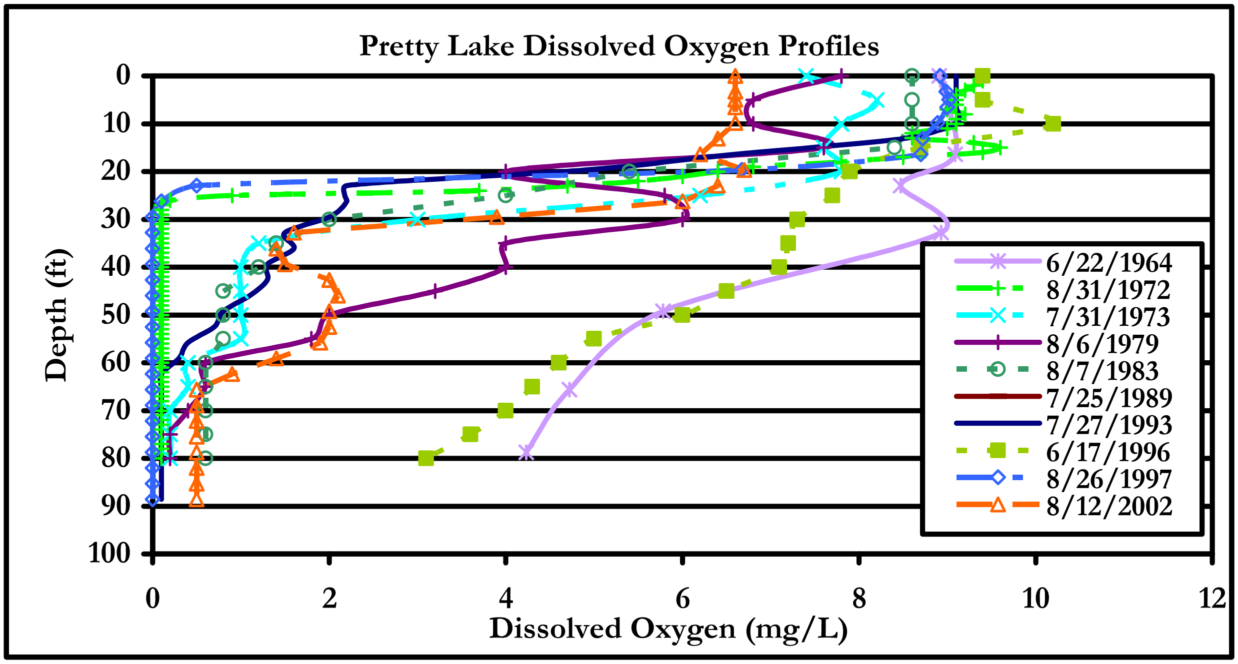

Figure 42. Historical dissolved oxygen profiles for Pretty Lake.
Source: McGinty, 1966; Grant, 1989; EarthSource, 1991; Ledet, 1984, 1998; Peterson, 1974, 1980; CLP, 1989, 1993, 1997, and 2002.

The lack of oxygen in the lake's water column may be more reflective of Pretty Lake's complex morphology than a sign of intense decomposition of plant material during the summer months. Decomposition of plant material undoubtedly occurs in the lake's deeper waters, removing oxygen from the water column. (Higher hypolimnetic ammonia concentrations suggest decomposition is occurring in the lake's bottom waters (Tables 19 to 22)). But the lake's morphology, specifically, its drop off at a depth of 20 feet (6.1 m), may prevent the lake from completely mixing during turnover periods. The fact that the lake's hypolimnion is composed of several isolated basins also reduces likelihood of complete turnover of the lake's deepest waters.

A similar situation occurs on Lake Maxinkuckee in Culver, Indiana. Lake Maxinkuckee possesses low nutrient levels and low productivity (lower than Pretty Lake), but Lake Maxinkuckee also exhibits anoxia in its hypolimnion. Historical documents show that Lake Maxinkuckee has always (at least prior to extensive settlement around the lake) lacked oxygen in its bottom waters (Evermann and Clark, 1920). Crisman (1986) suggests Lake Maxinkuckee's morphology prevents complete mixing of the lake during turnover periods. The lake's inability to completely mix prevents the reoxygenation of bottom waters in Lake Maxinkuckee. Thus, despite being a classified as an oligotrophic/mesotrophic lake, Lake Maxinkuckee experiences low percent water column oxic conditions that are more typical of a eutrophic lake.

Regardless of whether the lack of oxygen in Pretty Lake's hypolimnion is the result of its morphology or an indication of accelerated eutrophication of the lake, this lack of oxygen poses a problem for the lake's inhabitants. Fish and other aquatic organisms require oxygen to live. The lack of oxygen in the lake's hypolimnion reduces the amount of habitat available to fish. Fortunately, most of the lake's volume has oxygen levels sufficient to support fish. Based on the depth-volume curve (Figure 32), approximately 83% percent of the lake's volume is oxygenated. (The percent oxic parameter measures the vertical percent, not volumetric percent, of the water column with oxygen.)

The lack of oxygen in Pretty Lake's hypolimnion also affects the lake's chemistry. While mean total phosphorus concentrations are variable for the years displayed in Tables 19 through 22, a more detailed evaluation shows that hypolimnetic total phosphorus concentrations are typically higher than epilimnetic total phosphorus concentrations. Under anoxic conditions, the iron in iron phosphate, a common precipitate in lake sediments, is reduced, and the phosphate ion is released into the water column. This phosphate ion is readily available to algae, and can therefore spur algal growth. Further review of historical phosphorus data indicate that much of the total phosphorus was in the dissolved form of phosphorus (SRP). This indicates that Pretty Lake was releasing phosphorus from its bottom sediments. Additionally, Pretty Lake exhibited higher hypolimnetic ammonia concentrations than those observed in the lake's epilimnion during all of the assessments, suggesting decomposition of organic matter was occurring in the lake's bottom waters. Overall, these data suggest that Pretty Lake was a mesotrophic to moderately eutrophic lake during the 1989, 1993, 1997, and 2002 assessments.

Table 19. Historical water quality characteristics of Pretty Lake, July 25, 1989.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
Secchi Depth Transparency	2.8 m	-	0
Light Transmission @ 3 ft.	54%	-	2
Total Phosphorus	0.010 mg/L	0.016 mg/L	0
Soluble Reactive Phosphorus	0.005 mg/L	0.005 mg/L	0
Nitrate-Nitrogen	0.337 mg/L	0.606 mg/L	2
Ammonia-Nitrogen	0.026 mg/L	0.405 mg/L	0
Organic Nitrogen	1.402 mg/L	1.572 mg/L	3
Oxygen Saturation @ 5ft.	109%	-	0
% Water Column Oxic	95.8%	-	0
Plankton Density	2,806/L	-	0
Blue-Green Dominance	45%	-	0
		TSI Score	**7**

Table 20. Historical water quality characteristics of Pretty Lake, July 27, 1993.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.5	7.6	-
Alkalinity	141 mg/L	161 mg/L	-
Conductivity	370 µmhos	300 µmhos	-
Secchi Depth Transparency	3.5 m	-	0
Light Transmission @ 3 ft.	60%	-	2
1% Light Level	28 ft	-	-
Total Phosphorus	0.010 mg/L	0.129 mg/L	3
Soluble Reactive Phosphorus	0.005 mg/L	0.090 mg/L	3
Nitrate-Nitrogen	0.062 mg/L	0.028 mg/L	0
Ammonia-Nitrogen	0.025 mg/L	0.426 mg/L	0
Organic Nitrogen	0.046 mg/L	0.733 mg/L	1
Oxygen Saturation @ 5ft.	106%	-	0
% Water Column Oxic	65.9%	-	2
Plankton Density	4,437/L	-	1
Blue-Green Dominance	67%	-	10
Chlorophyll *a*	2.12 mg/m^3	-	-
		TSI Score	**22**

Table 21. Historical water quality characteristics of Pretty Lake, August 26, 1997.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.61	8.35	-
Alkalinity	123.6 mg/L	154.1 mg/L	-
Conductivity	294 µmhos	285 µmhos	-
Secchi Depth Transparency	3.4 m	-	0
Light Transmission @ 3 ft.	48%	-	3
1% Light Level	28 ft	-	-
Total Phosphorus	0.015 mg/L	0.070 mg/L	2
Soluble Reactive Phosphorus	0.002 mg/L	0.054 mg/L	0
Nitrate-Nitrogen	0.022 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.312 mg/L	0
Organic Nitrogen	0.600 mg/L	0.900 mg/L	2
Oxygen Saturation @ 5ft.	102.7%	-	0
% Water Column Oxic	32%	-	3
Plankton Density	7,483/L	-	2
Blue-Green Dominance	74%	-	10
Chlorophyll *a*	3.04 mg/m^3	-	-
		TSI Score	**22**

Table 22. Historical water quality characteristics of Pretty Lake, August 12, 2002.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.35	7.4	-
Alkalinity	114 mg/L	140 mg/L	-
Conductivity	350 μmhos	270 μmhos	-
Secchi Depth Transparency	4.8 m	-	0
Light Transmission @ 3 ft.	55%	-	2
1% Light Level	28 ft	-	-
Total Phosphorus	0.017 mg/L	0.034 mg/L	0
Soluble Reactive Phosphorus	0.006 mg/L	0.026 mg/L	0
Nitrate-Nitrogen	0.013 mg/L	0.033 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.181 mg/L	0
Organic Nitrogen	0.661 mg/L	0.756 mg/L	2
Oxygen Saturation @ 5ft.	83.0%	-	0
% Water Column Oxic	78.7%	-	0
Plankton Density	8,983/L	-	2
Blue-Green Dominance	83%	-	10
Chlorophyll *a*	1.01 mg/m^3	-	-
		TSI Score	**16**

4.4 Lake Water Quality Assessment

4.4.1 Lake Water Quality Assessment Methods

The water sampling and analytical methods used for Pretty 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 Pretty Lake on August 27, 2006 from the surface waters (***epilimnion***) and from the bottom waters (***hypolimnion***) of the lake at a location over the deepest water. These parameters include 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. Chlorophyll was determined only for an epilimnetic sample. 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: Ward and Whipple (1959), Prescott (1982), Whitford and Schumacher (1984), and Wehr and Sheath (2003).

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 °F (32.2 °C).

Dissolved Oxygen (DO). DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3 to 5 mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 4 mg/L for warmwater fish, but all waters must have a daily average of 5 mg/L. DO 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 DO. 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 yields a specific conductance range of approximately 1000 to 1360 µmhos. This report presents conductivity measurements at each site in µmhos.

Nutrients. Limnologists measure nutrients to predict the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a lake. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake. 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. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake. 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 Pretty 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 Pretty 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 (3.3 m) 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) 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 poor 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).

4.4.2 Lake Water Quality Assessment Results

Results from the Pretty Lake water characteristics assessment are included in Figure 43 and Tables 23 and 24.

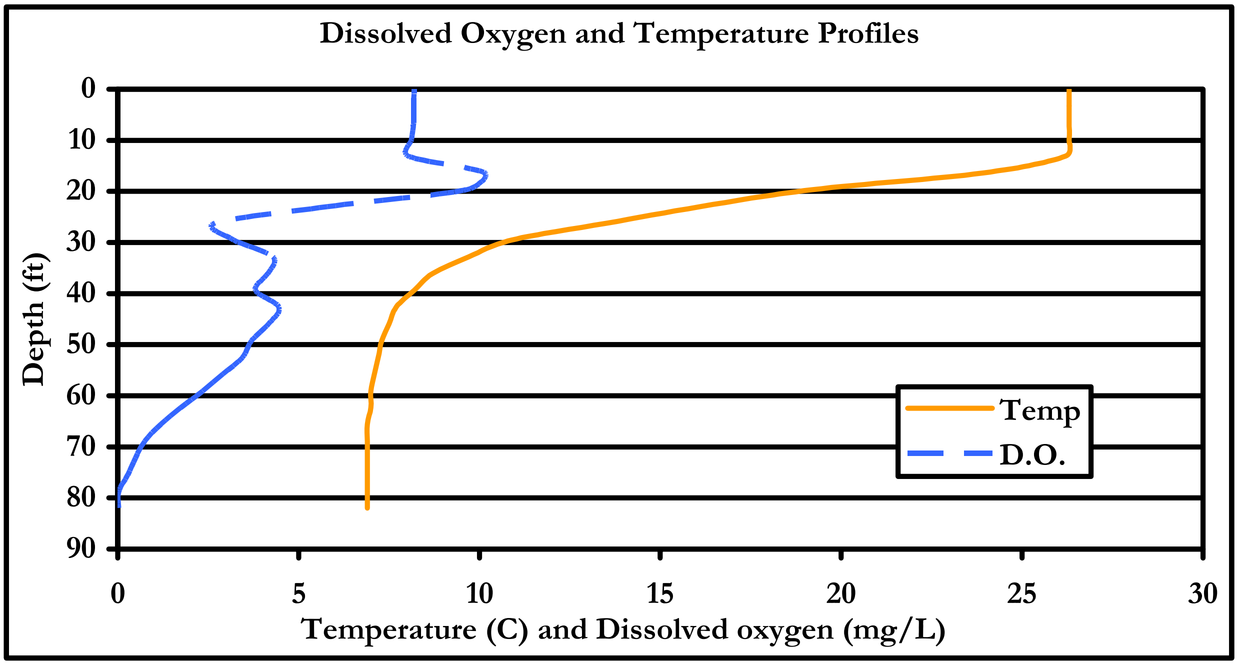

Figure 43. Temperature and dissolved oxygen profiles for Pretty Lake on July 27, 2006.

Table 23. Water quality characteristics of Pretty Lake, July 27, 2006.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.7	7.5	-
Alkalinity	108 mg/L	142 mg/L	-
Conductivity	322 µmhos	245 µmhos	-
Secchi Depth Transparency	3.6 meters	-	0
Light Transmission @ 3 ft.	16.4%	-	4
1% Light Level	23.0 feet	-	-
Total Phosphorus	0.021 mg/L	0.017 mg/L	0
Soluble Reactive Phosphorus	0.010 mg/L*	0.010 mg/L*	0
Nitrate-Nitrogen	0.018 mg/L*	0.018 mg/L*	0
Ammonia-Nitrogen	0.018 mg/L*	0.275 mg/L	0
Organic Nitrogen	0.706 mg/L	0.698 mg/L	1
Total Suspended Solids	1.177 mg/L	0.789 mg/L	-
Oxygen Saturation @ 5ft.	101%	-	0
% Water Column Oxic	83%	-	0
Plankton Density	901 nu/L	-	0
Blue-Green Dominance	64%	-	10
Chlorophyll *a*	0.14 µg/L	-	-
		TSI Score	**15**

*Method detection limit

Table 24. The plankton sample representing the species assemblage on July 27, 2006.

Species	Abundance (#/L)	Percent of Total
Blue-Green Algae (Cyanophyta)		
Microcystis	246	27.4%
Aphanocapsa	234	26.1%
Chroococcus	33	3.7%
Anabaena	33	3.7%
Woronichinia	22	2.5%
Coelospharium	11	1.2%
Green Algae (Chlorophyta)		
Ulothrix	33	3.7%
Pediastrum	22	2.5%
Diatoms (Bacillariophyta)		
Fragilaria	89	9.9%
Other Algae		
Dinobryon	33	3.7%
Ceratium	22	2.5%
Actinospaerium	11	1.2%
Miscellaneous protista	22	2.5%
Zooplankton		
Polyarthra	45	5.0%
Keratella	33	3.7%
Nauplius	3.5	0.4%
Cyclopoid Copepod	2.9	0.3%
Calanoid Copepod	0.2	0.0%
Daphnia	0.8	0.1%
Ostracoda	0.3	0.0%
Diaphanosoma	0.8	0.1%

The temperature profile for Pretty Lake shows that the lake was stratified at the time of sampling (Figure 43). During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the well-mixed *epilimnion* (surface waters) 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 13.1 feet (4 m) of water. The decline in temperature between 13.1 and 42.6 feet (4 and 13 m) defines the metalimnion or transition zone. The hypolimnion occupied water deeper than 13 meters (42.6 feet).

The dissolved oxygen profile mirrors the temperature profile and is consistent with historical dissolved oxygen profiles for the lake (Figure 42). The lake was slightly undersaturated maintaining a dissolved oxygen concentration of 8 mg/L from the water surface to a depth of 13.1 feet (4 m) before concentrations increased to form a peak at a depth of 16.4 feet (5 m). Although the peak is not as large as that present during the 1996 assessment, this supersaturation represents a *metalimnetic oxygen maximum* and is likely associated with a higher concentrations of phytoplankton at that particular depth layer. A peak like this typically results when the rate of settling plankton slows in the denser waters of the metalimnion. As the plankton at this depth photosynthesize, they release oxygen into the water column, creating a peak in oxygen at that level. The oxygen concentration decreases rapidly within the epilimnion to a depth of 26.2 feet (8 m), at which a rapid decline in DO levels begins to occur. This corresponds with the top edge of the *euphotic zone*, or the locations where insufficient light limits photosynthesis by phytoplankton. In this portion of the lake, aquatic fauna are respiring, or using available oxygen, while bacteria are consuming oxygen during decomposition. All of this results in declining dissolved oxygen concentrations. Dissolved oxygen concentrations increase again at 32.8 feet (10 m). This likely results from two main factors: 1) bacterial decomposition of the settling phytoplankton is complete at this depth and 2) water density declines at 32.8 feet (10 meters) which allows the phytoplankton to continue settling to the lake bottom. Below this point, DO levels decline until there is no dissolved oxygen remaining in the lake. This is likely due to biological oxygen demand (BOD) from excess organic detritus in the lake's deeper waters. Respiration by aquatic fauna and decomposition of organic matter likely depleted the oxygen supply in the lake's deeper waters. Water below 68.9 feet (21 m) did not contain sufficient dissolved 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 29% of the lake's water column was oxic, limiting the amount of habitat available for aquatic fauna.

Values for pH were within the normal range for Indiana lakes and typical of most fresh waters (Kalff, 2002). The alkalinity values, a measure of buffering capacity, indicate that Pretty Lake is well buffered against large changes in pH. Conductivity values, a measure of dissolved ions, were within the normal range for Indiana lakes.

Pretty Lake continues to exhibit good (excellent on a regional basis) water clarity. The lake's Secchi disk transparency depth at the time of sampling was 11.8 feet (3.6 m). This result is consistent with the measurement taken during the aquatic macrophyte survey on August 2, 2006. Despite the better than average transparency, light transmission at 3 feet (0.9 m) was relatively poor measuring only 16.4%.

Pretty Lake's rather large littoral and photic zones also highlight the lake's good water clarity. In previous sections of this report, Pretty Lake's littoral zone was estimated to be the area of the lake in which water depth was less than three times the lake's Secchi disk transparency depth. While this is a good estimate, by definition, the lake's littoral zone is the area of the lake in which water is shallow enough to support plant growth. Limnologists often use the lake's 1% light level to determine the lower limit of sufficient light to support plant photosynthesis, or growth. Thus, by definition, a lake's littoral zone is that area of the lake with water that is shallower than the lake's 1% light level.

Because of the lake's good water clarity, Pretty Lake's 1% light level is relatively deep, extending to a depth of 23 feet (7 m). Using the definition of littoral zone provided above, Pretty Lake's littoral zone is that portion of the lake with water depths less than 23 feet (7 m). Based on the depth-area curve in Figure 31, this would mean that Pretty Lake's littoral zone is approximately 101 acres (40.9 ha) in size and covers 55% of the lake's surface area. A previous section of this document suggests Pretty Lake's littoral zone is approximately 130 acres (52.6 ha) in size and covers approximately 70% approximately 75% of the lake. (This estimate was based on the lake's Secchi disk transparency.) The estimate of the lake's littoral zone using the 1% light level is more consistent with actual field conditions. Rooted plants cover an estimated 90 acres (36.4 ha) of the lake as observed during the rooted plant survey. This observation is less than the area predicted by both the 1% light level and the Secchi disk transparency. It is likely that hydrostatic pressure limits the ability of plants to grow in 30 feet (9.1 m) of water throughout the entire lake. Regardless of which estimate is used, Pretty Lake's littoral zone is extensive.

The lake's 1% light level also defines the lake's *photic zone*. A lake's *photic zone* is the volume of water with sufficient light to support algae growth. Based on Pretty Lake's depth-volume curve (Figure 32), more than 2,800 acre-feet of Pretty Lake (59% of total lake volume) lies above the 23-foot 1% light level. This volume constitutes the lake's photic zone.

Phosphorus and nitrogen are the primary plant nutrients in lakes and therefore are measured in lake water quality analyses. In the summer, Indiana lakes typically possess lower nutrient concentrations in their epilimnia compared to nutrient concentrations present in their hypolimnia. Algae in the lake's epilimnion often utilize a large portion of the readily available nutrients for growth. When the algae die and settle to the bottom sediments, nutrients are relocated to the hypolimnion. Higher concentrations of phosphorus in the hypolimnion may also result from chemical processes occurring at the sediment-water interface.

Nutrient concentrations in Pretty Lake remained low relative to other regional lakes and are on par with assessments completed in Pretty Lake in the past. At the time of sampling, nitrate-nitrogen concentrations in Pretty Lake were below the laboratory detection limit in both the epilimnion and hypolimnion. Due to being below the detection limit (0.018 mg/L), it is difficult to determine whether nitrate-nitrogen concentrations were higher than the USEPA target concentration of 0.008 mg/L (USEPA, 2000a). Additionally, as this concentration is less than the laboratory detection level, it may be difficult to determine if or when lakes actually meet this recommendation. The ammonia-nitrogen concentration in the lake's epilimnion (below the detection level) was lower than the corresponding hypolimnetic concentrations. Since ammonia-nitrogen is a byproduct of decomposition, a higher hypolimnetic concentration of ammonia-nitrogen suggests decomposition is occurring in the lake's bottom waters. The hypolimnetic concentration of ammonia-nitrogen observed during this sampling effort is similar to the hypolimnetic concentrations of ammonia-nitrogen observed during the most recent assessments indicating that the rate or amount of decomposition has not changed significantly over the years.

Additionally, Pretty Lake's total phosphorus and soluble reactive phosphorus concentrations were low measuring slightly less in both the epilimnion and hypolimnion compared to concentrations observed in 1997 and 2002. The lake's epilimnetic total phosphorus concentration of was below the detection limit (0.010 mg/L), which is below the threshold at which algae blooms can occur. Epilimnetic soluble reactive phosphorus concentrations in Indiana lakes are often below the laboratory detection limit because this form of phosphorus is readily consumed by algae. The lake's relatively low epilimnetic soluble reactive phosphorus concentration coupled with its relatively low plankton density suggest that nutrients may be limiting algae growth in the lake. Pretty Lake's hypolimnetic soluble reactive phosphorus concentration was also below the detection limit suggesting that the lake is not releasing phosphorus from its bottom sediments.

Pretty Lake's relatively low plankton density reflects the relatively low nutrient concentrations in the lake. Pretty Lake exhibited a chlorophyll *a* concentration of 0.14 μg/L. This concentration is slightly lower than the chlorophyll *a* concentrations observed in 1997 and 2002. Additionally, it is low relative to other lakes in the region and lower than the USEPA's recommended target concentration of 2.6 μg/L.

Pretty Lake's plankton density was similar to the density observed during all previous assessments (Table 24). At the time of the current sampling effort, *Microcystis* and *Aphanocapsa*, both blue-green algae, dominated the sample, accounting for 27% and 26% of the community, respectively. In total, 64% of the Pretty Lake plankton community consisted of blue-green algae. This is consistent with the findings of previous assessments on Pretty Lake. In four comprehensive examinations of the lake (CLP, 1988, 1994 and 2004), blue-green algae accounted for 45% to 83% of the lake's plankton density.

4.4.3 Lake Water Quality 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, results from Pretty Lake 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 1970's 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 (i.e. few rooted plants, no 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.

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)	0.008	0.027	0.084	>0.750
Total Nitrogen (mg/L)	0.661	0.753	1.875	-
Chlorophyll *a* (µg/L)	1.7	4.7	14.3	-

Pretty Lake's total phosphorus concentration (mean of 0.019 mg/L) was higher than lakes in Vollenweider's oligotrophic category; however, the mean total phosphorus level was lower than lakes in the mesotrophic category. The lake's total nitrogen concentration 0.702 mg/L (mean) also places Pretty Lake in the oligotrophic to mesotrophic range, while the chlorophyll *a* concentrations (0.14 µg/L) suggests that Pretty Lake is more oligotrophic in nature, using Vollenweider's criteria.

Comparison with Other Indiana Lakes

The Pretty Lake results can also be compared with other Indiana lakes. Table 26 presents data from 456 Indiana lakes collected during July and August from 1994 to 2004 under the Indiana Clean Lakes Program. The set of data summarized in the table are mean values obtained by averaging the epilimnetic and hypolimnetic pollutant concentrations in samples from each of the 456 lakes. It should be noted that a wide variety of conditions, including geography, morphometry, time of year, and watershed characteristics, can influence the water quality of lakes. Thus, it is difficult to predict and even explain the reasons for the water quality of a given lake.

Table 26. Water quality characteristics of 456 Indiana lakes sampled from 1994 through 2004 by the Indiana Clean Lakes Program. Means of epilimnion and hypolimnion samples were used.

	Secchi Disk (ft)	NO_3 (mg/L)	NH_4 (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	Chl *a* (µg/L)	Plankton (#/L)	Blue-Green Dominance
Minimum	0.3	0.01	0.004	0.230	0.01	0.01	0.013	39	0.08%
Maximum	32.8	9.4	22.5	27.05	2.84	2.81	380.4	753,170	100%
Median	6.9	0.275	0.818	1.66	0.12	0.17	12.9	35,570	53.8%
Pretty	**11.8**	**0.018**	**0.147**	**0.702**	**0.010**	**0.019**	**0.14**	**901**	**65%**

Overall, Pretty Lake possessed better water quality than most lakes in Indiana (Table 26) during the July 17, 2006 assessment. Pretty Lake's Secchi disk transparency depth measured nearly double that found in most lakes in Indiana. The total and soluble reactive phosphorus concentrations were an order of magnitude lower than concentrations found in most Indiana lakes (Figure 44). Pretty Lake was also less productive, as measured by chlorophyll *a* concentration and plankton density, than most Indiana lakes.

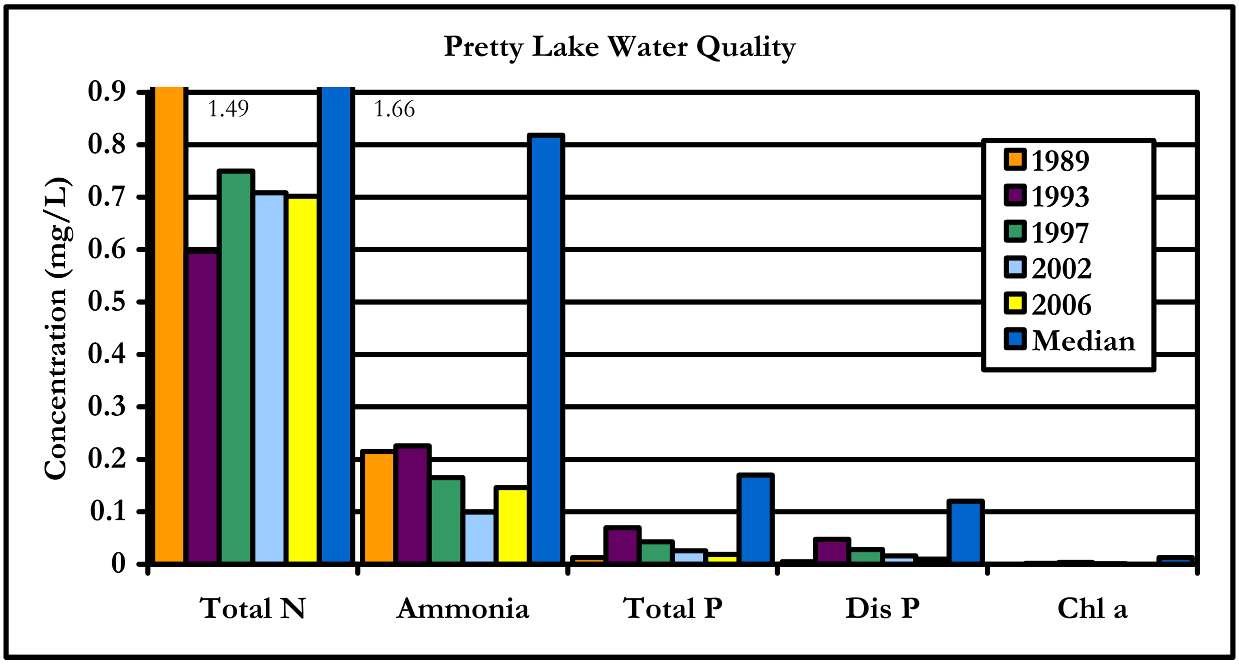

Figure 44. Selected nutrient concentrations within Pretty Lake compared to concentrations present in most lakes in Indiana.

Based on data collected in the five-year rotating basin cycle which occurred from 1999 to 2003, water quality within Pretty Lake is better than lakes throughout its ecoregion (SPEA, 2006). As previously discussed, Pretty Lake and its watershed lie entirely within the Southern Michigan/Northern Indiana Till Plains Ecoregion (Ecoregion 56). This ecoregion contains the largest number of lakes (239) found within any of Indiana's ecoregions (SPEA, 2006). Lakes within this ecoregion possessed a median Secchi depth of 5.9 feet (1.8 m), a median total phosphorus concentration of 0.079 mg/L, and a chlorophyll *a* concentration of 17.1 μg/L (SPEA, 2006). Lakes in this ecoregion rank third highest for Secchi disk transparency and total phosphorus concentration and possess the highest chlorophyll *a* concentration of any of Indiana's ecoregions. In comparison, Pretty Lake contained lower total phosphorus and chlorophyll *a* concentrations and possessed deeper water transparency. All of these translate to Pretty Lake containing better water quality than lakes throughout its ecoregion. Pretty Lake also possessed lower nitrate-nitrogen concentrations (0.018 mg/L compared to 0.057 mg/L), ammonia-nitrogen concentrations (0.047 mg/L compared to 0.437 mg/L), and total Kjeldahl nitrogen concentrations (0.702 mg/L compared to 1.341 mg/L) than most lakes in the ecoregion.

Using a Trophic State Index

In addition to simple comparisons with 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, numeric 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 score. Table 27 shows the point values assigned to 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

These categories correspond to the qualitative lake productivity categories described earlier (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 scores that do not necessarily indicate a long-term change in lake condition. (Jones (1996) suggests that changes in TSI scores of 10 or more points are indicative of changes in trophic status, while smaller changes in TSI scores may be more attributable to natural fluctuations in water quality parameters.)

At the time of the July 27, 2006 sampling, Pretty Lake possessed an Indiana Trophic State Index value of 15. This value places Pretty Lake in the oligotrophic category. This conclusion is generally consistent with results obtained from the comparison of the lake data to Vollenweider's data (Table 25), where nutrient parameters suggested the lake was oligotrophic to mesotrophic in nature. As will be described later in this section, the Indiana TSI score for Pretty Lake is also generally 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. Figure 45 illustrates the change in Pretty Lake's ITSI score over time. Figure 45 shows a general decline in Pretty Lake's ITSI score over time. The highest score calculated for Pretty Lake occurred in 1975 (25 points). Scores generally declined from this high to the current score of 15. The only exception to this occurred in 1989. The lake was assessment three times in 1989 with scores ranging from 8 to 13. The primary component that is missing from assessments that occurred in 1989 is the 10 points assigned for blue-green algal dominance. Blue-green algae did not dominate the plankton community during any of the assessments that occurred that year. Furthermore, higher total phosphorus, nitrate-nitrogen, and organic nitrogen concentrations; poorer light transmission, and higher plankton density typify the early assessments (1975 and 1989) compared with more recent assessments. Overall, ITSI scores declined by 10 points from the highest (worst) score (25) to the most recent and lowest ITSI score (15) calculated for the lake. Based on data from Jones (1996), a change ITSI score of 10 or more points indicates a change in water quality. If this holds true for Pretty Lake, water quality has improved within Pretty Lake in the last 30 years.

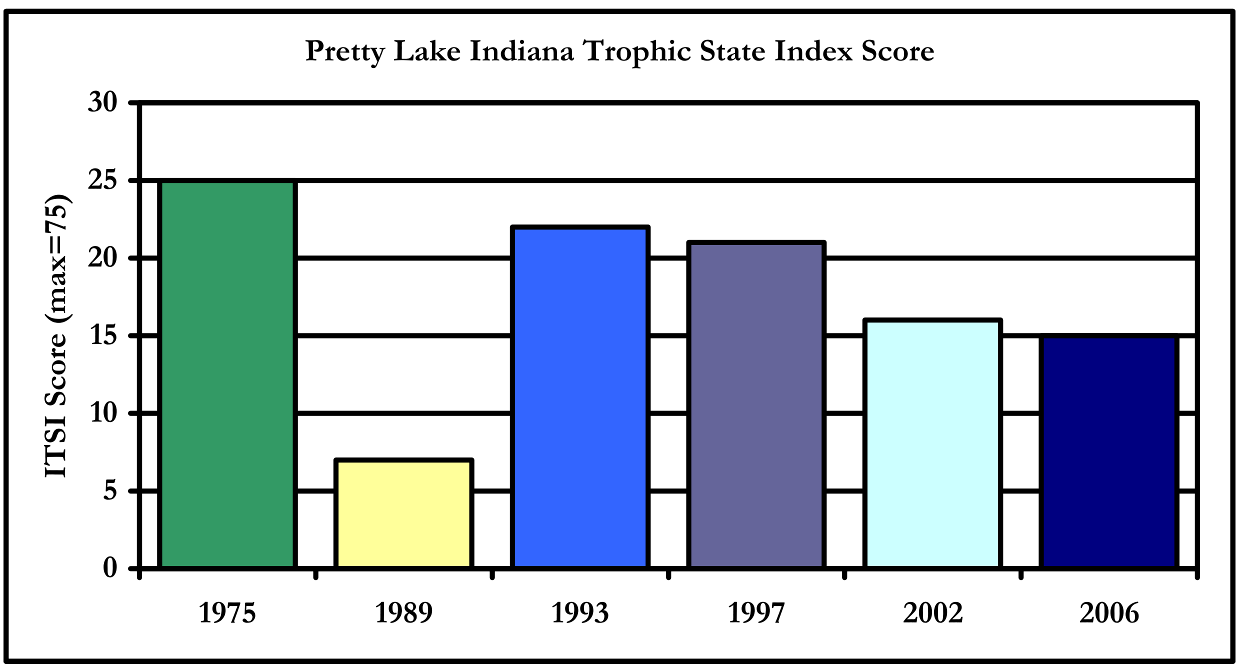

Figure 45. Indiana Trophic Index State scores for Pretty Lake from 1975 to 2006.

Using the ITSI to compare Pretty Lake to other lakes in the region, Pretty Lake's water quality is better than other lakes in the region. Based on data collected by the Indiana Clean Lakes Program during their 2000 to 2004 assessment cycle, approximately 19% of the lakes in the St. Joseph River Basin (which includes the Pretty Lake watershed) were classified as oligotrophic (IDEM, 2006).

Another 46% rated as mesotrophic. Twenty-nine percent fell in the eutrophic category, while 9% fell in the hypereutrophic category. Pretty Lake's placement in the oligotrophic category based on the ITSI suggests its water quality is among the upper 19% of lakes in the region when ranked by water quality. Pretty Lake's water quality rates better than 81% of the lakes in the St. Joseph River Basin. 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 on 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 for 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 46).

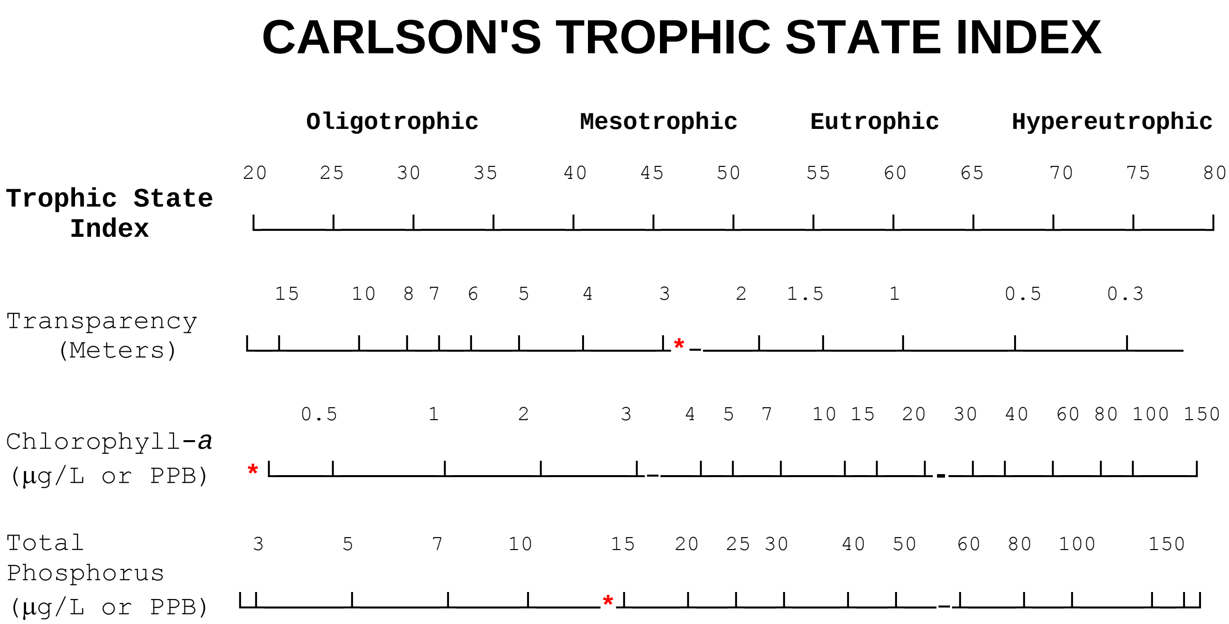

Figure 46. Carlson's Trophic State Index with Pretty Lake results indicated by asterisks.

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 summertime Secchi disk depth of 1 meter (3.3 feet) would have a TSI of 60 points (located in line with the 1 meter or 3.3 feet). This lake would be in the eutrophic category. Because the index was constructed using relationships among transparency, chlorophyll *a*, 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 *a* 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 *a* concentrations lower than might be otherwise expected from the total phosphorus concentrations or transparency measurements. 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.

Analysis of Pretty Lake's total phosphorus, transparency, and chlorophyll *a* data using to Carlson's TSI suggests that the lake is oligotrophic to mesotrophic (Figure 46). Pretty Lake's transparency and total phosphorus concentration place the lake in the mesotrophic category, while its chlorophyll *a* concentration places it off of the scale below the oligotrophic categories. This analysis is basically consistent with the results obtained when comparing the Pretty Lake data to Vollenweider's data. Both analyses suggest that Pretty Lake possesses sufficient phosphorus to support a greater level of productivity than the level suggested by the lake's chlorophyll *a* concentration.

As described above, the expected relationship between transparency, chlorophyll *a* concentration, and total phosphorus concentration is that Carlson's TSI score for each is the same. For Pretty Lake, Carlson's TSI scores using transparency and total phosphorus concentration are roughly equal (TSI (SD) = 41 and TSI (TP) = 46). However, Carlson's TSI score for chlorophyll *a* concentration is much lower (TSI (chl *a*) = 11). When TSI (SD) = TSI (TP) > TSI (chl *a*), something other than phosphorus is limiting algae growth. Potential limiting factors include zooplankton grazing and/or nitrogen limitation. In the case of Pretty Lake, zooplankton grazing may affect the lake's algal community. (Further studies would be needed to confirm this.) Additionally, the lake's extensive rooted plant community likely plays a role in limiting algae growth. Rooted plants have been shown to secrete alleopathic chemicals preventing algae growth. Again, more research (i.e. year round evaluation of the lake's temperature profile) is needed to determine if this is a factor in limiting algae production.

4.4.4 Lake Water Quality Assessment Summary

Pretty Lake contains more phosphorus than is ideal; however, phosphorus concentrations found in Pretty Lake are relatively low when compared with other lakes in the region. Nonetheless, the potential exists for excessive algal production to occur in Pretty Lake. Pretty Lake is considered mesotrophic when evaluated with both Carlson's total phosphorus TSI and when compared with Vollenweider's phosphorus data. Conditions visible on the surface of Pretty Lake appear to be better than most lakes in the region; likewise, conditions in the lake's hypolimnion are also relatively good. Years of plant and algae production and transport of organic material into Pretty Lake from its watershed have led to a build-up of decaying organic matter in the sediments of Pretty Lake (Table 28). As bacteria decompose this material, they consume oxygen and leave the bottom waters *anoxic* (dissolved oxygen concentrations < 1.0 mg/L). Currently, the lake becomes anoxic below 68.9 feet

(21 m). This results in more than 83% of the water column containing sufficient dissolved oxygen for aquatic biota.

Table 28. Summary of mean total phosphorus, total nitrogen, Secchi disk transparency, and chlorophyll a results for Pretty Lake.

Parameter	Pretty Lake
Mean total phosphorus (mg/L)	0.019
Mean soluble reactive phosphorus (mg/L)	0.010
Hypolimnetic ammonia-nitrogen (mg/L)	0.275
Total nitrogen:Total phosphorus[1]	33.6:1
Mean total nitrogen (mg/L)	0.702
Secchi disk transparency (ft)	11.8
Chlorophyll *a* (μg/L)	0.14
Sediment phosphorus release factor[2]	1

[1]Total nitrogen:Total phosphorus ratio is calculated based on epilimnetic concentrations.
[2]Hypo SRP concentration/Epi SRP concentration. For example, Pretty Lake's hypolimnetic SRP concentration is equal to the SRP concentration present in the epilimnion. This similarity is evidence of limited internal loading of phosphorus.

Despite the presence of anoxic conditions, there is little evidence of internal phosphorus release from Pretty Lake's sediment (Table 28). There are equal portions of soluble phosphorus in the hypolimnia (bottom waters) of Pretty Lake when compared to the lake's epilimnetic concentration. This is strong evidence that phosphorus is not being liberated from the sediments when oxygen is depleted or the lake is *anoxic*. The row labeled "Sediment Phosphorus Release" details the amount of soluble phosphorus (the form of phosphorus that can be released from the sediments) in the deepwater (hypolimnetic) sample to the surface (epilimnetic) sample. In Pretty Lake, the ratio is 1, which indicates that sediment phosphorus release is not occurring or if it is occurring, it is occurring at a very low rate. In most lakes in Indiana, phosphorus release from the sediments is an additional and important source of phosphorus to the lake that must be addressed along with watershed practices when designing a management plan to reduce nutrient loading to the lake. This *internal loading* of phosphorus is another source of phosphorus to these lakes that can promote excessive algae production. Current data suggest that internal loading of phosphorus is not a large component of the lake's phosphorus load. However, as will be discussed in more detail in the Phosphorus Modeling Section, this may not always be the case in Pretty Lake.

Pretty Lake also contains a relatively high ammonia nitrogen concentration in its hypolimnion (Table 28). Ammonia is a by-product of bacterial decomposition. When ammonia occurs in high concentrations, it is evidence of high biological oxygen demand. This biological oxygen demand comes from organic waste, such as dead algae and rooted plants, within the sediments, which provides further evidence of excess algae and rooted plant growth in these lakes.

4.5 Macrophyte Inventory

4.5.1 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 that rooted plant species such as northern watermilfoil, 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 determine the lake's fish community composition and structure. Submerged aquatic vegetation provides cover from predators and is a source of forage for many different species of fish (Valley et al., 2004). However, extensive and dense stands of exotic aquatic vegetation can have a negative impact on the fish community. For example, a lake's bluegill population can become stunted because dense vegetation reduces their foraging ability, resulting in slower growth. Additionally, dense stands reduce predation by largemouth bass and other piscivorous fish on bluegill which results in increased intraspecific competition among both prey and predator species (Olsen et al., 1998). Vegetation removal can have variable results on improving fish growth rates (Cross et al., 1992, Olsen et al., 1998). Conversely, lakes with depauperate plant communities may have difficulty supporting some top predators that require 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 Pretty 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 watermilfoil, 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 deeper water depth (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. Pretty Lake possesses better water clarity than the average Indiana lake. The Secchi disk depth measured during the plant survey was 11.5 feet (3.5 m). (This measurement was slightly poorer than the Secchi disk depth measured for the lake during the in-lake sampling portion of the study (11.8 feet or 3.6 m).) 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 to 3 times the lake's Secchi disk depth. This holds mostly true in Pretty Lake, where rooted plants were observed in water to a depth of approximately 35 feet (10.7 m), which is more than three times the lake's average Secchi disk depth.

Aquatic plants also require a steady source of nutrients for survival. Many 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. 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 watermilfoil or coontail, may increase macrophyte density rather than decrease it. Herbicide treatment can also affect the presence and distribution of aquatic macrophytes within a lake. As species or areas are selectively treated, the density and diversity of plant present within those locations can, and typically do change. For example, continuing to treat a specific plant bed which contains Eurasian watermilfoil can result in the disappearance of Eurasian watermilfoil and the resurgence of a variety of native species. It should be noted, however, that non-native plants can regrow in these locations just as easily as native plants.

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 waterfowl were observed utilizing Pretty Lake as habitat during the macrophyte survey. Aquatic plants such as pondweed, coontail, duckweed, watermilfoil, and arrowhead, also provide a food source to 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.

4.5.2 Macrophyte Inventory Methods

JFNew surveyed Pretty Lake on August 2, 2006 according to the Indiana Department of Natural Resources Tier One sampling protocol (IDNR, 2006). JFNew examined the entire littoral zone of the lake. As defined in the protocol, the 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 (23 feet or 7 m) during the in-lake sampling effort.) At the time of sampling, Pretty Lake's Secchi disk depth was 11.5 feet (3.5 m); thus, its 1% light level was estimated to be approximately 34.5 feet (10.5 m). Consequently, JFNew sampled that area of Pretty Lake that was less than 35 feet (10.7 m) deep.

A survey crew, consisting of one aquatic ecologist, one botanist, and a citizen volunteer boat driver, surveyed Pretty Lake in a clockwise manner, starting at the lake's southwest corner near the IDNR boat ramp. The survey crew drove their boat in a zig-zag pattern across the littoral zone of the lake while visually identifying plant species. The crew maintained a tight pattern to ensure the entire zone was observed. While the estimated littoral zones of the lake were quite shallow allowing for good visual identification of plant species, in areas of dense plant coverage, rake grabs were performed to ensure all species were identified.

Rooted plants ring Pretty Lake's entire perimeter. For the purposes of the survey, the plant community in the lake was divided into different beds. The survey crew used plant community structure, species diversity, and species dominance (all visually estimated) to differentiate one bed from another. For example, an area dominated by only coontail would be separated from an area supporting a more diverse mix of submerged species. While there is subjectivity inherent in this method, it allows for a rapid evaluation of the lake's rooted plant community that still meets the goals of the survey.

Once the crew had visually surveyed an entire plant bed, the crew broadly 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 and created a field sketch of the bed. 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. GIS technology was utilized to estimate the perimeters of plant beds based on the field sketches, field notes regarding the depth of rooted plant growth, the lake's bathymetric map, and aerial photography.

4.5.3 Macrophyte Inventory Results

Pretty Lake supports an extensive rooted plant community. The community extends from the lake's shoreline to water that is just over 32 feet (9.8 m) deep. This is better than the extent of the littoral zone based on the lake's 1% light level of 23 feet (7 m), measured at the time of the in lake water quality survey. Pretty Lake's aquatic plant community can be roughly divided into fourteen beds that differ in community composition and structure. Figure 47 shows the approximate location and extent of each bed.

In total, approximately 75 aquatic and emergent plant species inhabit the water and shoreline of Pretty Lake (Table 29). The LARE protocol used to conduct the aquatic plant survey requires surveyors to note all plant species observed from a boat. Thus, plants in the wetland complexes adjacent to the lake were only counted if they were visible from the boat. If these wetland complexes had been explored in greater detail, it is likely that the total number of plant species would increase significantly.

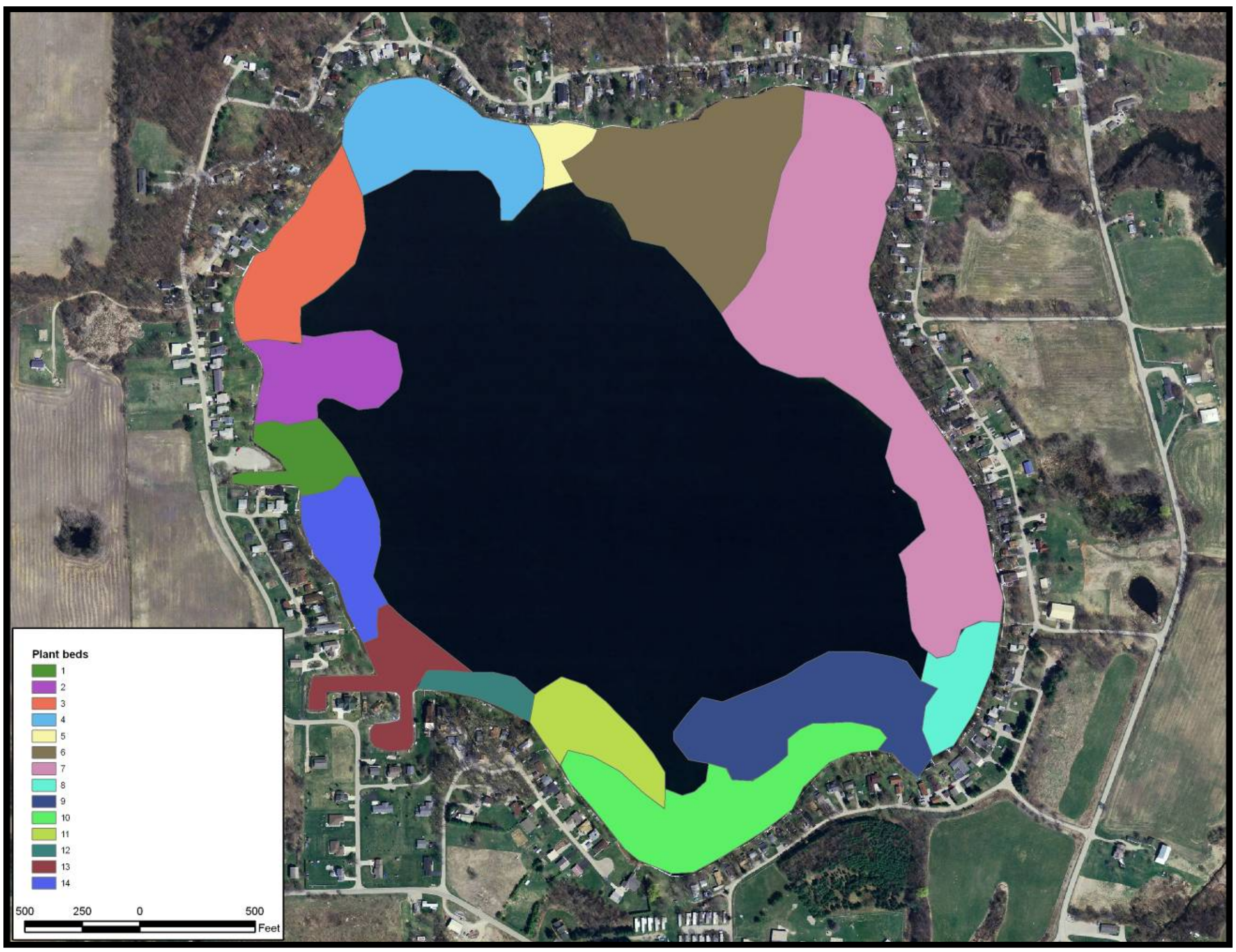

Figure 47. Pretty Lake plant beds as surveyed August 2, 2006.

Table 29. Plant species observed in Pretty Lake by plant bed as surveyed on August 2, 2006.

Scientific Name	Common Name	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9	Bed 10	Bed 11	Bed 12	Bed 13	Bed 14
Agrostis alba	Redtop (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Agrostis alba palustris	Bent grass (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Alisma subcordatum	Common water plantain (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Asclepias incarnata	Swamp milkweed (E)	--	--	<2%	--	--	<2%	--	--	--	--	<2%	<2%	--	--
Bidens cernua	Nodding beggar-ticks (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Bidens comosa	Swamp tickseed (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Boehmeria cylindrica	False nettle (E)	--	--	--	--	--	--	--	--	--	--	<2%	--	--	--
Brasenia schreberi	Water shield (RF)	--	--	--	--	--	--	--	--	<2%	<2%	2-20%	--	--	--
Ceratophyllum demersum	Coontail (S)	2-20%	<2%	--	<2%	--	<2%	<2%	--	<2%	--	<2%	--	<2%	--
Chara species	Chara species (S)	>60%	>60%	>60%	21-60%	<2%	21-60%	2-20%	2-20%	<2%	>60%	21-60%	>60%	21-60%	21-60%
Cicuta bulbifera	Bulblet-bear water-hemlock (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	<2%	--
Cirsium arvense	Creeping thistle (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Carex Comosa	Bearded sedge (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Decodon verticillatus	Whirled loosestrife (E)	<2%	--	--	--	--	<2%	--	--	<2%	<2%	<2%	--	--	--
Echinochloa crusgalli	Barnyard grass (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Eclipta prostrata	Yerba de tajo (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Eleocharis erythropoda	Bald spikerush (E)	<2%	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Eleocharis palustris	Creeping spikerush (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Elodea canadensis	Common water weed (S)	<2%	<2%	--	<2%	--	<2%	--	<2%	--	--	<2%	--	--	--
Elodea nuttallii	Nuttall's water-weed (S)	<2%	--	--	--	--	--	--	--	--	--	--	--	--	--

Scientific Name	Common Name	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9	Bed 10	Bed 11	Bed 12	Bed 13	Bed 14
Equisetum arvense	Field horsetail (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Filamentous algae	Filamentous algae (A)	21-60%	21-60%	2-20%	21-60%	<2%	21-60%	2-20%	2-20%	<2%	2-20%	2-20%	<2%	2-20%	<2%
Heteranthera dubia	Water star grass (S)	<2%	--	<2%	<2%	--	--	<2%	--	<2%	--	<2%	--	--	--
Iris virginica	Blue-flag iris (E)	--	--	--	<2%	--	--	--	--	--	--	--	--	<2%	--
Juncus species	Rush species (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Leersia oryzoides	Rice cut grass (E)	<2%	--	<2%	<2%	--	--	--	--	--	--	--	--	<2%	--
Lemna minor	Common duckweed (NF)	<2%	--	<2%	<2%	--	--	--	--	<2%	--	<2%	--	<2%	--
Lemna trisulca	Star duckweed (NF)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Ludwigia polycarpa	False loosestrife (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Lycopus uniflorus	Northern bugleweed (E)	<2%	--	<2%	--	--	--	--	--	--	--	--	--	<2%	--
Lysimachia nummularia	Creeping jennie (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Lythrum salicaria	Purple loosestrife (E)	--	--	--	--	--	<2%	--	--	--	--	--	<2%	--	--
Myosotis scorpioides	True forget-me-not (E)	--	--	--	--	--	--	--	--	--	--	--	--	<2%	--
Myriophyllum exalbescens	Northern watermilfoil (S)	<2%	--	--	<2%	--	--	<2%	--	--	--	--	--	--	--
Myriophyllum heterophyllum	Various leaved watermilfoil (S)	2-20%	<2%	--	<2%	--	<2%	<2%	--	21-60%	--	2-20%	--	2-20%	--
Myriophyllum spicatum	Eurasian watermilfoil (S)	2-20%	2-20%	2-20%	2-20%	--	21-60%	2-20%	--	2-20%	--	2-20%	--	21-60%	--
Najas flexilis	Slender naiad (S)	<2%	<2%	--	<2%	--	<2%	2-20%	2-20%	--	2-20%	<2%	<2%	--	<2%
Najas guadalupensis	Southern naiad (S)	--	<2%	<2%	<2%	--	--	<2%		<2%	--	--	--	--	<2%
Najas marina	Spiny naiad (S)	21-60%	<2%	--	<2%	--	<2%	<2%	<2%	<2%	--	<2%	21-60%	<2%	--
Nelumbo lutea	American lotus (RF)	--	--	--	--	--	--	--	--	--	--	<2%	--	--	--

Scientific Name	Common Name	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9	Bed 10	Bed 11	Bed 12	Bed 13	Bed 14
Nitella species	Nitella species (S)	--	--	--	2-20%	--	<2%	2-20%	--	<2%	--	--	<2%	--	2-20%
Nuphar advena	Spatterdock (RF)	2-20%		2-20%	<2%	--	2-20%	<2%	--	<2%	--	2-20%		2-20%	
Nymphaea tuberosa	White water lily (RF)	2-20%	<2%	2-20%	<2%	--	2-20%	<2%	--	<2%	<2%	2-20%	<2%	2-20%	<2%
Phalaris arundinacaea	Reed canary grass (E)	--	--	--	<2%	--	<2%	--	<2%						
Polygonum amphibium	Water knotweed (E)	<2%	--	--	--	--	--	--	--	--	--	--	--	--	--
Polygonum coccineum	Water heartsease (E)	<2%	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Polygonum lapathifolium	Willow-weed (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	--	--
Pontederia cordata	Pickerel weed (E)	2-20%	--	2-20%	2-20%	--	2-20%	<2%	--	<2%	<2%	2-20%	<2%	<2%	--
Potamogeton amplifolius	Large-leaf pondweed (S)	21-60%	--	<2%	2-20%	--	2-20%	2-20%	--	2-20%	--	2-20%	--	21-60%	--
Potamogeton berchtoldii	Broad-leaf small pondweed (S)	--	21-60%	2-20%	--	--	--	--	--	<2%		--	--	--	--
Potamogeton crispus	Curly-leaf pondweed (S)	<2%	--	--	--	--	--	--	--	--	--	--	--	--	--
Potamogeton foliosis	Leafy pondweed (S)	<2%	--	--	--	--	--	--	--	--	--	--	--	--	--
Potamogeton friesii	Fries's pondweed (S)	--	--	--	--	--	--	--	<2%	<2%	--	--	--	--	--
Potamogeton gramineus	Grassy pondweed (S)	2-20%	2-20%	2-20%	2-20%		2-20%	2-20%	<2%	2-20%	2-20%	2-20%	2-20%	<2%	2-20%
Potamogeton illinoensis	Illinois pondweed (S)	2-20%	21-60%	2-20%	2-20%	<2%	2-20%	2-20%	<2%	2-20%	<2%	2-20%	2-20%	--	<2%
Potamogeton natans	Floating-leaf pondweed (S)	--	<2%	--	<2%	--	--	--	--	--	--	<2%	--	2-20%	--
Potamogeton nodosus	Long-leaf pondweed (S)	<2%		<2%	<2%	--	--	--	--	--	--	--	--	--	--
Potamogeton pectinatus	Sago pondweed (S)	2-20%	2-20%	<2%	2-20%	--	2-20%	<2%	<2%	2-20%	--	<2%	<2%	2-20%	<2%
Potamogeton pusillus	Small pondweed (S)	<2%	--	--	2-20%	--	--	<2%		<2%	--	<2%	2-20%	--	<2%

Scientific Name	**Common Name**	**Bed 1**	**Bed 2**	**Bed 3**	**Bed 4**	**Bed 5**	**Bed 6**	**Bed 7**	**Bed 8**	**Bed 9**	**Bed 10**	**Bed 11**	**Bed 12**	**Bed 13**	**Bed 14**
Potamogeton richardsonii	Richardson pondweed (S)	--	--	--	--	--	<2%	--	--	--	--	--	--	--	--
Potamogeton zosteriformis	Flat-stem pondweed (S)	<2%	--	--	--	--	<2%	--	--	2-20%		<2%	--	--	--
Ranunculus longirostris	White water crowfoot (S)	--	--	--	--	--	--	--	--	--	--	<2%	--	--	--
Sagittaria latifolia	Common arrowhead (E)	<2%	--	<2%	--	--	--	--	--	--	--	--	--	<2%	--
Scirpus acutus	Hard-stem bulrush (E)	<2%	--	<2%	--	--	<2%	--	--	<2%	<2%	--	<2%	<2%	<2%
Scirpus fluviatilis	River bulrush (E)	--	--		--	--	--	<2%	--	--	<2%	--	--	--	--
Scirpus pungens	Chairmaker's rush (E)	--	--	<2%	<2%	--	--	<2%	<2%	--	--	<2%	<2%	<2%	--
Spearmint	Spearmint (E)	--	--	<2%	--	--	--	--	--	--	--	--	--	<2%	--
Spirodela polyrhiza	Large duckweed (NF)	--	--	<2%	--	--	--	--	--	--	--	--	--	<2%	--
Typha angustifolia	Narrow-leaf cattail (E)	--	--	--	--	--	--	--	--	--	--	<2%	--	<2%	--
Typha x *glauca*	Blue cattail (E)	<2%	--	--	--		--	--	--	--	--	<2%	--		--
Typha latifolia	Broad-leaf cattail (E)	<2%	--	<2%	--	--	<2%	<2%	--	<2%	--	<2%	--	<2%	--
Utricularia vulgaris	Common bladderwort (S)	--	--	--	--	--	--	<2%	--	--	--	--	--	<2%	--
Valisneria americana	Eel grass (S)	2-20%	21-60%	21-60%	2-20%	--	21-60%	<2%	--	21-60%	--	21-60%	2-20%	--	<2%

Of the 73 species observed in Pretty Lake, nearly half (27) were submerged plant species. Additionally, of the 27 submerged species, nearly half of those (13) were pondweeds (i.e. belonging to the *Potamogeton* genus). Compared to other lakes in the region this represents excellent species richness of the submerged strata. Chara was by far the most dominant submerged species. Chara was found in each of the fourteen plant beds in Pretty Lake. In all but two beds, chara covered at least 2% of the plant bed's canopy. In five of the 14 beds, chara covered more than 60% of the plant bed's canopy. Eurasian watermilfoil, grassy pondweed, Illinois pondweed, and eel grass are also common in Pretty Lake. Eurasian watermilfoil was observed in all but one plant bed and generally represented 2-20% of the bed's canopy. Grassy pondweed inhabited nine of the 14 plant beds and generally covered 2-20% of each bed's canopy. Eel grass and Illinois pondweed each inhabited eight of the 14 plant beds and they usually covered 21-60% and 2-20% of the bed' canopy, respectively. Spiny naiad, large-leaf pondweed, sago pondweed, small pondweed, various-leaved milfoil, filamentous algae, and slender naiad are also important components of the Pretty Lake submerged community. Four exotic species, including Eurasian watermilfoil, curly-leaf pondweed, purple loosestrife, and reed canary grass were identified within or adjacent to Pretty Lake.

Two of the 27 submerged species in Pretty Lake are state listed species. Fries' pondweed, a state rare species, was found near the boat ramp within Bed 01. Richardson's pondweed, a state rare species, was found within Bed 06 along the lake's northern shoreline. The presence of these species indicates that Pretty Lake contains sufficient water quality to support rare species like the two pondweeds mentioned above. (See the **Endangered, Threatened, and Rare Species** section for definitions of state listing categories.)

The species richness of the emergent was greater than the submerged strata, while the floating strata's species richness was lower than the submerged stata's richness. Thirty-eight emergent species were noted bordering Pretty Lake's edges, and only seven floating species were observed in the lake. (It is important to note that there are significantly fewer floating aquatic species that are native to Indiana lakes compared to the number of emergent and submerged species. Consequently, many lakes possess low numbers of floating species.) The most common emergent species include pickerel weed, cattails, and bulrushes. Many of these species were observed in more than half of the lake's plant beds, although they tended to be very sparse in most beds. The most common floating species are white water lilies and spatterdock which were found in two of the 14 beds, and water shield, which was found in three of the 14 beds.

Pretty Lake's plant community covers nearly half of the lake's surface area. Canopy coverage is generally fairly dense, with submerged species accounting for most of the coverage in each plant bed. Canopy coverage of the submerged portion of the community covers more than 60% of the canopy within each bed in all but four of the plant beds. In three of these beds, submerged species cover less than 20% of the canopy; however, one bed is so sparse that all plants cover less than 2% of the canopy. As noted above, this high level of coverage is due to the fact that large portions of the lake's littoral zone are covered with chara. In contrast, canopy coverage of emergent strata is sparse. In two thirds of the plant beds, emergent species accounted for less than 2% of the canopy coverage. Canopy coverage of the floating strata varies across the lake. In most beds (8), the floating species cover less than 2% of the bed. In Beds 01, 11, and 13, however, canopy coverage of the floating species was greater than 20%.

The following paragraphs detail each of the fourteen plant beds in Pretty Lake. Appendix F contains a list of species found in each bed during the plant survey. Both common and scientific name are provided in the list. Appendix F also included the data sheets prepared for each bed. Data sheets provide information on the size and location of each bed and the type of substrate supporting each bed.

Bed 01

Bed 01 is located on the west side of Pretty Lake adjacent to the lake's public access ramp. It covers 2.4 acres (0.97 ha). The presence of floating and emergent strata separate Bed 01 from Bed 02 and Bed 14. Bed 01 supports 35 species including 20 species that represent the submerged stratum. This stratum dominates the community and possesses a canopy cover of greater than 60%. Emergent, non-rooted floating, and rooted floating species account for 14 of the 35 species present in Bed 01. Rooted floating plants cover 21 to 60% of the bed's canopy, while emergent plants cover 2 to 20% of the canopy. Non-rooted floating plants cover less than 2% of Bed 01's canopy. Chara dominates the canopy cover in Bed 01 covering more than 60% of the bed's canopy. Coontail, filamentous algae, various-leaved watermilfoil, Eurasian watermilfoil, spiny naiad, spatterdock, white water lily, pickerel weed, large-leaf pondweed, grassy pondweed, Illinois pondweed, sago pondweed, and eel grass are also common in Bed 01. Two exotic species, curly-leaf pondweed and Eurasian watermilfoil were present in Bed 01. These species account for less than 2% and 2 to 20% of the plant bed's canopy cover, respectively. The predominance of emergent and rooted floating plants typify the community present in Bed 01 (Figure 48).

Figure 48. Submerged and emergent zones within Bed 01.

Bed 02

Bed 02 is located north of Bed 01 adjacent to residential development. This bed extends farther into the lake than other beds along the western shoreline of Pretty Lake. It covers 4.6 acres (1.9 ha) and includes a sunken island. Bed 02's limited floating stratum separates Bed 02 from beds on either side (Bed 01 and Bed 03). Bed 02 supports 16 species, a majority of which (14 of 16) are submerged species. This stratum dominates the bed's density as well as its diversity resulting in a canopy cover of greater than 60%. No emergent or non-rooted floating species are present in Bed 02. Only one rooted floating species is present. These strata cover less than 2% of the canopy cover in Bed 02. Chara dominates the canopy cover in Bed 02 accounting for more than 60% of the bed's canopy. Filamentous algae, broad-leaf small pondweed, Illinois pondweed, and eel grass are also common in Bed 02 and comprise 21% to 60% of the canopy cover. Other common species in Bed 02 include Eurasian watermilfoil, grassy pondweed, and sago pondweed. These species account for 2% to 20% of the canopy cover. All of the remaining species cover less than 2% of the canopy. Overall, this community is relatively sparse.

Bed 03

Bed 03 occupies 5.7 acres (2.3 ha) of Pretty Lake and is located adjacent to residential development in the northwest corner of the lake. There is a small wooded area on the northwest edge of the bed that possesses a natural shoreline which remains undeveloped (Figure 49). This area acts as a break between two residential areas. Bed 03 supports 32 species, a majority of which are emergent species (16 of 32). The submerged stratum is comprised of 11 species and accounts for greater than 60% of the canopy cover in Bed 02. Emergent and rooted floating species possess a canopy cover of 2 to 20%. Some of the common species identified within Bed 02 include chara, eel grass, Eurasian watermilfoil, southern naiad, large-leaf pondweed, broad-leaf small pondweed, grassy pondweed, Illinois pondweed, long-leaf pondweed, spatterdock, and white water lily. Eurasian watermilfoil is the only exotic species found in Bed 03. Eurasian watermilfoil is common adjacent to docks and around moored boats within this bed (Figure 50). As is typical of this plant, fragments from other areas of the lake get caught in boat propellers, and then re-grow where they drop onto available substrate.

Figure 49. Undeveloped woodlot adjacent to Pretty Lake's northern shoreline.

Figure 50. Eurasian watermilfoil growing adjacent to piers and boats within Pretty Lake.

Bed 04

Bed 04 is located on the northwest corner of the lake and is completely bordered by residential development. This bed supports 28 species, a majority of which (19 of 28) are submerged species. This stratum possesses a canopy cover of greater than 60%. Abundant species identified within the lake include: chara, filamentous algae, Eurasian watermilfoil, nitella, pickerel weed, and eel grass. The bed also contains a large variety of pondweeds including large-leaf, grassy, Illinois, sago, and small pondweed. Rooted floating species in Bed 04 account for 2 to 20% of the canopy cover. This stratum is composed of two species: spatterdock and white water lily. Bed 04 contains two exotic species, Eurasian watermilfoil and reed canary grass. Eurasian watermilfoil is present around docks and moored boats while reed canary grass is an emergent exotic species located along the lakes shoreline. The bed covers 7.1 acres (2.9 ha).

Bed 05

Bed 05 is the smallest (1.1 acres; 0.4 ha) and the least diverse bed in Pretty Lake. This bed contains only three species: chara, Illinois pondweed, and filamentous algae. All of these species account for less than 2% of the canopy cover in Bed 05.

Bed 06

Bed 06 is a large bed (12.5 acres; 5.1 ha) with a naturally modified shoreline. Most of this bed is adjacent to residentially developed areas. This bed contains the diverse plant bed adjacent to the lake's main inlet (Deal Ditch; Figure 51). The submerged community is relatively diverse and quite dense within this bed. The submerged species in Bed 06 account for greater than 60% of the bed's canopy cover and include 15 different species including: coontail, chara, common water weed, various-leaved watermilfoil, slender naiad, spiny naiad, nitella, and eel grass. This bed also supports a variety of pondweeds including large-leaf, grassy, Illinois, sago, Richardson, and flat-stem pondweed. Rooted floating species and emergent species account for 2 to 20% of the canopy cover. Non-rooted floating species cover less than 2% of the canopy. There are only two rooted floating species, spatterdock and white water lily present in Bed 06. Three exotic species, purple loosestrife, Eurasian watermilfoil, and reed canary grass were present within Bed 06.

Figure 51. Outlet of Deal Ditch and its associated plant bed within Pretty Lake.

Bed 07

Bed 07 is the largest plant bed on Pretty Lake covering approximately 22.7 acres (9.2 ha) along nearly the entire eastern shoreline of the lake. This bed also contains the entirety of Job's Hole, the shallow area located off of the northeast shoreline. The shoreline is mixed between natural, undeveloped shoreline and naturally modified shoreline and is mostly covered by of residential development. The rooted plant community here differs than much of the rest of the lake due to the higher wave action present along this shoreline (Figure 52). Submerged species in Bed 07 account for 2 to 20% of the canopy cover, while non-rooted floating, rooted floating, and emergent species account for less than 2% of the canopy cover. Submerged species in Bed 07 also comprise the majority of species (17 of 24) identified in the bed. Common species include coontail; chara; water star grass; Eurasian watermilfoil; various-leaved watermilfoil; slender, southern, and spiny naiad; large-leaf , grassy, Illinois, sago, and small pondweed; and eel grass. No non-rooted floating species and the only two rooted floating species, spatterdock and white water lily were found in Bed 07. The only exotic species identified in Bed 07 was Eurasian watermilfoil.

Figure 52. Example of wave action present within Bed 07.

Bed 08

Bed 08 is a small bed (2.6 acres; 1.1 ha) located in the southeast corner of the lake, just south of Bed 07 and adjacent to residential development. Submerged species in Bed 08 account for 2 to 20% of the canopy cover and comprise the majority (8 of 11) of species identified in the bed. The common submerged species include chara; common water weed; slender and spiny naiad; and grassy, Illinois, and sago pondweed. All other species in the bed account for less than 2% of the canopy cover including filamentous algae, reed canary grass, and chairmaker's rush. No non-rooted floating species were found in the bed. Additionally, only one exotic species, reed canary grass, was present within the bed. Overall, this community is relatively sparse compared with other beds located throughout the lake.

Bed 09

Bed 09 abuts the southern shoreline of Pretty Lake along a short distance and extends into the lake north of Bed 10 along much of the southern portion of the lake. Bed 09 borders the northern edge of Bed 10 and contains a majority (17 of 26) of submerged species. This stratum dominates the bed's density as well as its diversity resulting in a canopy cover of greater than 60%. Common submerged species include coontail; chara; water star grass; various-leaved watermilfoil; Eurasian watermilfoil; southern and spiny naiad; large-leaf, broad-leaf, grassy, Illinois, sago, small, and flat-stem pondweed; and eel grass. Common duckweed is the only non-rooted floating species and it accounts for less than 2% of the bed's canopy cover. Spatterdock and white water lily are the beds only rooted floating species and also comprise less than 2% of the canopy cover in Bed 09. Nitella was identified in this bed at a depth of 30 feet (9.1 meters). A narrow band of emergent species, including whirled loosestrife, pickerel weed, hard-stem bulrush, and broad-leaved cattail, cover less than 2% of the canopy. The only exotic species present in the bed was Eurasian watermilfoil.

Bed 10

Bed 10 covers approximately 8.2 acres (3.3 ha) and extends along a large portion of the southern shoreline. This bed is relatively sparse and is sandwiched between the residentially developed shoreline and the denser Bed 09. There is, however, a narrow portion of shoreline that possesses submergent, emergent, and floating zones (Figure 53). Although submerged species account for greater than 60% of the canopy cover, there are fewer species in this stratum than in the emergent stratum, which accounts for less than 2% of the canopy cover. Submerged species in Bed 10 include chara, slender naiad, grassy pondweed, and Illinois pondweed. Emergent species include whirled loosestrife, pickerel weed, hard-stem bulrush, and river bulrush. The only rooted floating plants identified were white water lily and water shield, both of which account for less than 2% of the canopy cover in Bed 10.

Figure 53. Natural shoreline present within Bed 10.

Bed 11

Bed 11 (3.4 acres; 1.4 ha) touches the shoreline along the southeast portion of the lake, and then extends into the lake along the northwest edge of Bed 10 (Figure 47). Bed 11 supports 31 species including 17 species that represent the submerged stratum. This stratum dominates the community and possesses a canopy cover of greater than 60%. Rooted floating species account for 4 of the 31 species present in Bed 11 and account for a canopy cover of 21 to 60%. The largest community of water shield identified within Pretty Lake was found in Bed 11 (Figure 54). The emergent stratum accounts for 2 to 20% of the canopy cover and includes only 9 representatives in Bed 11. Common duckweed is the only non-rooted floating species in the bed and accounts for less than 2% of the canopy cover. Some common species in the bed include coontail; chara; filamentous algae; water star grass; water shield; various-leaved and Eurasian watermilfoil; slender and spiny naiad; spatterdock; white water lily; pickerel weed; large-leaf, grassy, Illinois, sago, small, and flat-stem pondweed; broad-leaved cattail; and eel grass. This bed also contains American lotus (Figure 55);

this is the only location in which it was identified in Pretty Lake. Eurasian watermilfoil was the only exotic species found in Bed 11.

Figure 54. Water shield bed located along the southern shoreline of Pretty Lake Bed 11.

Figure 55. American lotus identified adjacent to the shoreline within Bed 11.

Bed 12

Bed 12 (1.3 acres; 0.5 ha) is located in the southwestern corner of Pretty. The entirety of this bed is adjacent to residential development. The submerged stratum represents 9 of the 16 species in the bed and possesses a canopy cover of greater than 60%. Only 5 emergent species were identified in Bed 12. This stratum possesses a canopy cover of less than 2%. White water lily is the only species representing the rooted floating stratum which has a canopy cover of less than 2%. No non-rooted floating species were identified in Bed 12. Common species found within this bed include chara; filamentous algae; slender and spiny naiad; pickerel weed; grassy pondweed; Illinois, sago, and small pondweed; and eel grass. Purple loosestrife was the only exotic species present within Bed 12.

Bed 13

Bed 13 is also located in the southwestern region of Pretty Lake north of Bed 12 and includes the two manmade channels in the lake's southwest corner, both of which contain largely natural shorelines (Figure 56). The bed covers 3.2 acres (1.3 ha). This bed contains the greatest number of species compared with other beds in the lake. The emergent stratum dominates the bed in number of species (23 of 39), but only accounts for 2 to 20% of the canopy cover. The submerged stratum includes only 10 species, but possesses a canopy cover of greater than 60%. Chara and large-leaf pondweed dominate the submerged portion of this bed. Variable-leaved watermilfoil, long-leaf pondweed, and sago pondweed were also common within Bed 13. Common, star, and large duckweed are the only non-rooted floating species in the bed and account for less than 2% of the canopy cover. The rooted floating stratum consists of spatterdock and white water lily, which represent 21-60% of the canopy cover in Bed 13. Eurasian watermilfoil is the only exotic species in the bed.

Figure 56. Typical shoreline located within the man-made channels in Pretty Lake's southwest corner.

Bed 14

Bed 14 covers approximately 3.5 acres (1.4 ha) and is located along the western shoreline of Pretty Lake adjacent to residential development. Although the Bed 14 is larger than Bed 13, it contains about one-third the number of species found in Bed 13. The submerged stratum possesses greater than 60% canopy coverage and includes 9 of 12 species. Chara dominates this stratum accounting for greater than 60% canopy coverage. Variable-leaf pondweed and nitella were also common in Bed 14. The only rooted floating species found in Bed 14 was white water lily. This species was relatively rare and possesses a canopy cover of less than 2%. No non-rooted floating species and only one emergent species, hard-stem bulrush, were identified in Bed 14. This resulted in less than 2% canopy cover. Overall, this bed is relatively sparse compared to other beds located throughout Pretty Lake.

4.5.4 Macrophyte Inventory Discussion

As noted earlier in this section, the composition and structure of the lake's rooted plant community often reflect the long-term water quality of a lake. Limnologists can use rooted plant data to support or better understand results of a chemical analysis of a lake. Because of their relative longevity (compared to the chemical constituents of a lake), rooted plant data may help in confirming trends observed in historical data. Pretty Lake's rooted plant data is no exception. The survey and analysis of Pretty Lake's rooted plant community presented above confirms many of the conclusions drawn from analysis of the lake's water chemistry

Secchi disk transparency depths measured as part of this study indicated that Pretty Lake possessed good water clarity. The Secchi disk transparency depth recorded during the rooted plant survey extended to 11.5 feet (3.5 m) which is deeper than the statewide median Secchi disk transparency depth. Historical Secchi disk data suggest that Pretty Lake has maintained this good water clarity over the last 15 years. Earlier data indicate the water quality may have been even better.

Pretty Lake's rooted plant community reflects this good water clarity. Several of Pretty Lake's dominant submerged plant species, including large-leaf pondweed, northern watermilfoil, and flat-stem pondweed, thrive in clear water (Davis and Brinson, 1980; Borman et al., 1997; Curtis, 1998). Other species that are less abundant than the ones listed above, such as Richardson's pondweed and grassy pondweed, are also characteristic of clear northeastern lakes (Davis and Brinson, 1980). While Pretty Lake supports some species that are very tolerant of lower light conditions such as coontail, southern naiad, and Sago pondweed, these species are ubiquitous in northeastern lakes. Thus, their presence is not necessarily an indication of turbid water.

Pretty Lake also exhibits moderate to low nutrient concentrations rather than high nutrient concentrations observed in many other lakes in the region. Pretty Lake's diverse rooted plant community is a reflection of this low to moderate nutrient level. For example, regional lakes with relatively high total phosphorus levels, such as Silver Lake, Webster Lake, Little Chapman Lake, Ridinger Lake, and Smalley Lake, possess far fewer submerged species compared to Pretty Lake (JFNew 2000a, 2000b, 2001, 2004a, and 2004b). Additionally, in lakes with high total phosphorus concentrations, species tolerant of eutrophic water such as Eurasian watermilfoil, Sago pondweed, and coontail tend to dominate the rooted plant communities to the exclusion of species that are more sensitive to eutrophic conditions. In contrast, Pretty Lake supports a rooted plant community more similar to Big Chapman Lake or Dewart Lake, which both possess relatively moderate nutrient levels. Pretty Lake, Dewart Lake, and Big Chapman Lake all exhibit good species richness and dominant species that include northern watermilfoil and large-leaf pondweed, which area less tolerant of eutrophic conditions (JFNew, 2005; Chapman Lake Conservation Association et al., 2006).

Pretty Lake's rooted plant community highlights some of the differences among various areas of the lake. For example, rooted plant beds inhabiting water in front of developed portions of the lake generally possessed lower submerged species diversity than rooted plant beds in front of undeveloped portions of the lake. This lack of diversity may be due to efforts to remove (either mechanically or chemically) submerged plants to improve access to and recreational use of the lake. Alternatively, submerged plants in the developed areas may be subjected to more damage from boat propellers or wash from speeding boats. These pressures may prevent more sensitive species from becoming established in front of developed shoreline. Similarly, developed portions of the lake tended to lack emergent plant cover compared to undeveloped portions. It is likely that lake residents removed emergent plants along their property to improve access to and views of the lake.

Manipulation of Pretty Lake's plant either via mechanical (harvesting, boating damage) or chemical (herbicide/algicide applications) means can impact the surviving plant community. For example, emergent vegetation filters runoff from adjacent areas and removal of emergent vegetation eliminates this function. The loss of this function may lead to an increase in nutrient and sediment concentration in the area of lake in front of developed shoreline. An increase in nutrient and sediment concentration can, in turn, shift the submerged plant community from a balanced community to one dominated by species tolerant of eutrophic water conditions.

Despite some areas of nuisance exotic species growth, Pretty Lake generally supports a healthy, relatively high quality rooted aquatic plant community. Pretty Lake supports a rich submerged community that includes 13 species of pondweed. Nearly half of the lake's littoral zone is vegetated and rooted plants are observed in water deeper than 30 feet (9 m). Additionally, several high quality, sensitive species live in Pretty Lake. These are all characteristics of lakes with high quality plant communities (Nichols et al., 2000).

Into the Future

Changes in a lake's rooted plant communities over time can illustrate unseen chemical changes in the lake. Unfortunately, limited data detailing Pretty Lake's historical rooted plant community exists for comparison to the current data. In the past, IDNR fisheries biologists conducted cursory vegetation surveys as a part of their general fisheries surveys. Historical studies recorded many of the same species that currently dominate Pretty Lake. In 1964, McGinty noted the presence of 12 emergent species and 14 submerged species including nine pondweeds (McGinty, 1966). The dominance of chara and lack of plant growth across much of the lake bottom were also noted during this survey. Several state endangered, threatened, or rare species including Robbin's pondweed, narrow-leaf pondweed (*Potamogeton pusillus*), fine-leaf pondweed (*Potamogeton strictifolius*) were identified during McGinty's survey. During multiple surveys by the IDNR in the 1970s, the IDNR identified 13 aquatic plant species including milfoil, chara, coontail, and multiple pondweed species (flat-stem, leafy, curly-leaf, and large-leaf pondweed). These same species dominated Pretty Lake's plant community during surveys conducted in 1985, 1989, 1996, and again during the current assessment. The maximum depth at which plants were found was also similar among historical studies and the current study. During the current study, plants were observed in water depths greater than 35 feet (10.2 m). The IDNR and EarthSource studies place the extent of the littoral zone closer to 15 feet (4.6 m) or 20 feet (6.1 m) as observed during the 1979 and 1989 surveys, respectively.

The biggest differences between the current study of Pretty Lake's plant community and the historical study is the variation in the diversity of submerged species and in the overall species richness. During the 1964 survey, the IDNR observed 27 plant species, 16 of which were submerged species. The 1973 and 1978 IDNR plant surveys indicate that 13 plant species, including 9 submerged species, were present within Pretty Lake, while the 1979 survey indicates the presence of only nine species in Pretty Lake. The current survey reports the presence of 73 species (28 submerged) within Pretty Lake. A difference in survey methodology is likely the reason for the observed difference in species richness rather than an actual increase in the number of plant species in Pretty Lake. Future IDNR fisheries surveys will likely be more detailed in scope than the historic surveys. These future IDNR fisheries surveys should be compared to the results of the rooted plant survey detailed in this report for the current assessment to document any of the changes described above.

The decline in density or distribution of high quality species may indicate a change in water quality. There is little evidence at this time to suggest that Pretty Lake's water quality may be declining. Rather, water quality within Pretty Lake appears to be increasing over quality observed during previous assessments. Nonetheless, the aquatic plant community will be the first source to indicate declining water quality. Aquatic plant species that should be monitored in Pretty Lake to determine if the plant community is signaling a larger change in water quality include large-leaf pondweed, long-leaf pondweed, grassy pondweed, floating-leaved pondweed, and flat-stem pondweed. Davis and Brinson (1980) suggest these pondweeds are fairly sensitive to increasing eutrophication. All of these species rate low on Davis and Brinson's survival index. (A low rating is associated with an inability to survive as the lake environment changes.) A decline or loss of these species from Pretty Lake might indicate an increase in eutrophication of Pretty Lake.

Nuisance and Exotic Plants

Although they have not yet reached the levels observed on many other regional lakes, several nuisance and/or exotic aquatic plant species grow in Pretty Lake. As nuisance species, these species will continue to proliferate if unmanaged, so data collected during the plant survey will be outdated quickly and should not be used to precisely locate nuisance species individuals or stands. (Additionally, it is likely that the watershed supports many terrestrial nuisance species plant species, but this discussion will focus on the aquatic nuisance species.) The plant survey revealed the presence of two submerged, aggressive exotics: Eurasian watermilfoil (Figure 57) and curly-leaf pondweed (Figure 58). It also supports two emergent exotic plant species: purple loosestrife (Figure 59) and reed canary grass (Figure 60). As exotic invasive species, these species have the potential to proliferate if left unmanaged. It is possible that these or other exotic species could exist within the thick emergent portions of the rooted plant community near the east and west ends of the lake but were not observed during this survey.

Figures 57. Eurasian watermilfoil (*Myriophyllum spicatum*) and 58. Curly-leaf pondweed (*Potamogeton crispus*).

 

Figure 59. Purple loosestrife (*Lythrum salicaria*) and Figure 60. Reed canary grass.

The presence of Eurasian watermilfoil in Pretty Lake is of concern, but it is not uncommon for lakes in the region. Eurasian watermilfoil is an aggressive, non-native species common in northern Indiana lakes. 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 watermilfoil 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 more or less aggressive than Eurasian watermilfoil. Its presence in the lake is a concern. Like many exotic invasive species, 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 more tolerant of cooler water temperature than 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.

Purple loosestrife is an aggressive, exotic species introduced into this country from Eurasia for use as an ornamental garden plant. Like Eurasian watermilfoil, 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 Pretty 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.

Although it was not identified in Pretty Lake during the aquatic plant survey, another exotic, invasive species, hydrilla, was identified for the first time in Indiana at Lake Manitou in Fulton County. Hydrilla is a submerged plant that resembles common waterweed. However, hydrilla can tolerate lower light levels and higher nutrient concentrations than most native aquatic species. Because of its special adaptations, hydrilla can live in deeper water and photosynthesize earlier in the morning than other aquatic species. Because of these factors, hydrilla is often present long before it becomes readily apparent. It often grows quickly below the water and becomes obvious only after out-competing other species and forming a monoculture. Dense mats of hydrilla often cause pH imbalances and temperature and DO fluctuations. This allows it to out-compete other aquatic-plant species and can cause imbalances in the fish community.

The presence of Eurasian watermilfoil, 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 watermilfoil 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 are discussed in the **Management** section of this report.

4.6 Fisheries

The Pretty Lake fishery was initially surveyed by the Indiana Department of Natural Resources (IDNR) in 1964 with subsequent general fishery surveys in 1973, 1979, 1983, and 1996. Angler-use or creel surveys were conducted concurrently with the general survey in 1983 and 1996. Special investigations were performed in 1979, 1985, and 1991 to assess the success of trout stocking programs (Koza, 1996). In 2005, a special survey occurred to investigate the success of the walleye stocking program (Ledet, 2005). A complete list of the fish species found during the various assessments can be found in Appendix G.

Pretty Lake can be described as primarily a panfish-largemouth bass fishery. Yellow perch and northern pike provide secondary recreational fishery options (Figure 61). Previously, rainbow trout were an important recreational resource and were actively managed through stocking efforts (McGinty, 1964; Petersen, 1974). However, due to a decrease in summer habitat conditions, (primarily water temperature) and angler interest, the stocking program was discontinued (Ledet, 1991). Walleye stocking started during the mid 1990s to provide an additional recreational fishery (Koza, 1996). The walleye stocking program continued on an annual basis from 1993 to present day (Ledet, 2005). In a 2005 evaluation of the walleye stocking program, Ledet (2005) determined that four of the 14 stockings were considered a success based on statewide criteria and recommended that stocking should continue to provide walleye angling opportunities.

The 1964 survey was the first IDNR survey of the lake and followed the U.S. Geological Survey's lake bathymetric mapping in 1956. Twenty-one fish species were sampled during the survey. Redear sunfish were the most common fish sampled comprising 38.3% of the relative abundance. Bluegill (21.3%), green sunfish (7.7%), largemouth bass (7.3%), and warmouth (5.2%) were the next four most abundant species. Although only two fish were identified during in the survey, Pretty Lake was known for producing fair numbers of stocked rainbow trout ranging from 5 to 8 pounds including the state record at the time of 8 lbs, 5 ounces. Northern pike comprised 3.0% of the catch and possessed "good" to "very good" growth rates. In addition, Pretty Lake was known as an excellent northern pike fishery (McGinty, 1964).

The following paragraphs provide a brief summary of the IDNR fishery management survey findings for each given survey year. A list of the IDNR reports used in the following summaries can be found in the literature cited. When reviewing the summaries below, and to some extent the IDNR reports themselves, it is important for the reader to understand that the collection methodologies and procedures used by the IDNR have changed over time. Therefore, any information below should be viewed for trends over time rather than direct comparisons from study year to year. In 2001, the IDNR addressed this by adopting a set of standardized sampling protocol for future studies.

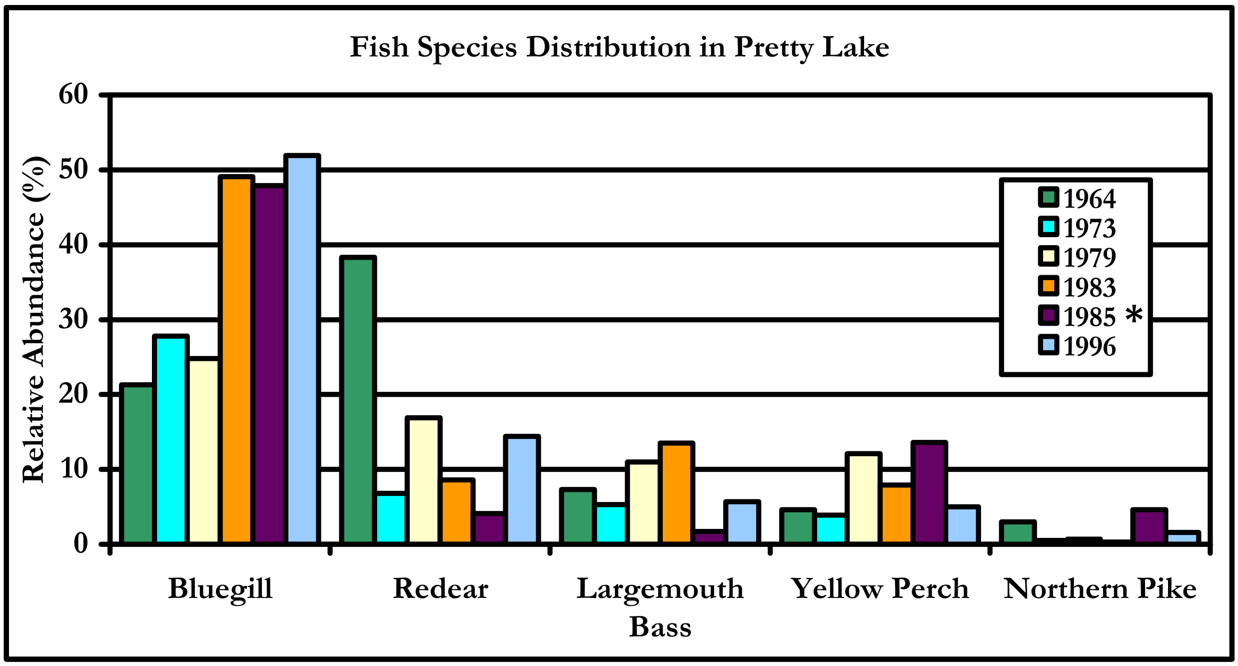

Figure 61. Percent community composition by number of fish collected for Pretty Lake.

Seventeen fish species were sampled during the 1973 general fisheries survey. Bluegill were the most abundant species comprising 27.8% of the relative abundance. 10.6% of the 114 bluegill sampled were of catchable size (six inches or greater). Warmouth (15.9%), green sunfish (9.3%), lake chubsucker (9.3%), and yellow bullhead (8.1%) were the next four most abundant species. The relative abundance of largemouth bass was 5.3%. Yellow perch and northern pike relative abundances were 3.9% and 0.5%, respectively (Petersen 1974).

In 1979, sixteen fish species were sampled during the general fisheries survey. Bluegills were again the most abundant comprising 24.8% of the total catch. Of the 152 bluegill sampled, 33.6% were of catchable size. Redear sunfish (16.9%), yellow perch (12.1%), largemouth bass (11.0%), and yellow bullhead (9.2%) were the next four most abundant species. Northern pike comprised only 0.7% of the total catch (Niefeldt, 1980).

Twenty fish species were sampled during the 1983 general fisheries survey. Bluegills were the most abundant, comprising 49.1%. Largemouth bass (13.5%), redear sunfish (8.6%), yellow perch (7.9%), and yellow bullhead (3.4%) were the next four most abundant species. Northern pike comprised only 0.3% of the total catch (Ledet, 1984).

The most recent general fisheries survey occurred in 1996 (Koza, 1996). Nineteen fish species were sampled during the survey. Bluegills were the most abundant comprising 51.9% of the overall catch. Redear sunfish (14.4%), largemouth bass (5.7), rock bass (5.5%), and yellow perch (5.0%) were the next four most abundant species. Walleye composed 2.3% of the total abundance, which is a result of a walleye stocking program that began in the 1990s. Northern pike comprised 1.6% of the total catch.

The water quality of Pretty Lake is reflected in the fishery. Naturally-reproducing populations of largemouth bass and northern pike; a quality bluegill/redear sunfish fishery combined; and a successful walleye stocking program indicate a lake with stable and excellent water quality. Although trout are no longer stocked, lack of angler interest probably played as large of a role in this management change as the loss of summer habitat conditions (primarily water temperatures). Figure 41 shows no significant change or trend in annual summer water temperature profiles. If water quality remains stable or continues to improve there should be no significant change to the fishery. However, the introduction of exotic plant and animal species, changes in angler harvest or pressure, or global climate change could have a negative impact on a quality recreational fishery.

4.7 Zebra Mussels

Zebra mussels are an exotic species of concern for many lakes and rivers throughout the state and for Pretty Lake as well. Zebra mussels were collected in Pretty Lake in 2004 (USGS, 2006). Zebra mussels are small, fingernail-size, freshwater mollusks which are native to the Caspian, Black, and Aral Seas of Eastern Europe. Mature females can produce between 30,000 and 100,000 eggs per year which hatch into larvae, called veligers, the size of the period at the end of this sentence. Within two to three weeks of hatching the veliger shells begin to harden and become able to attach and detach from hard surfaces like rock, wood, glass, rubber, metal, gravel, other zebra mussels, and shellfish. Zebra mussel shells were also found attached to vegetation during the aquatic plant survey conducted as part of this study.

Zebra mussels are one of at least 139 non-indigenous aquatic species that have become established in the Great Lakes area since the early 1800s. They were probably introduced from transoceanic ship ballast water around 1986. They rapidly spread throughout the Great Lakes and into several river systems of the eastern U.S. including the Ohio, Illinois, Mississippi, Mohawk, Hudson, Susquehanna, Tennessee, and Arkansas. Zebra mussels were probably first introduced into Pretty Lake in the early to mid-1990s. Brant Fisher (personal communication) reports the presence of zebra mussels in Pretty Lake during his 1999 survey of the lake. Larry Clemens (personal communication) of The Nature Conservancy claims that because larger Indiana lakes received zebra mussels first, the primary mechanism of spread has been via boat transport from Lake Michigan. Experts accredit their rapid spread mainly to veliger drift in currents and transport from one water body to another via bilges, bait buckets, and ballast water. Zebra mussels will likely continue spreading throughout most of the U.S. unless effective preventative measures are employed.

Property damage and ecosystem impairment can be attributed to the nuisance exotic species. Zebra mussels pose a multi-billion dollar threat to water supplies for municipalities, industry, and agriculture and cause costly damage to shoreline facilities and residences. Mussel colonies, reaching densities of 115,000/m^2, can clog water intake pipes, valves, and screens at municipal water facilities, industrial facilities, and power plants. The mollusks cause costly shipping and boating damages by attaching to motors, propellers, buoys, hulls, and cooling systems of engines. Zebra mussels also have detrimental effects on the biological and ecological functions of aquatic ecosystems in North America. They colonize the shell surfaces of native unionid mussels disrupting feeding, locomotion, respiration, and reproduction. Death usually occurs within two years. Due to the zebra mussel invasion and other environmental problems, fifty-five percent of native North American unionid mussels are extinct or imperiled.

Zebra mussels are efficient filter-feeders and consume large amounts of phytoplankton (microscopic algae) which are food for zooplankton (small animals) that nourish small fish. Without the plants at the base of the food chain, zooplankton populations decline causing fish recruitment to decline as well. Additionally, mussels essentially filter out contaminants like PCB and other hazardous hydrocarbons from the water column and concentrate them in their tissues. The toxins may then be biomagnified in mussel predators higher in the food web. Filter-feeding also results in a rerouting of dissolved and particulate-bound contaminants from the water column to the sediments in the form of feces and pseudofeces where benthic or bottom-feeding invertebrates may ingest them. Fish consuming the invertebrates further biomagnify the toxins, and since zebra mussel introduction, PCB concentrations in top-predators have increased.

Because zebra mussels did not evolve in North America, infected waters lack an efficient predator to biologically control their populations. Although diving ducks, freshwater drum, carp, sturgeon, sunfishes, and suckers do eat mollusks, no predator is capable of controlling mussel populations. Introducing other Eurasian molluscivores is risky because biomanipulation efforts often fail since introduced predators will not feed on the introduced pest or will not inhabit the areas occupied by the pests. Historically, the introduced predator has become an invader itself or has negatively affected other native species.

Zebra mussels also affect water quality by altering the sediments and the water column of infested water bodies. Colonies of mussels increase the amount of benthic organic matter through the production of waste products. A shift in the community composition of the invertebrates that inhabit the benthic sediments occurs, and invertebrates usually indicative of poorer water quality become dominant (like tubificid oligochaetes and chironomids). Zebra mussels are also associated with an increase in water clarity and light penetration which in turn may result in increased macrophytic vegetation growth. However, they selectively filter out small forms of phytoplankton (diatoms and cryptophytes), with no impact on colonial and filamentous cyanobacteria. Nutrient resources no longer used by the small members of the algal community become available to cyanobacteria causing noxious blooms. Zebra mussels also release large amounts of bioavailable nitrogen (ammonium, NH_4^+) which may be utilized by large, undesirable algae. Additionally, the invading mussels are associated with increasing fractions of dissolved, bioavailable toxins in the water column.

Because recreational boating is the primary mechanism for dissemination of adult and larval zebra mussels, following some simple precautions can help prevent the spread of this aquatic nuisance organism:

1. Remove visible vegetation from equipment and objects that were in the water.
2. Flush engine cooling system, live wells, and bilge with hot water or tap water. Water of 110°C and 140°C will kill veligers and adults respectively.
3. Rinse any other areas that get wet like trailers, boat decks, etc.
4. Air dry boat and equipment for two to five days before using in uninfested waters.
5. Examine boat exterior if it has been docked in mussel-infested waters. If mussels or large amounts of algae are found, clean the surfaces or dry the boat for at least five days.
6. Do not reuse bait or bait bucket water if they have been exposed to mussel-invaded waters.

Many times recreational users are the first to document exotic species in an area. To help local natural resource officials, learn how to identify exotic species found in northeastern Indiana. If an unidentifiable fish or other aquatic organism is encountered, note the date and location where the specimen was found and collect it if possible. Store it in rubbing alcohol and contact the local USFWS or state natural resources office.

Identify zebra mussels by:

1. Shell Appearance: zebra mussels look like small D-shaped clams of a yellow or brown color. The shell is characterized by light and dark striping resembling tiger stripes (Figure 62).
2. Size and Location: most zebra mussels are only the size of a fingernail but may be up to two inches long. They tend to grow in colonies of multiple individuals in shallow, productive waters.
3. Attachment: no other freshwater mussels can firmly attach themselves to solid substrates.

Figure 62. Adult zebra mussel.

5.0 MODELING
5.1 Water Budget

Inputs of water to Pretty Lake are limited to:

1. direct precipitation to the lake
2. discharge from the intermittent inlet streams
3. sheet runoff from land immediately adjacent to the lake
4. groundwater

Water leaves the lake system from:

1. discharge from the outlet stream to Mud Lake
2. evaporation
3. groundwater

There are no discharge gauges in the watershed to measure water inputs and the limited scope of this study did not allow us to quantitatively determine annual water inputs or outputs. Therefore, the water budget for Pretty 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 gauged watershed of similar land and topographic features, to the total amount of precipitation falling on that watershed. The nearest gauged watershed is a U.S.G.S. gauging station on the North Branch Elkhart River at Cosperville, Indiana (Morlock et al., 2004). The 33-year (1972–2005) mean annual runoff for this watershed is 12.95 inches (32.9 cm). With mean annual precipitation of 32.99 inches (83.8 cm) (Hillis, 1980), this means that on average, 39% of the rainfall falling on this watershed runs off on the land surface.
- No groundwater records exist for the lake; therefore an initial assumption that groundwater inputs equal outputs was utilized to calculate the water budget for Pretty Lake. However, Ficke (1965) made efforts to estimate seepage corrections necessary to calculate Pretty Lake's water budget from local data collected from 1963 to 1965. Estimates range from 0 cm/day to 0.41 cm/day of water leaving Pretty Lake and entering the groundwater on a daily basis. Ficke (1965) concluded that Pretty Lake possesses a nearly constant seepage of 0.2 cm/day. Because the seepage estimates were completed more than 40 years ago, their relevance to today's environment is questionable. Therefore, to be conservative a water budget was calculated assuming that groundwater inputs equaled outputs or seepage equaled 0 cm/day. This estimate was used in the current water budget calculation. To determine the impact of Ficke's estimate of seepage on Pretty Lake's water budget, his value (0.2 cm/day) was used to generate a second water budget; the results of which are discussed in more detail in the following sections.
- 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 Pretty Lake is located in Valparaiso, Indiana. Annual evaporation from a 'standard pan' at the Valparaiso site averages 28.05 inches (71.2 cm) per year. The Valparaiso pan value falls within the range (25.6 to 32.3 inches or 65 to 82 cm) calculated during studies to test various pan evaporation

methods from the Pretty Lake area from 1963 to 1965 (Ficke, 1965). Because evaporation from the standard pan overestimates evaporation from a lake by about 30%, the evaporation rate from the Valparaiso pan was corrected by this percentage, yielding an estimated evaporation rate from the lake surface of 19.95 inches (50.7 cm) per year. Multiplying this rate times the surface area of each lake yields an estimated volume of evaporative water loss from Pretty Lake.

The water budget for Pretty Lake, based on the assumptions discussed above, is shown in Table 30.

Table 30. Water budget calculation for Pretty Lake.

Parameter	Data
Watershed size (ac)	1,231
Mean Watershed Runoff (ac-ft/yr)	1,324
Lake Volume (ac-ft)	4,753
Runoff Estimates	
Closest gauged stream	North Branch Elkhart River
Stream watershed (mi^2)	142
Stream watershed (acres)	90,880
Mean annual daily Q (cfs)	135
Mean annual total Q (ac-ft/yr)	97,736
Mean ppt (in/yr)	32.99
Mean watershed ppt (ac-ft/yr)	249,844
Watershed C	0.391
Evaporation Estimates	
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	184
Estimated lake evaporation (ac-ft)	286
Direct precipitation to lake (ac-ft)	481
Runoff from watershed (ac-ft)	1,324
Evaporation (ac-ft)	286
TOTAL LAKE OUTPUT (ac-ft)	**1,519**
Hydraulic Residence Time (yr)	3.1
Watershed Area: Lake Area	6.7:1

Dividing the volume of Pretty Lake by the volume of water flowing out of the lake yields a *hydraulic residence time* of 3.1 years. This means that on average, water entering the lake stays in the lake for nearly 37 months or just over 3 years before it leaves. If Ficke's (1965) seepage rate is utilized, the hydraulic residence time of Pretty Lake increases to 5.2 years. This result is even longer than the result from the assumption that groundwater inputs equal outputs. This result should be viewed with caution due to the fact that groundwater data collected from 1963 to 1965 may not be reliable or applicable in today's climate. (All subsequent calculations involving residence time utilize the 3.1 years predicated with groundwater inputs equaling groundwater outputs.) Using either calculation method, the resulting hydraulic flushing rate is longer than many glacial lakes in this part of the county. 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 and Simpson, 1980). A lake's hydraulic residence time is strongly correlated with its watershed size to lake surface area ratio. Pretty Lake possesses a watershed size to lake surface area ratio of 6.7 to 1. Most glacial lakes have a watershed area to lake surface area ratio of around 10:1 (Vant, 1987). Thus, the water budget estimate appears reasonable. Additionally, because of its substantial depth Pretty Lake's volume contributes greatly to its longer residence time.

5.2 Phosphorus Budget

Since phosphorus is the limiting nutrient in Pretty 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 control the biological productivity of Pretty Lake.

The limited scope of this LARE study did not allow for the outright determination of phosphorus inputs and outputs. Therefore, a standard phosphorus model was used 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 31 shows the phosphorus export coefficients developed by Reckhow and Simpson (1980).

To obtain an annual estimate of the phosphorus exported to Pretty Lake from the lake's watershed, the export coefficient for a particular land use was multiplied by the area of land in the land use category. Mid-range estimates of phosphorus export coefficient values for all watershed land uses (Table 31) were used in this calculation.

Table 31. 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.

Direct phosphorus input via precipitation to Pretty Lake was estimated by multiplying mean annual precipitation in Lagrange County (0.84 m/yr) times the surface area of the lake times a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). Because homes surrounding Pretty Lake are on sewer, there is no current phosphorus input from septic systems. It should be noted that nutrients can continue to leach from old septic systems into the lake for a number of years after use of these systems has been discontinued. Additionally, any septic inputs due to sewer shutoffs or overflows also impact phosphorus levels in Pretty Lake. Finally, any septic systems associated with residences located adjacent to the inlet stream can directly contribute to the lake's phosphorus level as well. However, none of these items can be addressed by Vollenweider's model. Adding the phosphorus export loads from the watershed and precipitation yielded an estimated 463 kg of phosphorus loading to Pretty Lake (Table 32). The greatest estimated source of phosphorus loading to the lake is from row crop agriculture which accounts for over 84% of total watershed loading.

Table 32. Phosphorus model results for Pretty Lake.

Input Data		**Unit**		
Area, Lake	175	acres		
Volume, Lake	4,753	ac-ft		
Mean Depth	27.2	ft		
Hydraulic Residence Time	3.10	yr		
Flushing Rate	0.32	1/yr		
Mean Annual Precipitation	0.84	m		
[P] in precipitation	0.03	mg/l		
[P] in epilimnion	0.021	mg/l		
[P] in hypolimnion	0.017	mg/l		
Volume of epilimnion	3,050	ac-ft		
Volume of hypolimnion	1,703	ac-ft		
Land Use (in watershed)	**Area**	--------	**P-export Coefficient**	
Deciduous Forest	63.00	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	3.40	hectare	0.1	kg/ha-yr
Evergreen Forest	0.40	hectare	0.15	kg/ha-yr
High Intensity Residential	0.30	hectare	1.5	kg/ha-yr
High Intensity Commercial	0.40	hectare	1.3	kg/ha-yr
Low Intensity Residential	6.0	hectare	0.6	kg/ha-yr
Mixed Forest	0.1	hectare	0.175	kg/ha-yr
Pasture/Hay	83.8	hectare	0.6	kg/ha-yr
Row Crops	250.3	hectare	1.5	kg/ha-yr
Woody Wetlands	15.2	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
OUTPUT				
P load from watershed	444.8	kg/yr		
P load from precipitation	17.8	kg/yr		
P load from septic systems	0.00	kg/yr		
Total External P load	462.6	kg/yr		
Areal P loading	0.653	g/m^2-yr		
Predicted P from Vollenweider	0.052	mg/l		
Back Calculated L total	0.248	g/m^2-yr		
Estimation of L internal	-0.405	g/m^2-yr		
% of External Loading	263.5	%		
% of Internal Loading	-163.5	%		

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 27, 2006 sampling of Pretty Lake, the mean volume weighted phosphorus concentration in the lake was 0.200 mg/L. It is useful to determine how much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.200 mg/L in Pretty Lake. Plugging this mean concentration 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 0.248 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.200 mg/L in Pretty Lake, a total of 0.248 grams of phosphorus must be delivered to each square meter of lake surface area per year. However, the phosphorus loading model (Reckhow et al., 1980) estimated that 0.653 g/m^2-yr of phosphorus is delivered to Pretty Lake from watershed sources. This raises the question: what happened to the extra phosphorus (0.653 g/m^2-yr - 0.248 g/m^2-yr = 0.405 g/m^2-yr).

There are several possible explanations:

1. The phosphorus loading model overestimated the watershed phosphorus delivery to the lake.
2. The excess phosphorus settles down to the sediments where it doesn't contribute to the in-lake phosphorus concentration.
3. Aquatic plants growing in the very deep portions of Pretty Lake's photic zone are using the available phosphorus to produce additional growth.
4. The results of the July 27, 2006 sampling of Pretty Lake were in error or were an anomaly.

Determining which of the above may be important in explaining the phosphorus dynamics in Pretty Lake is difficult. Small lakes with large volumes like Pretty Lake have significantly more dilutional capacity than do shallower lakes of the same surface area. Thus, they can be sinks for nutrients as suggested by point two above. However, this only works to a point where the excess phosphorus exceeds the sediments' capacity to retain it. The theory of aquatic plants utilizing the phosphorus available in the lake's hypolimnion thereby reducing the available phosphorus is also a possibility. If plants covered the entire portion of the lake with a depth of 35 feet (10.7 m) or less, then they would utilize much of the phosphorus available within the hypolimnion. However, it is unlikely that plants grow at 30 to 35 feet (9.1 to 10.7 m) throughout the entire lake. Aquatic plant growth is likely limited by water clarity, wind speed, and hydrostatic pressure in many parts of the lake. There were at least two areas where plants were identified at a depth greater than 30 feet (9.1 m) during the August 2, 2006 aquatic plant survey. Therefore, the theory described in point three above holds true for at least a portion of Pretty Lake.

However, previous assessments indicate that, unlike the present assessment, higher phosphorus concentrations have been present in the lake's hypolimnion sample than in the epilimnion sample (Table 33). Following spring turnover, phosphorus concentrations are typically uniform throughout the lake (Ficke, 1965). As the stratification of the lake's water into two separate layers (the epilimnion and hypolimnion), the hypolimnetic phosphorus concentration typically increases due to the release of phosphorus from the sediments. Lipscomb (1966) noted the separation of Pretty Lake into two layers and the subsequent increase in phosphorus concentration in the lake's hypolimnion. Thus we have evidence that the Pretty Lake sediments can be a source of phosphorus and release phosphorus into the water. Table 33 displays more recent data collected by the Clean Lakes Program in the more recent past indicate that phosphorus release from Pretty Lake's sediments is a relatively common occurrence. Given the past history of Pretty Lake, the data we collected this year may be an anomaly as suggested by number four above.

Table 33. Historic soluble reactive phosphorus epilimnetic and hypolimnetic concentrations and calculated sediment phosphorus release factors for Pretty Lake.

Year	Epilimnetic SRP Concentration (mg/L)	Hypolimnetic SRP Concentration (mg/L)	Sediment Phosphorus Release Factor[1]
1989	0.005	0.005	1.0
1993	0.005	0.090	18.0
1997	0.002	0.054	27.0
2002	0.006	0.026	4.3
2006	0.010	0.010	1.0

[1]Hypo TP concentration/Epi TP concentration. For example, in 1997 the hypolimnetic SRP concentration was 27 times that in the epilimnetic concentration. This difference is strong evidence of substantial internal loading of phosphorus.

The significance of areal phosphorus loading rates is better illustrated in Figure 63 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 represent an acceptable loading rate that yields a phosphorus concentration in lake water of 30 µg/L (0.03 mg/L). The areal phosphorus loading rate for Pretty Lake is slightly above the acceptable line.

This figure can also be used to evaluate management needs. For example, areal phosphorus loading to Pretty Lake would have to be reduced from 0.653 g/m^2-yr to 0.379 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 0.274 g/m^2-yr to the lake, which is equivalent to a total phosphorus mass loading reduction of 194 kg P/yr or 44% of current total loading to the lake. As the current estimate indicates that internal loading does not account for any portion of the phosphorus within Pretty Lake, the natural assumption indicates that eliminating watershed phosphorus loading will meet the required reduction. However, as noted above, internal phosphorus loading occurred within Pretty Lake in the past and it is not unlikely that internal phosphorus is a source of phosphorus to the lake during at least some portion of the year. With this in mind, eliminating internal phosphorus loading is also an important component in meeting the reduction needed. Both internal and watershed loading reductions are required to reduce the phosphorus concentration within Pretty Lake (Table 34).

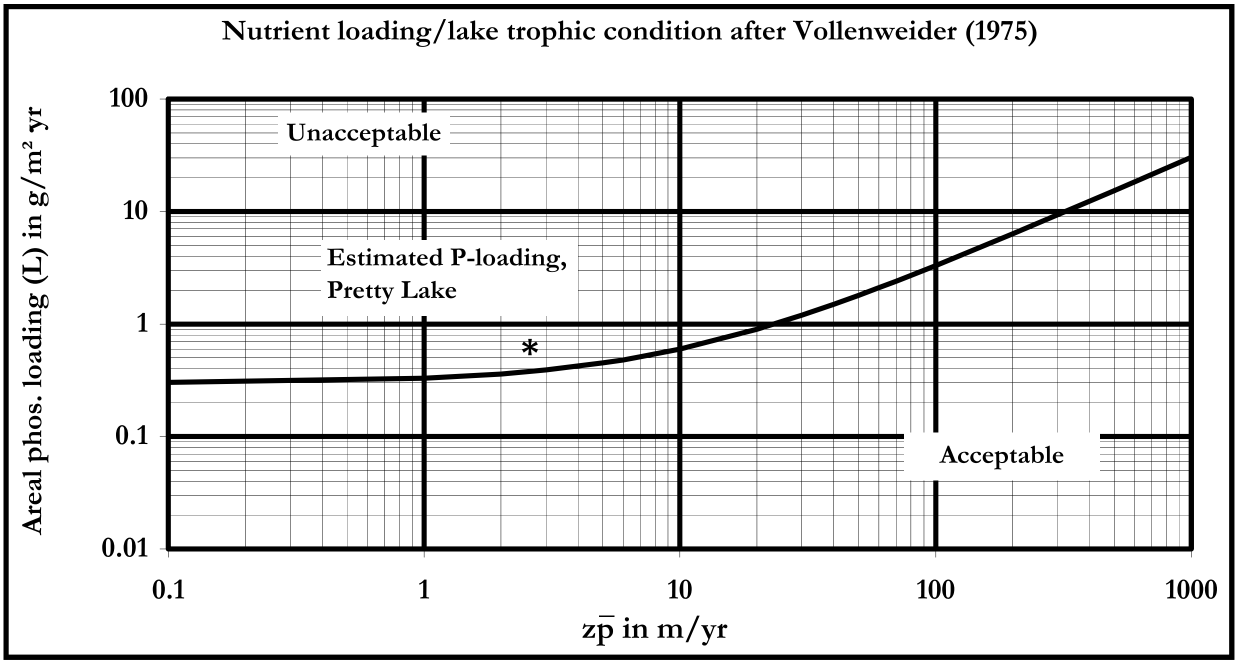

Figure 63. Estimated external phosphorus loadings to Pretty Lake compared to acceptable loadings determined from Vollenweider's model. The dark line represents the upper limit for acceptable loading.

Table 34. Phosphorus reduction required to achieve acceptable phosphorus loading rate and a mean lake phosphorus concentration of 0.03 mg/L.

Lake	Current External Total Areal P Loading (g/m^2-yr)	Acceptable Areal P Loading (g/m^2-yr)	Reduction Needed (kg P/yr and %)
Pretty	0.653	0.379	194 kg (44%)

6.0 MANAGEMENT

The preceding sections of this report detailing Pretty Lake's current condition indicate that the lake possesses very good water quality in comparison to other lakes in the region and throughout the state. The lake has good water clarity with a Secchi disk depth of 11.5 feet (3.5 m). Nutrient concentrations are lower than the state medians. The lake's volume weighted total phosphorus concentration places the lake in the mesotrophic category based on Carlson's TSI. Furthermore, most of the phosphorus is equally distributed throughout the lake's water column but does not produce excessive algal growth. The lower than average nutrient levels present in Pretty Lake result in low productivity levels. The lake's chlorophyll *a* concentration, Indiana TSI score, and Secchi disk depth suggest Pretty Lake is oligotrophic to mesotrophic in nature.

The lake's relatively healthy biological community indicates that the long-term water quality is on par with that indicated by its water chemistry sampling. Pretty Lake supports a diverse submerged plant community including 13 pondweed species, nitella, and northern watermilfoil. Additionally, the state listed species, Richardson's pondweed and Fries' pondweed, were also present in Pretty Lake during the 2006 assessment. These species are all indicators of good water quality and are found in several places throughout the lake. IDNR fisheries biologists also describe Pretty Lake's fisheries community as healthy. The popularity of the lake for fishing supports this assessment.

Pretty Lake historically exhibited good water quality and recent samplings indicate that water quality remains good and may actually be improving in the lake. There is some evidence that this trend should continue into the future. The phosphorus modeling shows that much of the phosphorus entering the lake from the watershed is absorbed by the lake in that internal phosphorus loading is negative. Much of the phosphorus entering the lake is used by the lake's flora and fauna for production. Modeling suggests that typical internal sources of phosphorus, including sediment or decomposing plant materials, are not providing phosphorus to the water body. This leads to Pretty Lake containing a low level of productivity. Similarly, the oxygen profile indicates that photosynthesis occurs within Pretty Lake to a depth of 32.8 feet (10 m). Below 69 feet (21 m), lack of oxygen in the lake's lower levels suggests the rate of photosynthesis (oxygen production) is less than the rate of oxygen consumption. The elevated concentration of ammonia in Pretty Lake's hypolimnion suggests decomposition rates may be the primary reason for the oxygen consumption. However, soluble reactive phosphorus concentrations in the hypolimnion indicate that phosphorus release from the sediment was likely not occurring within the lake during the assessment. Based on this evidence, the rate of organic material input to the lake is likely below the level that the lake effectively processes material without compromising water quality.

Pretty Lake's relatively large capacity (volume) also likely helps offset any effects of the phosphorus and organic matter loading from both the lake's watershed (external loading) and the lake's sediment (internal loading). Thus, even if phosphorus inputs were higher, the lake's productivity (algae, plant, and fish populations) would remain more typical of moderately productive to productive lake. Based on current data, the lake can continue to absorb phosphorus and organic matter for a long period of time without a concurrent change in its water quality. This will not last indefinitely. Based on current watershed practices, it appears that there is little danger of Pretty Lake needing to absorb large volumes of phosphorus or organic matter. However, if loading rates increased it is likely that Pretty Lake will eventually reach a "breaking point" at which the lake's biological community may begin to reflect more eutrophic conditions. The observable effects once this "breaking point" is reached could include more algae blooms, poorer water clarity, and shifts in the rooted plant and fish community to a dominance of less desirable species.

While Pretty Lake enjoys very good water quality today, the signs suggest that the lake could degrade in the future. These signs include:

1. The very deepest water within Pretty Lake contains no oxygen. This is due to the decomposition of organic matter on the sediments by bacteria that consume oxygen in the process. The sources of this organic matter are likely algae and rooted plants produced within the lake, and organic material washed into the lake from the watershed.
2. Anoxic conditions in the lake's hypolimnion allow ammonia concentrations to accumulate and increase.
3. Anoxic conditions in the hypolimnion have allowed phosphorus release from the sediments during previous years' sampling. However, there was no evidence of this during the 2006 assessment. Internal phosphorus release from the sediments can help fuel algal growth and this, along with hypolimnetic oxygen concentrations should be monitored in the future.
4. Phosphorus loadings to Pretty Lake from its watershed exceed permissible rates needed to maintain good water quality by 44%. The lake's deep volume has mitigated these loadings in

the past but for the long-term health of the lake, external phosphorus loadings should be reduced.

To preserve Pretty Lake's high water quality and diverse biological community, Pretty Lake residents and other watershed stakeholders are strongly encouraged to actively manage their lake and watershed. Management efforts should focus on reducing both external and internal phosphorus loading to the lake, even though the current assessment indicates that internal loading is not occurring within Pretty Lake. Pretty Lake's low watershed area to lake area ratio suggests actions taken along the shoreline and in the immediate watershed can have a significant impact of the lake's health. Thus management of near shore channels, individual residential properties, and storm drains in the vicinity of the lake should be prioritized. Deal Ditch's elevated phosphorus and bacteria levels indicate that watershed management techniques that treat these pollutants are also important. Finally, the lake's relatively long hydraulic residence time means in-lake management, which can affect nutrient cycling, should also receive a high priority. The following paragraphs describe the management techniques that historically occurred in the Pretty Lake watershed and details those techniques recommended for Pretty Lake and its watershed in the future. For the sake of clarity, the techniques are separated into two categories: watershed management techniques and in-lake management techniques.

6.1 Historic Watershed Management

An initial watershed diagnostic study was completed for Pretty Lake and its watershed by EarthSource in 1991. The study recommended that the following areas of concern be addressed:

1. Residents accept responsibility for maintaining their own waste disposal systems.
2. Residents should limit the use of fertilizers on lakefront lawns and, where possible, should utilize lake water for irrigation purposes.
3. The lake association should actively monitor future development and ensure that setbacks and septic systems are utilized/installed properly.
4. Implement cropping practices to minimize the transport of sediment from areas of highly erodible soils.
5. Consider wetland restoration projects in the two recommended areas: CR 400 South west of hog farm and CR 400 South east of hog farm. Both could be implemented with minimal construction.
6. Design and construct a filter strip between the agricultural field adjacent to CR 890 East and Pretty Lake
7. Stabilize streambank or ditch banks and allow native vegetation adjacent to the streams to regrow.

Many of these projects have been implemented by the PLCC or other entities within Lagrange County. Initially, the PLCC sought LARE funding to implement wetland restoration and filter strip installation projects recommended by EarthSource. However, after determining that the matching fund requirement could not be met, the PLCC along with the Lagrange County SWCD requested that the funds be transferred into the Watershed Land Treatment Program. Funds were transferred in 1995 and the Lagrange County SWCD implemented one wetland restoration project, installed one sediment control structure, and planted 10 acres of trees and 15 acres of pasture and/or hayland planting. This includes a portion of one of the recommended wetland restoration projects and the filter strip adjacent to County Road 890 East. Additionally during this time period, the PLCC worked with the watershed hog farmer and the Lagrange County SWCD to design and construct a new storage lagoon for hog waste and to fence the hogs out of Deal Ditch. Finally, the Lagrange County Regional Waste Management District (LCRWMD) installed a sewer system that treats waste from all residences adjacent to Pretty Lake's shoreline. No records are available to determine whether the agricultural fields targeted for improved cropping practices have been enacted.

6.2 Watershed Management

Despite efforts to implement all of the recommendations from the original Pretty Lake Diagnostic Study (EarthSource, 1991), projects where water quality improvements could occur still remain in the watershed. The areas that would benefit most from watershed management techniques are detailed in Figure 64. Watershed management techniques are broken into a few major categories. Specifics about each of these areas are detailed below.

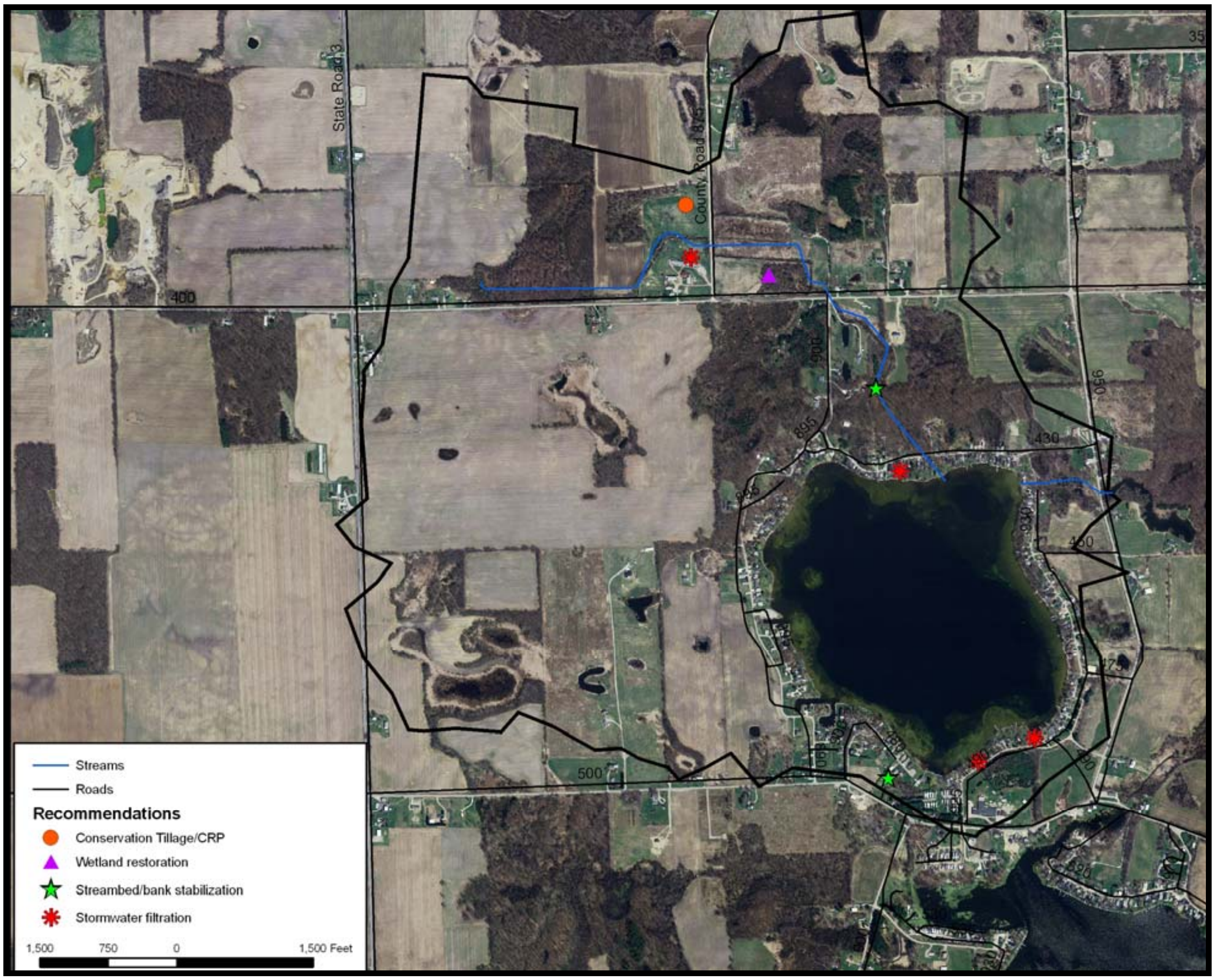

Figure 64. Areas in the Pretty Lake watershed that would benefit from watershed management technique installation.

JFNew and PLCC representatives completed a tour of the watershed on March 23, 2006. The majority of the tour was conducted by driving the watershed roads and stopping and walking in areas of interest. Additional areas were identified during subsequent visits to the watershed (water quality sampling, plant surveys, etc.) and through landowner suggestions.

6.2.1 Stream Channel Management

Pretty Lake possesses one main drainage, Deal Ditch (Figure 65), and a couple of minor drainages. The minor drainages are intermittent (dry throughout most of the year) and are located on the lake's south side (Figure 66). The primary drain in question exhibits a grade of 10% or higher. The soil units associated with this drain are considered potentially highly erodible (Figure 5). The drain also possesses little stabilization and is typically an open dirt-lined channel flowing through adjacent yards. In the case of Deal Ditch, the channel flows through hydric soils and has been down-cut over the years either through natural processes or through channel maintenance processes. Given these site conditions, it is not surprising that both the small drainage and portions of Deal Ditch are actively eroding. Property owners indicate that during large storm events sediment from both drainages turn portions of Pretty Lake brown.

Figure 65. View of a Deal Ditch where it is down-cut from its adjacent floodplain.

Figure 66. Stream channel in need of stabilization and erosion control on the south side of Pretty Lake.

Sediment reaching Pretty Lake has the potential to impair the lake via several mechanisms. Of greatest concern to the residents is the impact sediment can have on the lake's water clarity. Sediment from actively eroding stream channels contributes to this problem. The sediment also reduces lake depth which can affect swimming and other recreational uses of the lake. Lastly, nutrients attached to sediment that reaches the lake can promote algae and rooted plant growth, which in turn can impact recreational use of the lake.

Some of the erosion occurring within the stream channels is natural. The landscape's slopes coupled with the sandy and loamy soil naturally predispose ravine areas to erosion. However, both of the stream may experience greater erosion rates as explained by the following: In pre-settlement times, forest likely covered the landscape both north and south of Pretty Lake. Due to the structure and physical composition of forested land, forested land typically has very low stormwater runoff volumes and flow rates. To understand this, it is helpful to consider the path of rain falling on a forested landscape. Some portion of the rain falling on forested land never reaches the ground. The multi-layered canopy of forested land intercepts this portion of rain. Of the rain that does reach the forest floor, herbaceous ground cover and decaying organic matter absorb another portion of the total rain volume. An additional portion of the total rain volume is infiltrated into the forest soil. This leaves a very small amount of rain that actually flows across the forest floor as overland runoff. This low stormwater runoff volume and consequently low flow rate translates into lower potential for soil erosion.

Much of the forested canopy is maintained along Deal Ditch; however, headwaters portions of the stream do not possess a canopy (Figure 67), while the smaller drainage on the south side of the lake flows through mostly residential property. Additionally, at some point during settlement of the Pretty Lake watershed, settlers cleared much of the forested areas to allow for agricultural production. Historical aerial photography confirms that much of the land at the headwaters of Deal Ditch has been, and in some cases still is, in agricultural production. Agricultural land has significantly higher stormwater runoff volumes and rates compared to forested land. These higher stormwater runoff volumes and rates are increased even further when agricultural land is tiled to improve drainage. The result is an increase in the volume and rate of stormwater runoff reaching the drainages as the water drains toward the lake. The increased volume and rate of stormwater runoff increases the erosion and subsequent down-cutting that occurs within the drains.

Figure 67. Headwaters portion of Deal Ditch which lacks adequate canopy cover and possesses a narrow filter adjacent to the stream.

A multi-pronged approach is recommended to address the erosion and down-cutting problem within the drains in Pretty Lake's watershed. First, the landscape up-gradient from the stream channels should be examined to determine whether a reduction of stormwater runoff from these areas is possible. Retiring agricultural land and planting the land to forest or prairie habitat or restoring areas to wetland to increase water storage capacity would reduce stormwater runoff from areas up-gradient of the drains. Use of the Conservation Reserve Program (described below) may be a cost-effective means to achieve this goal.

Erosion control may be possible within the stream channels themselves. Depending upon the slope and soil composition, it may be possible to install a series of check dams or grade control structures within the drains. Check dams reduce erosion by pooling water behind them, slowing the velocity and erosive potential of runoff. As the water slows behind the check dam, some of the sediment in the runoff will drop out of suspension and remain trapped behind the check dam. in the smaller drain, the use of a French drain or simple slope regrading, seeding, and blanketing may suffice to stabilize the channel.

Specific areas available for restoration should be investigated to determine the feasibility for sediment trap and check dam installation. Finally, with respect to reducing erosion from the stream channel, very careful planning will be necessary if developing the land around or up-gradient of these streams for residential or commercial use ever becomes and issue. Residential/commercial development of these areas should employ conservation designs to reduce impervious surfaces and maximize buffer zones and infiltration areas. Other best management practices that should be considered are the use of grassed pavers in place of roads, driveways, and sidewalks; reduction in street, driveway, and sidewalk widths; the use of vegetated roadside swales rather than curb and gutter systems; and the use of green rooftops, rain gardens, and/or rain barrels to keep stormwater on individual lots. Reducing the volume and velocity of stormwater reaching nearby streams will be essential to limiting erosion within these streams or drainages.

6.2.2 Sewer System Connection/Septic System Replacement

The Lagrange County Regional Sewer District operates a sewer system that treats wastewater from all residences adjacent to Pretty Lake's shoreline. However, there are a number of residences immediately adjacent to Deal Ditch and other drainages that are not currently connected to the sewer system. *E. coli* concentrations present in samples collected by the Pretty Lake Conservation Club and during this project indicate that elevated *E. coli* concentrations are present in Deal Ditch and have been for some time. Additional efforts to identify if the source of this *E. coli* resulted in the identification of horse and/or human sources of *E. coli* along Deal Ditch's mainstem upstream of the lake. The exact source of this *E. coli* cannot be identified at this time; however, the Lagrange County Health Department indicated that based on the *E. coli* concentrations and the source tracking samples, they would be willing to talk with landowners who utilize septic systems in areas adjacent to Deal Ditch. They cannot, however, force individuals to upgrade or modify systems or hook on to the Regional Sewer District lines. At this time, the PLCC should continue to work with the Lagrange County Health Department to determine if there are any additional actions that the PLCC can take or if there is any assistance that they may offer to the Health Department.

6.2.3 Individual Property Management

Individual property owners can take several actions to maintain or improve Pretty Lake's existing water quality. First, shoreline landowners should seriously consider re-landscaping lakeside properties to protect their lake. Many of the homes on Pretty Lake have maintained turf grass lawns that extend to the lake's edge. Runoff from residential lawns can be very high in phosphorus. In a study on residential areas in Madison, Wisconsin, Bannerman et al. (1992) found extremely high total phosphorus concentrations in stormwater samples from residential lawns. The average phosphorus concentration of runoff water from residential lawns was nearly 100 times the concentration at which algae blooms are expected in lake water. While some dilution occurs as runoff water enters the lake, this source of phosphorus is not insignificant. Other researchers have found similarly high total phosphorus concentrations in lawn runoff water (Steuer et al., 1997).

The ideal way to re-landscape a shoreline is to replant as much of the shoreline as possible with native shoreline species. Rushes, sedges, pickerel weed, arrowhead, and blue-flag iris are all common species native to northeastern lake margins. These species provide an aesthetically attractive, low profile community that will not interfere with views of the lake. Plantings can even occur in front of existing seawalls. Bulrushes and taller emergents are recommended for this. On drier areas, a variety of upland forbs and grasses that do not have the same fertilizer/pesticide maintenance requirements as turf grass may be planted to provide additional filtering of any runoff. Plantings can be arranged so that access to a pier or a portion of the lakefront still exists, but runoff from the property to the lake is minimized. Thus, the lake's overall health improves without interfering with recreational uses of the lake. Henderson et al. (1998) illustrate a variety of landscaping options to achieve water quality and access goals. Appendix H contains a list of potential species that could be planted at the lake's shoreline and further inland to restore the shoreline.

Restoring Pretty Lake's shoreline by planting the area with native vegetation will return the functions the shoreline once provided the lake. In addition to filtering runoff, well-vegetated shorelines are less likely to erode, reducing sediment loading to the lake. Well-vegetated shorelines also discourage Canada geese, which may not be considered at nuisance levels at Pretty Lake at this point in time. However, evidence of their presence and its potential impact on nutrient and pathogen levels is readily apparent on docks and lawns around the lake. Canada geese prefer maintained lawns because any predators are clearly visible in lawn areas. Native vegetation is higher in profile than maintained lawns and has the potential to hide predators, increasing the risk for the geese. Wire fences or string lines do little to discourage geese, since these devices do not obscure geese sight line and geese learn to jump wire fences. Additionally, unlike concrete or other hard seawalls, vegetated shorelines dampen wave energy, reducing or even eliminating the "rebound" effect seen with hard seawalls. Waves that rebound off hard seawalls continue to stir the lake's bottom sediments, reducing water clarity and impairing the lake's aesthetic appeal. (Residents might also consider replacing or refacing concrete seawalls with glacial stone to reduce the "rebound" effect.) Finally, well-vegetated shorelines provide excellent habitat for native waterfowl and other aquatic species.

Purple loosestrife and reed canary grass were identified in several locations along Pretty Lake's lakeshore and in adjacent lawns. Both of these species are introduced from Eurasia and spread rapidly through prolific seed production, vegetative growth, and cultivation. Without individual control, both species can spread along the lakeshore inhibiting boat mooring and individual access to the lake. (See the Macrophyte Discussion for more information on these plants.) Landowners should replace these plants with native species that provide equal or better quality aesthetics and are more useful to birds, butterflies, and other wildlife as habitat and a food source. Reed canary grass should be replaced with switch grass, Indian grass, or even big blue stem depending on the landowner's desired landscaping (Figure 68). Swamp blazing star, swamp milkweed, cardinal flower, blue-flag iris, or blue lobelia all offer more habitat and aesthetic variety than that offered by purple loosestrife (Figure 69). A mixture of these species will also allow for colorful blooms throughout the growing season.

Figure 68. Switch grass (left), big bluestem (center), and Indian grass (right) are some of the grass species suggested for shoreline planting along Pretty Lake.

Figure 69. Some of the forbs suggested for shoreline planting along Pretty Lake are swamp blazing star (top left), swamp milkweed (top right and with bumblebee top center), cardinal flower (bottom left), blue-flag iris (bottom center), and blue lobelia (bottom right).

In addition to re-landscaping lakefront property, all lake and 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 lake. 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 lake either directly from those residents' lawns along the lake's shoreline or indirectly via storm drains. This simply fertilizes the rooted plants and algae in the lake. 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.

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 lake, 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 Purdue University Extension 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 Pretty Lake or its tributaries as this adds to the nutrient base of the lake. Pet and other animal waste that enters the lake also contributes nutrients and pathogens to it. All of these substances require oxygen to decompose. This increases the oxygen demand on the 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 (Figure 70), roads, parking areas, driveways, and roof tops. Resident surveys conducted on other northern Indiana lakes have indicated that many lakeside houses have local drains of some sort on their properties (JFNew, 2002). These drains contribute to sediment and nutrient loading and thermal pollution of the lake. Driveways transversing steep slopes adjacent to Pretty Lake should be constructed in a manner that limits the transport of sediment and nutrients to the lake. Where possible, alternatives to piping the water directly to the lake should be considered. Alternatives include French drains (gravel filled trenches), wetland filters, catch basins, and native plant overland swales. Residents might also consider the use of rain gardens or rain barrels to treat stormwater on individual lots.

Figure 70. Storm drain adjacent to one of the driveways around the lake.

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 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.

6.2.4 Residential and Commercial Development Erosion Control

There are relatively few active residential developments currently in progress in the Pretty Lake watershed. However, there is one major development southeast of the lake that could impact the water quality within Pretty Lake. Additionally, areas immediately adjacent to Pretty Lake 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 or agricultural field. 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 areas were observed where the use of erosion control methods would have prevented or at least minimized the loss of sediment from the site. While current regulations may not have required the use of silt fencing on this site (under new regulations, anyone planning to disturb more than an acre of land must file an erosion control plan with the State), the use of erosion control practices would certainly reduce the amount of sediment reaching Pretty Lake from development sites. The use of common erosion control practices are strongly recommended regardless of whether they are required by the State.

6.2.5 Conservation Reserve Program

Some landowners in the Pretty Lake watershed are currently enrolled in the Conservation Reserve Program (CRP), but increased participation in the program would benefit the lake's health. The CRP is a cost-share program designed to encourage landowners to remove a portion of their land from agriculture 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. These techniques are particularly appropriate along surface drainages; however, they do not account for pollutants transported to the lake via subsurface drainage tiles.

Land that is removed from agricultural production and planted with herbaceous or woody vegetation benefits the health of aquatic ecosystems located down gradient of that property in a variety of ways. Woody and/or herbaceous vegetation on CRP land stabilizes the soil on the property, preventing its release off site. Vegetation on CRP land 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 watershed's natural hydrology. Rainwater infiltrates into the soil more readily on land covered with grasses and trees 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 ecological benefits that land enrolled in CRP provides, 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.

Specific areas where enrollment in CRP is recommended are shown in Figure 64. Each of these areas shares the some common characteristics: they are mapped in a highly erodible soil unit and are currently being utilized for agricultural production. The highest priority area is shown in Figure 64. This owner may already utilize grassed waterways under the CRP, but removal of a larger portion of these fields from agricultural production should be considered. Further, there may be other areas in the watershed that were not observable from the road during the windshield tour that may warrant consideration for enrollment in CRP.

6.2.6 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 exact percentage of watershed crop land on which producers were utilizing conservation tillage methods was beyond the scope of this study, use of conservation tillage on some of the agricultural land was noted during the windshield tour of the watershed. County-wide estimates from tillage transect data may serve as a reasonable estimate of the amount of crop land on which producers are utilizing conservation tillage methods in the Pretty Lake watershed. County-wide tillage transect data for Lagrange County provides an estimate for the portion of cropland in conservation tillage for the Pretty Lake watershed. In Lagrange County, soybean producers utilize no-till methods on 64% of soybean fields and some form of reduced tillage on 92% of soybean fields (IDNR, 2004b). Lagrange County corn producers used no-till methods on 14% of corn fields and some form of reduced tillage on 38% of corn fields in production (IDNR, 2004a). The percentages of fields on which no-till methods were used in Lagrange County were above the statewide median percentages for soybean production, but below the state average for corn production. Continued use of conservation tillage, particularly no-till conservation tillage, is recommended in the Pretty Lake watershed. The areas targeted for CRP implementation noted above should be farmed using no-till methods if they are not already doing so and removal of the land from production is not a feasible option.

6.2.7 Wetland Restoration

Visual observation and historical records indicate at least a portion of the Pretty Lake watershed has been altered to increase its drainage capacity. Riser tiles in low spots on the landscape and tile outlets along the waterways in the Pretty Lake watershed confirm the fact that the landscape has been hydrologically altered. Historical aerial photography and written accounts indicate that Pretty Lake's shoreline 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 Pretty Lake watershed could return many of the functions that were lost when these wetlands were drained. Figure 64 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 64 were selected because they are areas where large scale restoration is possible. Current research suggests that the installation of wetlands can remove more than 80% of sediment and approximately 45% of nutrients (Metropolitan Washington Council of Governments, 1992; Claytor and Schueler, 1996; and Winer, 2000). However, if the individual landowner is reluctant to install a wetland filter, at a minimum, a rock lined culvert out fall and vegetated embankments should be installed at this site to reduce nutrient and sediment loading to the lake.

6.2.8 Additional Treatment of Stormwater Runoff

All hardscape within the Pretty Lake watershed are sources of urban pollutants. The urban landscape can contribute more pollutants to nearby waterbodies than some agricultural landscapes. The U.S. Environmental Protection Agency's National Urban Runoff Program (USEPA, 1983) results suggest that pollutant runoff rates, including nutrients and suspended solids, will increase as land is converted from agricultural fields to urban landscapes. Reckhow and Simpson (1980) found similar results in their review of studies of nutrient export rates from various landscapes. Bannerman et al. (1992) reported that streets and parking lots release significant amounts of stormwater contaminants. Given the potential for water pollution from typical urban landscapes, watershed stakeholders must also focus on urban watershed management.

The potential for installing stormwater Best Management Practices (BMPs) that promote infiltration should also be investigated. These issues are of particular concern in two main locations: adjacent to the gravel road in Deal Ditch's headwaters (Figure 71) and in reference to the storm drains that are located within the county right-of-way adjacent to roads around Pretty Lake (Figure 72). Both of these are great examples of areas where soils are appropriate for infiltration BMPs. Filtration trenches, sand filters, and biofilters (a variation of sand filters that are planted with native vegetation to allow additional nutrient uptake) provide good treatment for stormwater pollutants. Research (Winer, 2000) suggests these infiltration BMPs are particularly good for treating pollutants of concern in the Pretty Lake watershed. These BMPs also promote infiltration of stormwater rather than storing it and discharging it at a later time. This simulates the natural hydrology of the watershed by recharging the groundwater with at least a portion of the stormwater rather than sending the whole volume downstream. Unfortunately, these BMPs can be costly and difficult to maintain, factors that should be balanced with the benefits derived from these BMPs.

Figure 71. Gravel road crossing over Deal Ditch where an infiltration BMP would be appropriate to reduce sediment and nutrient loading to Pretty Lake.

Residential runoff carries yard waste, fertilizer, and other debris to the lake via storm drains. Pollution from these drains was not directly categorized or quantified but varies at each drain. For example, at least one storm drain was entirely clogged by sediment and organic matter (Figure 72). This drain likely carries sand, gravel, and road salt from wintertime applications of these pollutants to the adjacent roads; other storm drains likely release sediment, sediment-attached nutrients, pesticides, yard debris, and garbage. Most of the drains examined could be improved in some way to reduce their respective pollutant loads to the lake. A majority of the storm drains located during the watershed tour were constructed by individual landowners. Generally, residents designed their drains based on the location of standing water on or near their property at the time of construction. Most of these drains were sized to reduce the depth and duration of water ponding and consist of a grated metal or cement inlet structure connected to a plastic, clay, or metal pipe which conveys water directly into the lake. The general design of an inlet to a pipe flowing directly to the lake provides little to no stormwater pollutant reduction and often does not allow for drain cleaning or maintenance.

The storm drains were not sampled for pollutant export; therefore only limited conclusions can be drawn on the amount of pollutants that these drains are delivering to Pretty Lake and what impact the proposed solutions will have. Road salts, nutrients from adjacent lawns and leaf litter, and hydrocarbons are going directly to the lake as they are washed from the roads. Properly maintained catch basins have been found to remove 32-97% of total suspended solids (Pitt et al., 2000; Mineart and Singh, 1994). Wetland vegetated filters have been found to remove between 40-90% of hydrocarbons, nutrients, and sediment from runoff (Moustafa, 1997; Wang and Mitsch, 1996; Warwick et al., 1998). Projects vary in efficiency due to size and type of construction as well as the age of filters. Mature wetland filters absorb fewer pollutants than newly constructed filters. This study assumes that the storm drains around the lake play a minor role in the delivery of pollutants to the lakes. However, the drains are contributing pollutants and the cost of treatment is relatively low compared to some of the other issues identified throughout the watershed, therefore treatment is recommended.

Figure 72. Storm drain that was previously covered by sediment and is filled with organic matter. Routine maintenance and cleaning is necessary to reduce sediment and nutrient loading to the lake.

6.2.9 Manure Management

Nutrient management has been the focus of agricultural research in many parts of the country. Studies have shown that every year about 15% of the applied nitrogen, 68% of the residual nitrogen in the non-root zone layer of the soil, and 20% of the residual nitrogen in the root zone layer are leached to the groundwater (Yadav, 1997). To address this concern, the Penn State Cooperative Extension Service designed a nutrient management plan based on: 1) crop yield goals; 2) soil type; 3) methods of manure and commercial fertilizer application; 4) nitrogen concentrations in soils; 5) nitrogen concentrations in manure to be used for fertilizer; and 6) crop rotations (Hall and Risser, 1993). With this plan in place: 1) fertilizer application as manure and commercial fertilizer decreased 33% from 22,700 lbs/year to 15,175 lbs/year; 2) nitrogen loads in groundwater decreased 30% from 292 lbs of nitrogen per 1,000,000 gallons of groundwater to 203 lbs per 1,000,000 gallons; and 3) the load of nitrogen discharged in groundwater was reduced by 11,000 lbs for the site over a three-year period (70 lbs/ac/yr).

In special areas of environmental concern, such as fields that border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Lagrange County Purdue Cooperative Extension Agency, fertilizer setbacks are accomplished with filter strips; most farmers are conscientious of application near tile drains and open ditch areas. Farmers are typically extremely aware of fertilizer application near streams and drainage tiles. Producers on highly erodible land in some areas of concern tend to be more conscientious with respect to fertilizer application; many of these producers are diligently following their production plans and continue to maintain highly erodible field in hay or wheat and avoid tilling these fields in the fall.

Though not a nutrient in and of itself, *E. coli* bacteria contamination of waterways is an indirect effect of applying animal waste as fertilizer. *E. coli* and other bacteria from the intestinal tracts of warm blooded animals can cause gastroenteritis in humans and pets. Symptoms of gastroenteritis include: nausea, vomiting, stomachache, diarrhea, headache, and fever. Due to high *E. coli* counts, about 81% of the assessed waters in Indiana did not support "full body contact recreation" in 1994-1995 (IDEM, 1995). Of over 800 samples collected in the St. Joseph River (Ft. Wayne) in northern Indiana during 1996-1997, the average of all samples was 2,000 colonies/100 ml, or about 16 times the maximum allowable level (Frankenberger, 2001). Samples collected near 19 USGS gauging stations in the St. Joseph River (South Bend) Watershed during 2002 contained *E. coli* concentrations of 7-4,600 colonies/100 ml. The USGS determined that 33-95% of these colonies were to be pathogenic strains (O157:H7) of *E. coli* (Duris et al., 2003). During the present study, many of the Pretty Lake watershed streams were in violation of the Indiana state standard; concentrations ranged from 520-1,240 colonies/100 ml (Table 9). To prevent manure from entering tiles, ditches, and streams, producers can: 1) apply manure at optimal times for plant uptake; 2) apply manure when potential for plant uptake is high and runoff is low; 3) inject or incorporate manure to reduce runoff potential; 4) use filter strips; and 5) use setbacks from surface inlets to tile lines.

6.3 In-Lake Management

6.3.1 Aquatic Plant Management

Development of an aquatic plant management plan is also a recommended in-lake management step for Pretty Lake. Like a recreational use management plan, an aquatic plant management plan takes into account the lake's current and historical ecological condition as well as the recreational desires of the lake's user groups. The following is a list of recommendations that should form the foundation of any aquatic plant management plan for Pretty Lake. 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.

1. Pretty Lake's high rooted plant diversity and high quality plant species should be protected (Figure 73). The lake supports excellent rooted plant diversity and this undoubtedly plays a role in supporting its healthy fishery. Management techniques that are not species specific, such as contact herbicides or large scale harvesting, should be avoided to ensure the protection of the high quality community. Additionally, Pretty Lake residents may wish to consider re-establishing portions of the emergent plant community that previously existed in the lake. One particular area in which this could occur would be the wide, flat shelf along the southern shoreline of the lake.

Figure 73. Example of Pretty Lake's diverse rooted plant community.

2. Pretty Lake residents should take steps to restore the lake's shoreline vegetation. Currently, some of the developed portion of the lake's shoreline lacks a healthy emergent plant population. In other areas, exotic species like purple loosestrife and reed canary grass are present in landscaping adjacent to the lake. Removal of these species and restoration of the shoreline would return many of the functions provided by healthy riparian areas. A more detailed discussion of shoreline functions and restoration techniques was provided above in the Individual Property Management Section.

3. Pretty Lake residents should investigate spot treatment options for areas where aquatic plants are especially dense or occur in nuisance stands. Specific areas include the dense eel grass and Eurasian watermilfoil along the northern shoreline of Pretty Lake in Beds 04, 06 and 07 (Figure 74). Spot treatment within these areas will likely improve travel through these areas and increase individual resident's ability to utilize their shoreline. Treatment history indicates that curly-leaf pondweed and Eurasian watermilfoil reach nuisance levels in various locations within the lake. However, at the time of the current survey, curly-leaf pondweed was found in low density throughout the lake, while Eurasian watermilfoil was identified in most beds sometimes with high densities throughout the lake. Curly-leaf pondweed typically reaches its greatest density early in the growing season; therefore, its lack of dominance at the time of the assessment is not surprising. If individual residents in these areas feel that 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, spot treatment of aquatic vegetation, or the use of bottom covers. Please be aware that permits may be required for these activities. Residents should consult with the IDNR Division of Fish and Wildlife before implementing any of these management methods. If hand harvesting is utilized as a treatment method, residents need to remove the

plant material from the lake rather than allowing it to remain in the lake, float to other areas, and re-root. Additionally, if plants are removed from the lake by hand, plants should not be left along the shoreline or piled on adjacent sea walls. The nutrients from the plants return to the water through decomposition and decay. This is an additional source of nutrient loading to the lake. An educational program highlighting the benefits a healthy plant community, including emergent species, might help residents make informed decisions on balancing their desire for relatively plant-free water in front of their property with the desire for a healthy, productive fish community in the lakes.

Figure 74. Example of the density of eel grass and Eurasian watermilfoil along the north shoreline of Pretty Lake.

4. Residents should take action to educate themselves on Eurasian watermilfoil and hydrilla. Given the high density of off-shore users, residents should be especially diligent in education all users regarding the threat of Eurasian watermilfoil and hydrilla to Pretty Lake and other area lakes. These exotic invasive species offer poor habitat to the lake's biota and often interferes with recreational uses of a lake. Creating an inspection or boat washing facility would likely be the best option to prevent the infestation of the lake with Eurasian watermilfoil or hydrilla. Furthermore, lake users should also educate themselves on both species. The Stop the Hitchhikers! (www.protectyourwaters.net) campaign offers great resources on preventing the spread of exotic and/or invasive species. Taking precautionary measures such as ensuring that all plant material is removed from boat propellers following their use prevents the spread of these and other invasive species. Lake users should also refrain from boating through stands of Eurasian watermilfoil in other lakes. (Access to the only lake in Indiana containing a known population of hydrilla is currently restricted. Therefore, boating through hydrilla is unlikely within Indiana lakes.) Caution should be used if an individual observes hydrilla. This individual should contact Doug Keller, IDNR ANS

coordinator, immediately if hydrilla is observed in or around any of Indiana's lakes. 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 watermilfoil or hydrilla can sprout and establish a new plant. This is likely the source of the Eurasian watermilfoil present around this boat motor (Figure 75). Signage at the public boat ramp informing visitors of these best management practices would also be useful. It is important to note that IDNR approval is required to post any signs at the public boat ramp.

Figure 75. Eurasian watermilfoil growing adjacent to a boat lift and dock. This provides a great example of cut fragments re-growing and shows the need for spot treating the plant community at this particular residence. Other areas like this exist around the lake but were not recorded photographically.

A good aquatic plant 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 aquatic plant management techniques, including chemical control, harvesting, and biological control, require a permit form the IDNR. Depending on 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. The following paragraphs describe some aquatic plant management techniques that may be applicable to Pretty Lake, given its specific ecological condition.

Chemical Control

Herbicides are the most traditional means of controlling aquatic vegetation. No recorded herbicide control occurred within Pretty Lake (Lagrange County) in 2005 or 2006. Herbicides have been used in the past on Pretty Lake. However, 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 target lake. In addition, 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. These herbicides, also called contact herbicides, are only effective for controlling submerged vegetation on the short term. Such herbicides can kill non-target plants and sometimes even fish species in a lake. Rather, selective or systemic herbicides (triclopyr, fluoridone, etc.) are recommended for effective control of Eurasian watermilfoil. Fluoridone is typically recommended for whole lake treatment of Eurasian watermilfoil due to the lower tolerance of Eurasian watermilfoil to Fluoridone compared with other aquatic plant species. 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 $300 to $400 per acre or $750 to $1000 per hectare (Nate Long, Aquatic 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 Pretty Lake since treated plants are often left to decay in the water. This will contribute nutrients to the lake's water column. Additionally, plants left to decay in the water column will consume oxygen. The in-lake sampling conducted during this study showed that Pretty Lake possessed relatively low nutrient concentrations compared to many Indiana lakes. Nonetheless, as evidenced during the plant survey, the lake's total phosphorus concentration is high enough to support filamentous algae and, based on the water chemistry samples collected during the previous in-lake assessments, the lake may also experience algal blooms. The plankton community present in Pretty Lake further iterates this issue in that the community is dominated by blue-green algae. Furthermore, the blue-green algae that comprised the largest portion of the plankton community have been known to cause taste, odor, and toxicity problems in other lakes. Chemical treatment is likely the best way to control growth and spread of Eurasian watermilfoil in Pretty Lake.

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 watermilfoil 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.

Hand harvesting may be the most economical means of harvesting on Pretty Lake. Hand harvesting is recommended in small areas where human uses are hampered by extensive growths (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 76). 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. Depending on the size to be treated, a permit may be required for hand-harvesting. (The IDNR Division of Fish & Wildlife can assist lake residents in determining whether a permit is needed and how to obtain one.)

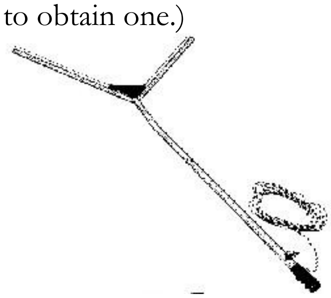

Figure 76. An aquatic weed cutter designed to cut emergent weeds along the edge of ponds. It has a 48" cutting width, uses heavy-duty stainless steel blades, can be sharpened, and comes with an attached 20' rope and blade covers.

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 region with suitable habitat, it grows rapidly because its native predators have not been introduced to the new region along with the plant species. This is the case with some of the common pest plants in northeast Indiana such as Eurasian watermilfoil and purple loosestrife. Neither of these species is native to Indiana, yet both exist in and around Lagrange County.

Researchers have studied the ability of various insect species to control both Eurasian watermilfoil and purple loosestrife. Cooke et al. (1993) points to four different species that may reduce Eurasian watermilfoil 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 watermilfoil. Purple loosestrife biocontrol researchers have examined the potential for three insects, *Gallerucella calmariensis, G. pusilla*, and *Hylobius transversovittatus,* to control the plant.

While the population of purple loosestrife on Pretty Lake is relatively small and therefore may not be suitable for biological control efforts, it may be worthwhile for Pretty Lake residents to understand the common biocontrol mechanisms for this species should the situation on the lake change. Likewise, as Eurasian watermilfoil is present in Pretty Lake, residents should be cognizant of infestation issues and biocontrol mechanisms for Eurasian watermilfoil. Therefore, treatment options for the plant are discussed below merely as reference material for use in case of future infestation. Residents should also be aware that under new regulations an IDNR permit is required for the implementation of a biological control program on a lake.

Eurasian Watermilfoil

Euhrychiopsis lecontei has been implicated in a reduction of Eurasian watermilfoil in several Northeastern and Midwestern lakes (USEPA, 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 (Madsen, 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 watermilfoil. A nine-year study of nine southeastern Wisconsin lakes suggested that weevil activity might have contributed to Eurasian watermilfoil declines in the lakes (Helsel et al, 1999).

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian watermilfoil (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 watermilfoil 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.

The Indiana Department of Natural Resources released *E. lecontei* weevils in three Indiana lakes to evaluate the effectiveness of utilizing the weevils to control Eurasian watermilfoil in Indiana lakes. The results of this study were inconclusive (Scribailo and Alix, 2003), and the IDNR considers the use of the weevils on Indiana lakes an unproven technique and only experimental (Rich, 2005). If future infestation of Eurasian watermilfoil should occur, Pretty Lake residents should take the lack of proven usefulness in Indiana lakes into consideration before attempting treatment of the lake's Eurasian watermilfoil with the *E. lecontei* weevils.

Purple Loosestrife

Biological control may also be possible for inhibiting the growth and spread of the emergent purple loosestrife. Like Eurasian watermilfoil, 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 shallow water and moist soil environment, 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 watermilfoil, 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.

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 bottom cover materials placed on 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.

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 77). 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. The Stop the Hitchhikers! campaign offers information on the prevention of spreading exotic invasive species. Visit their website at for more information: www.protectyourwaters.net

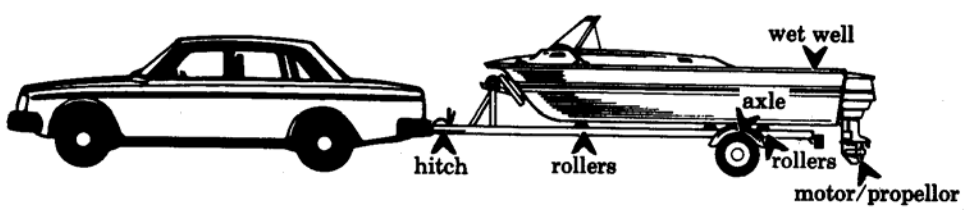

Figure 77. Locations where aquatic macrophytes are often found on boats and trailers.

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 Pretty Lake. Eurasian watermilfoil is present in Pretty Lake and other area lakes; therefore, educational programs and lake signage will help prevent the spread of this nuisance species into other parts of the lake or into other area lakes. This is particularly important given the popularity of Pretty Lake. Non-resident anglers and other visitors will use their boats in other lakes in addition to Pretty Lake, potentially spreading Eurasian watermilfoil to uninfested lakes. Signs addressing any best management practices to prevent the spread of nuisance aquatic species will ultimately help protect all lakes as new nuisance (often non-native) species are finding their way to Indiana lakes all the time.

6.3.3 Dredging

Sediment removal by dredging removes phosphorus enriched sediments from lake bottoms, thereby reducing the likelihood of phosphorus release from the sediments. Dredging also deepens lakes for recreational purposes and limits the growth area for rooted macrophytes. Because this technique is capital-intensive, it can only be justified in small lakes or in lakes where the sediment-bound phosphorus is limited to a small, identifiable area. Dredging is not effective in lakes where additional sediment loading cannot be controlled. Sediment removal might be justified in a seepage lake, where watershed controls are not applicable. Furthermore, the use of dredging as a plant control technique may not be completely effective considering that dredged areas may be recolonized by nuisance exotic species.

A potentially troublesome consequence of dredging is the resuspension of sediments during the dredging operation and the possible release of toxic substances bound loosely to sediments. Because of this, sediment cores must be analyzed prior to dredging to determine sediment composition. Such an analysis would also provide a profile of phosphorus concentrations with depth in the sediments. If phosphorus concentrations do not decline with depth, dredging for phosphorus control would not be effective since phosphorus could continue to be released from the sediments.

Cost must be carefully evaluated before dredging operations occur. In deep lakes, the cost of dredging can be prohibitive. In small lakes, it may be easier and more cost-effective to dewater the lake and remove sediments with front end loaders and trucks. Perhaps the most economically and logistically prohibitive part of a dredging operation is disposal of the removed sediments. Sediment disposal must be investigated *before* the decision to dredge can be made. Dredging costs range from $25,000 to $30,000 per acre (Jeff Krevda and Steve Tennant, personal communication). This estimate excludes any administrative costs associated with dredging. Any dredging activities in a freshwater public lake will require permits from the Corps of Engineers, the Indiana Department of Environmental Management, and Indiana Department of Natural Resources, further increasing the cost of dredging.

Dredging should not be the first priority to resolve nutrient problems in Pretty Lake. After the association addresses sediment and nutrient loading issues within the watershed, a sediment removal plan should be completed. Under the Lake and River Enhancement sediment removal program, applicants have to complete a sediment removal plan in order to qualify for funding. Lake and River Enhancement program staff indicate that lake associations that have targeted watershed issues to reduce sediment and nutrient loading will receive higher priority for sediment removal funding. After addressing these issues, completing a sediment removal plan would be the ideal avenue for understanding dredging needs on the lakes. The Pretty Lake Conservation Club has already identified areas where recreation is impaired and dredging may be a solution. These areas include the mouth of Deal Ditch and the outlet stream. As the outlet stream dredging is the highest priority, this area was investigated to determine the amount of sediment that is necessary to remove (Figure 78). As the Deal Ditch mouth is not of high priority, no mapping was completed during this project. Before any dredging or sediment removal planning begins, the PLCC should consult with local IDNR fisheries biologists to determine if dredging of desired areas is feasible.

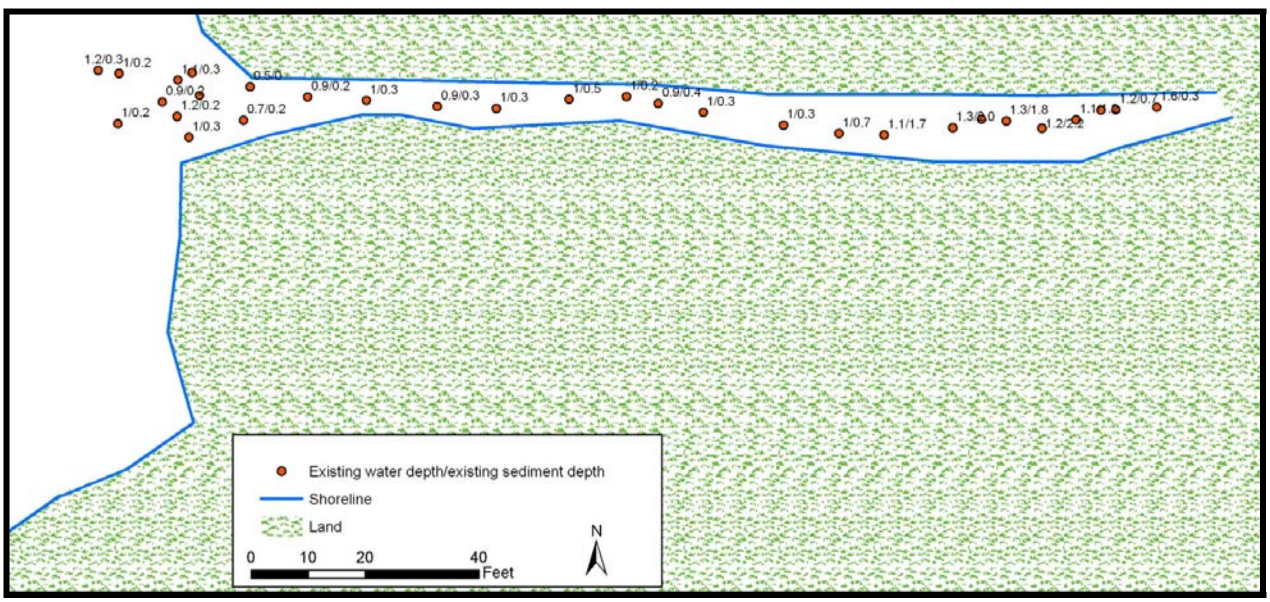

Figure 78. Sediment and water depths (in feet) in the Pretty Lake outlet stream where the PLCC wishes to complete dredging. Points indicate locations where sampling occurred. Numbers indicate water depth/sediment depth.

6.3.4 Water Quality Monitoring

The Indiana Clean Lakes Volunteer Monitoring Program trains and equips citizen volunteers to measure Secchi disk transparency, water color, total phosphorus, and chlorophyll *a* in Indiana lakes.

Citizen volunteers monitor over 115 lakes for transparency and 40 lakes for phosphorus and chlorophyll. Volunteers also have access to temperature and oxygen meters to track changes in these parameters throughout the year. Data collected by volunteers helps elucidate any trends in water quality and provides more timely information with which lake management decisions can be made. Pretty Lake has participated in this program in the past and should continue providing a citizen volunteer. Participation in the Indiana Clean Lakes Volunteer Monitoring Program is highly recommended. It is also recommended that the PLCC maintain their volunteer stream sampling efforts.

7.0 RECOMMENDATIONS

As noted in the previous section, Pretty Lake currently possesses good water quality. However, there is cause for concern that the lake will not be able to continue to absorb the pollutant load reaching the lake. Results from the modeling and lake and stream assessments indicate that current pollutant; particularly phosphorus, nitrate, organic matter, and bacteria, concentrations and loads are of concern for the lake's long-term health. Lake residents have already noted declines in water clarity in portions of the lake following heavy boating activity, suggesting sediment is also of concern. Many residents have also observed negative shifts in the lake's rooted plant composition and density.

Given the Pretty Lake's specific characteristics, both in-lake and watershed management is recommended to maintain the lake's good water quality. Pretty Lake's low watershed area to lake area ratio suggests actions taken along the shoreline can have a significant impact of the lake's health. Thus, management of near shore streams and individual residential properties should be prioritized. The lake's relatively long hydraulic residence time means in-lake management, which can affect nutrient cycling, should also receive a high priority. Watershed management techniques to reduce the elevated total phosphorus and bacteria levels observed in Deal Ditch are also important.

The following list summarizes the recommendations for maintaining and improving Pretty Lake's chemical, biological, and physical condition. Each of the following recommendations should be implemented and will help maintain Pretty Lake's good water quality. The list is prioritized based on the current ecological conditions of Pretty Lake and its watershed. These conditions may change as land and lake use change requiring a change in the order of prioritization. Watershed stakeholders may also wish to prioritize these management recommendations differently to accommodate specific needs or desired uses of the lake. It is important for watershed stakeholders to know that action need not be taken in this order. Some of the smaller, less expensive recommendations, such as the individual property owner recommendations, may be implemented while funds are being raised to implement some of the larger projects. (Appendix I provides a list of possible funding sources to implement recommended projects.) Many of the larger projects will require feasibility studies to ensure landowner willingness to participate in the project and regulatory approval of the project.

1. Stabilize actively eroding streams (Deal Ditch and a minor drainage on the south side of the lake) by reducing the volume and velocity of water moving through the streams. Consider the installation of sediment traps and check dams in streams where erosion is most severe.

2. Implement individual property owner management techniques. These apply to all watershed property owners rather than simply those who live immediately adjacent to Pretty 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. Additionally, consider replacing or refacing concrete seawalls with glacial stone seawalls.
e. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
f. 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. Stabilize bare drainage ditches with vegetation where possible or rock where flow rates are too high for vegetation.
g. Obey no-wake zones.
h. Clean boat propellers after lake use and refrain from dumping bait buckets into the lake to prevent the spread of exotic species.

3. Manage the Eurasian watermilfoil present on the lake to prevent its spread and protect the diverse, native submerged rooted plant community. Ensure buoy placement limits boat traffic through Eurasian watermilfoil hot spots until these areas can be treated.

4. Restore wetland habitat within the Pretty Lake watershed where feasible. Figure 64 shows areas that are good candidates for wetland restoration.

5. Monitor and improve erosion control techniques on residential and commercial development sites. Bring areas of concern to the attention of the appropriate authorities such as the Lagrange County SWCD.

6. Connect the properties adjacent to drainage ditches to the existing sewer system. Alternately, construct a wastewater wetland to treat the human waste stream from residences near the lake that are not currently connected to the existing sewer system.

7. Increase usage of the Conservation Reserve Program in the Pretty Lake watershed particularly on land mapped in highly erodible soils.

8. Implement stormwater filtration projects including assessment the number of storm drains adjacent to the lake and determining pollutant loads for each drain and designing and construction a stormwater filter for the gravel road crossing over Deal Ditch at CR 875 East.

9. Continue active volunteer monitoring through the Indiana Clean Lakes Program volunteer monitoring program. Pretty Lake has had a volunteer in the past and continues to participate in the volunteer program currently; continued participation in this program is recommended. 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.

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APPENDICES

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

APPENDIX A:

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

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

DNR Indiana Department of Natural Resources

Mitchell E. Daniels, Jr., Governor
Kyle J. Hupfer, Director

Division of Nature Preserves
402 W. Washington St., Rm W267
Indianapolis IN 46204-2739

November 3, 2005

Mr. Mark Pranckus
J.F. New
708 Roosevelt Road
Walkerton, IN 46574

Dear Mr. Pranckus:

I am responding to your request for information on the endangered, threatened, or rare (ETR) species, high quality natural communities, and natural areas documented from a the Pretty Lake Watershed project area, LaGrange County, Indiana. The Indiana Natural Heritage Data Center has been checked and following you will find information on the ETR species documented from the project area.

1. The state non-game protected animal Taxidea taxus, American badger, was documented in Sections 9 in 1989 and in Section 17 in 1983, T36N, R11E in the watershed area.

For more information on the animal species mentioned, please contact Katie Smith, Nongame Supervisor, Division of Fish and Wildlife, 402 W. Washington Room W273, Indianapolis, Indiana 46204, (317)232-4080.

The information I am providing does not preclude the requirement for further consultation with the U.S. Fish and Wildlife Service as required under Section 7 of the Endangered Species Act of 1973. You should contact the Service at their Bloomington, Indiana office.

U.S. Fish and Wildlife Service
620 South Walker St.
Bloomington, Indiana 47403-2121
(812)334-4261

At some point, you may need to contact the Department of Natural Resources' Environmental Review Coordinator so that other divisions within the department have the opportunity to review your proposal. For more information, please contact:

Kyle Hupfer, Director
Department of Natural Resources
attn: Christie Kiefer
Environmental Coordinator
Division of Water
402 W. Washington Street, Room W264
Indianapolis, IN 46204
(317)232-4160

Please note that the Indiana Natural Heritage Data Center relies on the observations of many individuals for our data. In most cases, the information is not the result of comprehensive field surveys conducted at particular sites. Therefore, our statement that there are no documented significant natural features at a site should not be interpreted to mean that the site does not support special plants or animals.

Due to the dynamic nature and sensitivity of the data, this information should not be used for any project other than that for which it was originally intended. It may be necessary for you to request updated material from us in order to base your planning decisions on the most current information.

Thank you for contacting the Indiana Natural Heritage Data Center. You may reach me at (317)232-8059 if you have any questions or need additional information.

Sincerely,

Ronald P. Hellmich

Ronald P. Hellmich
Indiana Natural Heritage Data Center

enclosure: invoice

APPENDIX B:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, LAGRANGE COUNTY

PRETTY LAKE DIAGNOSTIC STUDY LAGRANGE COUNTY, INDIANA

Indiana County Endangered, Threatened and Rare Species List

County: Lagrange

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Alasmidonta viridis	Slippershell Mussel			G4G5	S2
Epioblasma triquetra	Snuffbox		SE	G3	S1
Venustaconcha ellipsiformis	Ellipse		SSC	G3G4	S2
Villosa fabalis	Rayed Bean	C	SSC	G1G2	S1
Insect: Homoptera					
Dorydiella kansana			ST	GNR	S1
Prairiana kansana	The Kansas Prairie Leafhopper		SE	GNR	S1S2
Insect: Lepidoptera (Butterflies & Moths)					
Anepia capsularis	The Starry Campion Capsule Moth		SR	G5	S1S2
Apamea verbascoides	The Boreal Apamea		ST	G5	S1S2
Bellura densa	A Noctuid Moth		ST	G5	S1S2
Boloria selene myrina	Silver-bordered Fritillary		ST	G5T5	S2
Calephelis muticum	Swamp Metalmark		ST	G3	S2
Capis curvata	A Noctuid Moth		ST	G4	S2S3
Catocala praeclara	Praeclara Underwing		SR	G5	S2S3
Chortodes inquinata	Tufted Sedge Moth		ST	GNR	S1S2
Crambus girardellus	Orange-striped Sedge Moth		SR	GNR	S2S3
Cryptocala acadiensis	Catocaline Dart		ST	G5	S1S2
Dasychira cinnamomea	A Moth		SR	G4	S1
Euphydryas phaeton	Baltimore		SR	G4	S2
Euphyes bimacula	Two-spotted Skipper		ST	G4	S2
Exyra rolandiana	Pitcher Window Moth		SE	G4	S1S2
Glaucopsyche lygdamus couperi	Silvery Blue		SE	G5T4	S1
Grammia oithona	Oithona's Grammia		SR	G4Q	S2S3
Hemileuca sp. 3	Midwestern Fen Buckmoth		ST	G3G4Q	S1?
Iodopepla u-album	A Noctuid Moth		SR	G5	S2
Leucania inermis	A Moth		SR	G4	S2S3
Leucania multilinea			ST	G5	S1S2
Loxagrotis grotei	Grote's Black-tipped Quaker		ST	G4	S2
Lycaeides melissa samuelis	Karner Blue	LE	SE	G5T2	S1
Lycaena dorcas dorcas	Dorcas Copper		SR	G5TU	S2
Lycaena helloides	Purplish Copper		SR	G5	S2S4
Macrochilo absorptalis	A Moth		SR	G4G5	S2S3
Macrochilo bivittata	Two-striped Cord Grass Moth		SE	G3G4	S1
Macrochilo hypocritalis	A Noctuid Moth		SR	G4	S2
Melanchra assimilis	The Shadowy Arches		SE	G5	S1S2
Neonympha mitchellii mitchellii	Mitchell's Satyr	LE	SE	G1G2T1T2	S1
Oligia bridghami	A Noctuid Moth		ST	G4	S1
Panthea furcilla			SR	G5	S2S3
Papaipema silphii	Silphium Borer Moth		ST	G3G4	S2
Pieris oleracea	Eastern Veined White		SE	G4G5	S1
Poanes viator viator	Big Broad-winged Skipper		ST	G5T4	S2
Spartiniphaga includens	The Included Cordgrass Borer		ST	G4	S1
Speyeria idalia	Regal Fritillary		SE	G3	S1
Insect: Odonata (Dragonflies & Damselflies)					
Aeshna mutata	Spatterdock Darner		ST	G4	S1S2
Aeshna tuberculifera	Black-tipped Darner		ST	G4	S2
Cordulegaster bilineata	Brown Spiketail		SE	G5	S1
Cordulegaster obliqua	Arrowhead Spiketail		SR	G4	S2S3
Dorocordulia libera	Racket-tailed Emerald		SE	G5	S1
Gomphus quadricolor	Rapids Clubtail		ST	G3G4	S2
Gomphus ventricosus	Skillet Clubtail		ST	G3	S1S2
Hagenius brevistylus	Dragonhunter		SR	G5	S2S3

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GRANK: Global Heritage Rank: G1 = critically imperiled globally; G2 = imperiled globally; G3 = rare or uncommon globally; G4 = widespread and abundant globally but with long term concerns; G5 = widespread and abundant globally; G? = unranked; GX = extinct; Q = uncertain rank; T = taxonomic subunit rank
SRANK: State Heritage Rank: S1 = critically imperiled in state; S2 = imperiled in state; S3 = rare or uncommon in state; G4 = widespread and abundant in state but with long term concern; SG = state significant; SH = historical in state; SX = state extirpated; B = breeding status; S? = unranked; SNR = unranked; SNA = nonbreeding status unranked

Indiana County Endangered, Threatened and Rare Species List

County: Lagrange

Species Name	Common Name	FED	STATE	GRANK	SRANK
Nannothemis bella	Dwarf Skimmer		SE	G4	S1
Nehalennia gracilis	Sphagnum Sprite		SE	G5	S1
Stylurus amnicola	Riverine Clubtail		ST	G4	S1S2
Stylurus scudderi	Zebra Clubtail		SE	G4	S1
Sympetrum semicinctum	Band-winged Meadowhawk		SR	G5	S2S3
Insect: Tricoptera (Caddisflies)					
Nectopsyche pavida	A Longhorned Casemaker Caddisfly		SR	G5	S2
Fish					
Coregonus artedi	Cisco		SSC	G5	S2
Moxostoma valenciennesi	Greater Redhorse		SE	G4	S2
Amphibian					
Ambystoma laterale	Blue-spotted Salamander		SSC	G5	S2
Hemidactylium scutatum	Four-toed Salamander		SE	G5	S2
Rana pipiens	Northern Leopard Frog		SSC	G5	S2
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Emydoidea blandingii	Blanding's Turtle		SE	G4	S2
Nerodia erythrogaster neglecta	Copperbelly Water Snake	PS:LT	SE	G5T2T3	S2
Sistrurus catenatus catenatus	Eastern Massasauga	C	SE	G3G4T3T4	S2
Bird					
Accipiter striatus	Sharp-shinned Hawk	No Status	SSC	G5	S2B
Ammodramus henslowii	Henslow's Sparrow		SE	G4	S3B
Ardea herodias	Great Blue Heron			G5	S4B
Bartramia longicauda	Upland Sandpiper		SE	G5	S3B
Buteo lineatus	Red-shouldered Hawk		SSC	G5	S3
Buteo platypterus	Broad-winged Hawk	No Status	SSC	G5	S3B
Chlidonias niger	Black Tern		SE	G4	S1B
Circus cyaneus	Northern Harrier		SE	G5	S2
Cistothorus palustris	Marsh Wren		SE	G5	S3B
Cistothorus platensis	Sedge Wren		SE	G5	S3B
Dendroica cerulea	Cerulean Warbler		SSC	G4	S3B
Dendroica virens	Black-throated Green Warbler			G5	S2B
Empidonax alnorum	Alder Flycatcher			G5	S2B
Gallinago delicata	Wilson's Snipe			G5	S1S2B
Gallinula chloropus	Common Moorhen	No Status	SE	G5	S3B
Grus canadensis	Sandhill Crane	No Status	SSC	G5	S2B,S1N
Ixobrychus exilis	Least Bittern		SE	G5	S3B
Lanius ludovicianus	Loggerhead Shrike	No Status	SE	G4	S3B
Nycticorax nycticorax	Black-crowned Night-heron		SE	G5	S1B
Rallus limicola	Virginia Rail		SE	G5	S3B
Sturnella neglecta	Western Meadowlark		SSC	G5	S2B
Tyto alba	Barn Owl		SE	G5	S2
Vermivora chrysoptera	Golden-winged Warbler		SE	G4	S1B
Wilsonia canadensis	Canada Warbler			G5	S2B
Wilsonia citrina	Hooded Warbler		SSC	G5	S3B
Mammal					
Condylura cristata	Star-nosed Mole		SSC	G5	S2?
Lutra canadensis	Northern River Otter			G5	S2
Lynx rufus	Bobcat	No Status		G5	S1
Mustela nivalis	Least Weasel		SSC	G5	S2?
Myotis sodalis	Indiana Bat or Social Myotis	LE	SE	G2	S1
Taxidea taxus	American Badger			G5	S2
Vascular Plant					

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Indiana County Endangered, Threatened and Rare Species List

County: Lagrange

Species Name	Common Name	FED	STATE	GRANK	SRANK
Actaea rubra	Red Baneberry		SR	G5	S2
Amelanchier humilis	Running Serviceberry		SE	G5	S1
Andromeda glaucophylla	Bog Rosemary		SR	G5	S2
Arabis missouriensis var. deamii	Missouri Rockcress		SE	G4G5QT3?Q	S1
Arenaria stricta	Michaux's Stitchwort		SR	G5	S2
Aster borealis	Rushlike Aster		SR	G5	S2
Besseya bullii	Kitten Tails		SE	G3	S1
Bidens beckii	Beck Water-marigold		ST	G4G5T4	S1
Botrychium matricariifolium	Chamomile Grape-fern		SR	G5	S2
Calla palustris	Wild Calla		SE	G5	S1
Carex alopecoidea	Foxtail Sedge		SE	G5	S1
Carex brunnescens	Brownish Sedge		SE	G5	S1
Carex debilis var. rudgei	White-edge Sedge		SR	G5T5	S2
Carex flava	Yellow Sedge		ST	G5	S2
Carex limosa	Mud Sedge		SE	G5	S1
Carex pedunculata	Longstalk Sedge		SR	G5	S2
Carex retrorsa	Retrorse Sedge		SE	G5	S1
Carex sparganioides var. cephaloidea	Thinleaf Sedge		SE	G5	S2
Chimaphila umbellata ssp. cisatlantica	Pipsissewa		ST	G5T5	S2
Circaea alpina	Small Enchanter's Nightshade		SX	G5	SX
Cirsium hillii	Hill's Thistle		SE	G3	S1
Conioselinum chinense	Hemlock Parsley		SE	G5	S1
Cornus rugosa	Roundleaf Dogwood		SR	G5	S2
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper		SR	G5	S2
Cypripedium candidum	Small White Lady's-slipper		WL	G4	S2
Deschampsia cespitosa	Tufted Hairgrass		SR	G5	S2
Drosera intermedia	Spoon-leaved Sundew		SR	G5	S2
Eleocharis equisetoides	Horse-tail Spikerush		SE	G4	S1
Eleocharis robbinsii	Robbins Spikerush		SR	G4G5	S2
Epigaea repens	Trailing Arbutus		WL	G5	S3
Equisetum variegatum	Variegated Horsetail		SE	G5	S1
Eriophorum angustifolium	Narrow-leaved Cotton-grass		SR	G5	S2
Eriophorum gracile	Slender Cotton-grass		ST	G5	S2
Eriophorum viridicarinatum	Green-keeled Cotton-grass		SR	G5	S2
Geum rivale	Purple Avens		SE	G5	S1
Gnaphalium macounii	Winged Cudweed		SX	G5	SX
Hydrocotyle americana	American Water-pennywort		SE	G5	S1
Juglans cinerea	Butternut		WL	G3G4	S3
Juncus balticus var. littoralis	Baltic Rush		SR	G5T5	S2
Lathyrus ochroleucus	Pale Vetchling Peavine		SE	G4G5	S1
Lathyrus venosus	Smooth Veiny Pea		ST	G5	S2
Linum sulcatum	Grooved Yellow Flax		SR	G5	S2
Lycopodiella inundata	Northern Bog Clubmoss		SE	G5	S1
Lycopodium hickeyi	Hickey's Clubmoss		SR	G5	S2
Lycopodium obscurum	Tree Clubmoss		SR	G5	S2
Matteuccia struthiopteris	Ostrich Fern		SR	G5	S2
Melampyrum lineare	American Cow-wheat		SR	G5	S2
Milium effusum	Tall Millet-grass		SR	G5	S2
Myriophyllum verticillatum	Whorled Water-milfoil		SR	G5	S2
Oryzopsis racemosa	Black-fruit Mountain-ricegrass		SR	G5	S2
Panax trifolius	Dwarf Ginseng		WL	G5	S2
Panicum boreale	Northern Witchgrass		SR	G5	S2
Panicum leibergii	Leiberg's Witchgrass		ST	G5	S2
Panicum subvillosum	A Panic-grass		SE	GNRQ	S1
Platanthera ciliaris	Yellow-fringe Orchis		SE	G5	S1

Indiana County Endangered, Threatened and Rare Species List

County: Lagrange

Species Name	Common Name	FED	STATE	GRANK	SRANK
Platanthera hyperborea	Leafy Northern Green Orchis		ST	G5	S2
Platanthera leucophaea	Prairie White-fringed Orchid	LT	SE	G3	S1
Platanthera psycodes	Small Purple-fringe Orchis		SR	G5	S2
Poa paludigena	Bog Bluegrass		WL	G3	S3
Potamogeton friesii	Fries' Pondweed		ST	G4	S1
Potamogeton praelongus	White-stem Pondweed		ST	G5	S1
Potamogeton pusillus	Slender Pondweed		WL	G5	S2
Potamogeton richardsonii	Redheadgrass		SR	G5	S2
Potamogeton robbinsii	Flatleaf Pondweed		SR	G5	S2
Pyrola rotundifolia var. americana	American Wintergreen		SR	G5	S2
Rudbeckia fulgida var. fulgida	Orange Coneflower		WL	G5T4?	S2
Salix serissima	Autumn Willow		ST	G4	S2
Scheuchzeria palustris ssp. americana	American Scheuchzeria		SE	G5T5	S1
Schizachne purpurascens	Purple Oat		SE	G5	S1
Scirpus purshianus	Weakstalk Bulrush		SR	G4G5	S1
Scirpus subterminalis	Water Bulrush		SR	G4G5	S2
Selaginella rupestris	Ledge Spike-moss		ST	G5	S2
Spiranthes lucida	Shining Ladies'-tresses		SR	G5	S2
Spiranthes romanzoffiana	Hooded Ladies'-tresses		ST	G5	S1
Stipa avenacea	Blackseed Needlegrass		SR	G5	S2
Tofieldia glutinosa	False Asphodel		SR	G5	S2
Triglochin palustris	Marsh Arrow-grass		SR	G5	S2
Utricularia cornuta	Horned Bladderwort		ST	G5	S2
Utricularia resupinata	Northeastern Bladderwort		SX	G4	SX
Vaccinium oxycoccos	Small Cranberry		ST	G5	S2
Valeriana uliginosa	Marsh Valerian		SE	G4Q	S1
Viburnum cassinoides	Northern Wild-raisin		SE	G5T5	S1
Viburnum opulus var. americanum	Highbush-cranberry		SE	G5T5	S1
Xyris difformis	Carolina Yellow-eyed Grass		ST	G5	S2
Zigadenus elegans var. glaucus	White Camas		SR	G5T4T5	S2
High Quality Natural Community					
Forest - flatwoods sand	Sand Flatwoods		SG	G2?	S1
Forest - floodplain wet	Wet Floodplain Forest		SG	G3?	S3
Forest - floodplain wet-mesic	Wet-mesic Floodplain Forest		SG	G3?	S3
Forest - upland dry	Dry Upland Forest		SG	G4	S4
Forest - upland mesic	Mesic Upland Forest		SG	G3?	S3
Lake - lake	Lake		SG	GNR	S2
Wetland - beach marl	Marl Beach		SG	G3	S2
Wetland - bog acid	Acid Bog		SG	G3	S2
Wetland - bog circumneutral	Circumneutral Bog		SG	G3	S3
Wetland - fen	Fen		SG	G3	S3
Wetland - fen forested	Forested Fen		SG	G3	S1
Wetland - marsh	Marsh		SG	GU	S4
Wetland - meadow sedge	Sedge Meadow		SG	G3?	S1
Wetland - swamp forest	Forested Swamp		SG	G2?	S2
Wetland - swamp shrub	Shrub Swamp		SG	GU	S2

APPENDIX C:

E. COLI SOURCE TRACKING METHODOLOGY AND RESULTS

PRETTY LAKE DIAGNOSTIC STUDY LAGRANGE COUNTY, INDIANA

BACTERIAL SOURCE TRACKING OF ENTEROCOCCI
Pretty Lake Watershed

Water samples were collected from five locations in the Pretty Lake watershed by James Mertz on July 10, 2006 and transported to I.P.F.W. On the same day, enterococci were isolated from the water samples, which were maintained under refrigeration until filtration. They were analyzed for antibiotic resistance by the attached protocol.

Results of the antibiotic resistance analysis are reported below in terms of percentages of the total number of strains which were matched by discriminate analysis to the indicated sources. Typically, 48 enterococcal strains are isolated per water sample.

Sample	% swine	% other lvsk	% pets	% wildlife	% human	% horse
#2	0	6.0	14.5	0	12.5	67.0
#3	16.7	2.1	22.9	0	20.8	37.5
#7	0	4.2	12.5	0	0	83.3
#8	0	6.3	4.2	0	35.8	53.7
#9	2.1	10.5	11.6	2.1	4.2	69.5

The results indicate a the antibiotic resistance pattern characteristic of swine appears at site 3. The antibiotic resistance pattern characteristic of cattle appears at site 9, but otherwise livestock do not make a significant contribution within this watershed. Antibiotic resistance patterns identified as belonging to domestic pets make significant contributions at all sites except 8. None of the observed antibiotic resistance patterns are that of wildlife. The primary human antibiotic resistance patterns is significant at three of the sites within the watershed: 2, 3 and 8. The secondary human antibiotic resistance pattern, also shared by horses, is significant at all sites within the watershed.

In conclusion, the swine antibiotic resistance pattern can be detected at site 3. The antibiotic resistance pattern characteristic of domestic pets can be detected along the watershed to varying degrees. Similarly, the human antibiotic resistance pattern can be detected along the watershed, but particularly at 2, 3 and 8. The horse antibiotic resistance pattern needs to be further investigated, since a significant minority of human strains also produce that antibiotic resistance pattern. A census of horses and where they are located along the watershed would enable the source of that antibiotic resistance pattern to be appropriately identified.

Estimates of counts of fecal enterococci from the initial isolation media are as follows:

Site 2	600 bacteria/100 mL
Site 3	2,920 bacteria/100 mL

Site 7	220 bacteria/100 mL
Site 8	1,800 bacteria/100 mL
Site 9	1,200 bacteria/mL

These figures cannot be substituted for fecal coliform numbers, but they do indicate relative levels of fecal contamination along the watershed.

A random sample of bacterial strains were isolated and analyzed for characteristics of fecal enterococci: Gram positive cocci, ability to produce esculin, ability to grow at 43° C and ability to grown in 6% NaCl. All strains were positive.

PROTOCOL FOR BACTERIAL SOURCE ANALYSIS OF WATER SAMPLES

Filtering of Water Samples

Within 6 hours of sample collection, samples are filtered using a sterile filter apparatus and presterilized Gelman GN-6 filters (0.22 micron poor size). Amount of water to be filtered depends on the investigator's estimate of the numbers of bacteria in the sample. For pristine water, two 25 mL and one 50 mL samples may be used, while for more polluted water, 2 5 mL and one 10 mL samples may be used. After filtration, the filter is placed on the surface of mENT agar in a Petri dish using a sterile forceps. The plates are incubated for 48 hours at 37°C.

Isolation of Fecal Enterococci

After 48 hours incubation, red colonies are picked off of the filters using sterile toothpicks and inoculated into wells of a microwell plate containing Enterococcosel broth. 48 colonies are transferred per sample. Plates are incubated for 24 hours at 37°C.

Antibiotic Resistance Testing

Media containing antibiotics is made up at least one day in advance by adding various amounts of antibiotic stock solutions to 100 mL of sterile TSA to give the target concentration.

Antibiotics and their concentrations which are routinely used are:

Control	
Tetracycline	10, 10, 30, 50, 100 ppm
Chlortetracycline	60, 80, 100 ppm
Oxytetracycline	20, 40, 60, 80, 100 ppm
Neomycin	40, 60, 80 ppm
Cephalothin	10, 15, 30, 50 ppm
Erythromycin	10, 15, 30, 50 ppm
Streptomycin	40, 60, 80, 100 ppm
Vancomycin	2.5 ppm
Amoxicillin	0.156 ppm

Microwells are examined for the presence of a black color due to hydrolysis of bile esculin, which is diagnostic for enterococci. Any wells not turning black are noted and are not used in the data analysis. Plates are inculated by replica plating with a flame sterilized metal replicator containing 48 prongs. The replica plater is dipped into the microwells and then placed on top of the agar surface to transfer the bacteria. After drying, the plates are inverted and incubated for 48 hours at 37°C.

Data Recording

Growth of each isolate on each antibiotic is recorded as positive or negative on record sheets.

Data Analysis

Data are analyzed by discriminate analysis using the JMP-IN program.

Quality Control

Two strains from each water sample are selected at random and transferred from the 96-well plates to slants. They are characterized by standard bacteriological identification tests for fecal enterococci.

APPENDIX D:

MACROINVERTEBRATE DATA

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

Table 1. mIBI scoring calculation, Deal Ditch.

mIBI Metric		Metric Score
HBI	4.64	4
Number of Taxa (family)	12	4
Total Count (Number of individuals)	69	0
Percent Dominant Taxa	34.8	4
EPT Index (Number of families)	2	0
EPT Count (Number of individuals)	25	2
EPT Count/Total Count	0.36	4
EPT Abundance/Chironomid Abundance	3.13	4
Chironomid Count	8	8
mIBI Score		**3.3**

Table 2. Macroinvertebrate community and mIBI scoring calculation, Deal Ditch.

Class/Order	Family	#	EPT	# w/t	Tolerance (t)	# x t	%
Amphipoda	*Gammaridae*	11		11	4	44	15.94
Coleoptera	*Elmidae*	8		8	4	32	11.59
Coleoptera	*Haliplidae*	1		1	7	7	1.45
Diptera	*Chironomidae*	8		8	6	48	11.59
Ephemeroptera	*Baetidae*	1	1	1	4	4	1.45
Gastropoda	*Planorbidae*	1		1	7	7	1.45
Gastropoda	*Viviparidae*	2		2	6	12	2.90
Hirudinea		4		4	10	40	5.80
Isopoda	*Asillidae*	2		2	8	16	2.90
Platyhelminthes	*Planaria*	5		5	1	5	7.25
Polydesmida		2				0	2.90
Trichoptera	*Hydropsychidae*	24	24	24	4	96	34.78
Totals		**69**	**25**	**67**		**311.0**	**100.00**

Table 3. mIBI scoring calculation, outlet stream.

mIBI Metric		Metric Score
HBI	5.53	2
Number of Taxa (family)	18	8
Total Count (Number of individuals)	72	0
Percent Dominant Taxa	15.3	8
EPT Index (Number of families)	4	4
EPT Count (Number of individuals)	29	2
EPT Count/Total Count	0.40	4
EPT Abundance/Chironomid Abundance	2.90	4
Chironomid Count	10	8
mIBI Score		**4.4**

Table 4. Macroinvertebrate community and mIBI scoring calculation, outlet stream.

Order	Family	#	EPT	# w/t	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	8		8	4	32	11.11
Bivalvia	Sphaeriidae	2		2	8	16	2.78
Coleoptera	Elmidae	1		1	4	4	1.39
Diptera	Chironomidae	10		10	6	60	13.89
Diptera	Nematocera pupae	2				0	2.78
Ephemeroptera	Caenidae	7	7	7	7	49	9.72
Ephemeroptera	Heptageniidae	10	10	10	4	40	13.89
Ephemeroptera	Leptophlebiidae	1	1			0	1.39
Gastropoda	Physidae	4		4	8	32	5.56
Gastropoda	Planorbidae	2		2	7	14	2.78
Gastropoda	Valvatidae	3				0	4.17
Hemiptera	Gerridae	1		1	5	5	1.39
Hemiptera	Mesoveliidae	1				0	1.39
Hirudinea		3		3	10	30	4.17
Hirudinea	Glossiphoniidae	1		1	8	8	1.39
Lepidoptera	Ostrinia	1				0	1.39
Oligochaeta		4		4	5	20	5.56
Trichoptera	Hydropsychidae	11	11	11	4	44	15.28
Totals		**72**	**29**	**64**		**354.0**	**100.00**

APPENDIX E:

QUALITATIVE HABITAT EVALUATION INDEX (QHEI) DATASHEETS

PRETTY LAKE DIAGNOSTIC STUDY LAGRANGE COUNTY, INDIANA

STREAM: Deal Ditch **RIVER MILE:** ______ **DATE:** 7/27/2006 **QHEI SCORE** 39.0

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 4.0

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

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

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

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)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 15.0

TYPE (Check all that apply)
- [x] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] 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)
- [x] EXTENSIVE >75%(11)
- [ ] 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** 6.0

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

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

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

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

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

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 6.0

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

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

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[x]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	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)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[x]	MODERATE(2)
[x]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 0.0

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

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [x] POOL WIDTH<RIFFLE WIDTH(0)

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

COMMENTS:

RIFFLE SCORE 0.0

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) [ ] NONE(2)
- [ ] MODERATE(0) [x] NO RIFFLE(0)
- [ ] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 35.2 **% POOL** 0 **% RIFFLE** 0 **% RUN** 100 **GRADIENT SCORE** 8

Conducted by:______

Project Number: ___________

STREAM: Pretty Lake Outlet **RIVER MILE:** ______ **DATE:** 7/27/2006 **QHEI SCORE** 61.5

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

SUBSTRATE SCORE 14.0

TYPE			POOL	RIFFLE	TYPE			POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[x]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[ ]	SAND(6)		x
[x]	[ ]	COBBLE(8)			[ ]	[ ]	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)	[x] SILT-MOD(-1)
[ ] SILT-NORM(0)	[ ] SILT-FREE(1)

Extent of Embeddedness (check one)

[ ] EXTENSIVE(-2)	[x] 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 12.0

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1)	[ ] DEEP POOLS(2)	[ ] OXBOWS(1)
[x] OVERHANGING VEGETATION(1)	[x] ROOTWADS(1)	[x] AQUATIC MACROPHYTES(1)
[x] 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 14.0

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER	
[ ] HIGH(4)	[ ] EXCELLENT(7)	[x] NONE(6)	[ ] HIGH(3)	[ ] SNAGGING	[ ] IMPOUND
[x] MODERATE(3)	[ ] GOOD(5)	[ ] RECOVERED(4)	[x] MODERATE(2)	[ ] RELOCATION	[ ] ISLAND
[ ] LOW(2)	[x] FAIR(3)	[ ] RECOVERING(3)	[ ] LOW(1)	[ ] CANOPY REMOVAL	[ ] LEVEED
[ ] NONE(1)	[ ] 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 8.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[x]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[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)
[x]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	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** 0.0

MAX.DEPTH (Check 1)

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

MORPHOLOGY (Check 1)

- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [x] 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 5.0

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

- [x] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

[ ] EXTENSIVE(-1)	[ ] NONE(2)
[x] MODERATE(0)	[ ] NO RIFFLE(0)
[ ] LOW(1)	

COMMENTS: ______

6) GRADIENT (FEET/MILE): 45.3

% POOL ______ **% RIFFLE** 20 **% RUN** 80 **GRADIENT SCORE** 8

Conducted by:______

Project Number: ___________

APPENDIX F:

PLANT COMMUNITY SURVEY

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

Abbreviation	Scientific Name	Common Name	Stratum
AGRALB	*Agrostis alba*	Redtop	Emergent
AGRALP	*Agrostis alba palustris*	Bent grass	Emergent
ALISUB	*Alisma subcordatum*	Common water plantain	Emergent
ASCINC	*Asclepias incarnata*	Swamp milkweed	Emergent
BIDCER	*Bidens cernua*	Nodding beggar-ticks	Emergent
BIDCOM	*Bidens comosa*	Swamp tickseed	Emergent
BOECYC	*Boehmeria cylindrica*	False nettle	Emergent
BRASCH	*Brasenia schreberi*	Water shield	Emergent
CERDEM	*Ceratophyllum demersum*	Coontail	Submergent
CHARA	*Chara* species	Chara species	Submergent
CICBUL	*Cicuta bulbifera*	Bulblet-bear water-hemlock	Emergent
CIRARV	*Cirsium arvense*	Creeping thistle	Emergent
CXCOMO	*Carex Comosa*	Bearded sedge	Emergent
DECVER	*Decodon verticillatus*	Whirled loosestrife	Emergent
ECHCRU	*Echinochloa crusgalli*	Barnyard grass	Emergent
ECLPRO	*Eclipta prostrata*	Yerba de tajo	Emergent
ELEERY	*Eleocharis erythropoda*	Bald spikerush	Emergent
ELEPAL	*Eleocharis palustris*	Creeping spikerush	Emergent
ELOCAN	*Elodea canadensis*	Common water weed	Submergent
ELONUT	*Elodea nuttallii*	Nuttall's water-weed	Submergent
EQUARV	*Equisetum arvense*	Field horsetail	Emergent
FILALG	*Filamentous algae*	Filamentous algae	Algae
HETDUB	*Heteranthera dubia*	Water star grass	Submergent
IRIVIR	*Iris virginica*	Blue-flag iris	Emergent
JUN sp.	*Juncus* species	Rush species	Emergent
LEEORY	*Leersia oryzoides*	Rice cut grass	Emergent
LEMMIN	*Lemna minor*	Common duckweed	Floating
LEMTRI	*Lemna trisulca*	Star duckweed	Floating
LUDPOL	*Ludwigia polycarpa*	False loosestrife	Emergent
LYCUNI	*Lycopus uniflorus*	Northern bugleweed	Emergent
LYSNUM	*Lysimachia nummularia*	Creeping jennie	Emergent
LYTSAL	*Lythrum salicaria*	Purple loosestrife	Emergent
MYOSCO	*Myosotis scorpioides*	True forget-me-not	Emergent
MYREXA	*Myriophyllum exalbescens*	Northern water milfoil	Submergent
MYRHET	*Myriophyllum heterophyllum*	Various leaved water milfoil	Submergent
MYRSPI	*Myriophyllum spicatum*	Eurasian watermilfoil	Submergent
NAJFLE	*Najas flexilis*	Slender naiad	Submergent
NAJGUA	*Najas guadalupensis*	Southern naiad	Submergent
NAJMAR	*Najas marina*	Spiny naiad	Submergent
NELLUT	*Nelumbo lutea*	American lotus	Floating
NIT sp.	*Nitella* species	Nitella species	Submergent

Abbreviation	**Scientific Name**	**Common Name**	**Stratum**
NUPADV	*Nuphar advena*	Spatterdock	Floating
NYMTUB	*Nymphaea tuberosa*	White water lily	Floating
PHAARU	*Phalarus arundinacaea*	Reed canary grass	Emergent
POLAMS	*Polygonum amphibium stipulaceum*	Water knotweed	Emergent
POLCOC	*Polygonum coccineum*	Water heartsease	Emergent
POLLAP	*Polygonum lapathifolium*	Willow-weed	Emergent
PONCOR	*Pontederia cordata*	Pickerel weed	Emergent
POTAMP	*Potamogeton amplifolius*	Large-leaf pondweed	Submergent
POTBER	*Potamogeton berchtoldii*	Broad-leaved small pondweed	Submergent
POTCRI	*Potamogeton crispus*	Curly leaf pondweed	Submergent
POTFOL	*Potamogeton foliosis*	Leafy pondweed	Submergent
POTFRE	*Potamogeton friesii*	Fries's pondweed	Submergent
POTGRA	*Potamogeton gramineus*	Grassy pondweed	Submergent
POTILL	*Potamogeton illinoensis*	Illinois pondweed	Submergent
POTNAT	*Potamogeton natans*	Floating-leaf pondweed	Submergent
POTNOD	*Potamogeton nodosus*	Long-leaf pondweed	Submergent
POTPEC	*Potamogeton pectinatus*	Sago pondweed	Submergent
POTPUS	*Potamogeton pusillus*	Small pondweed	Submergent
POTRIC	*Potamogeton richardsonii*	Richardson pondweed	Submergent
POTZOS	*Potamogeton zosteriformis*	Flat-stem pondweed	Submergent
RANLON	*Ranunculus longirostris*	White water crowfoot	Submergent
SAGLAT	*Sagittaria latifolia*	Common arrowhead	Emergent
SCIACU	*Scirpus acutus*	Hard-stem bulrush	Emergent
SCIFLU	*Scirpus fluviatilis*	River bulrush	Emergent
SCIPUN	*Scirpus pungens*	Chairmaker's rush	Emergent
Spearmint	*Spearmint*	Spearmint	Emergent
SPIPOL	*Spirodela polyrhiza*	Large duckweed	Floating
TYPANG	*Typha angustifolia*	Narrow leafed cattail	Emergent
TYPGLA	*Typha* x *glauca*	Blue cattail	Emergent
TYPLAT	*Typha latifolia*	Broad leafed cattail	Emergent
UTRVUL	*Utricularia vulgaris*	Common bladderwort	Submergent
VALAME	*Valisneria americana*	Eel grass	Submergent

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 2.4 acres					Latitude: 645489 Northing
Substrate: 1	Waterbody ID:				Longitude: 4604110 Easting
Marl?	Total # of Species: 35				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CERDEM	2			
CHARA	4			
DECVER	1			
ELEERY	1			
ELOCAN	1		1	
ELONUT	1		1	
FILALG	3			
HETDUB	1			
LEEORY	1			
LEMMIN	1			
LYCUNI	1			
MYREXA	1			
MYRHET	2		1	
MYRSPI	2			
NAJFLE	1			
NAJMAR	3			
NUPADV	2			
NYMTUB	2			
POLAMS	1			
POLCOC	1			
PONCOR	2			
POTAMP	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 2.4 acres					Latitude: 645489 Northing
Substrate: 1	Waterbody ID:				Longitude: 4604110 Easting
Marl?	Total # of Species: 35				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POTCRI	1			
POTFOL	1		1	
POTGRA	2			
POTILL	2			
POTNOD	1			
POTPEC	2			
POTPUS	1		1	
POTZOS	1			
SAGLAT	1			
SCIACU	1			
TYPGLA	1			
TYPLAT	1			
VALAME	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 02	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 4.6 acres					Latitude: 645514 Northing
Substrate: 2	Waterbody ID:				Longitude: 4604220 Easting
Marl?	Total # of Species: 16				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CERDEM	1			
CHARA	4			
ELOCAN	1			
FILALG	3			
MYRHET	1		1	
MYRSPI	2			
NAJFLE	1			
NAJGUA	1			
NAJMAR	1			
NYMTUB	1			
POTBER	3		1	
POTGRA	2			
POTILL	3			
POTNAT	1			
POTPEC	2			
VALAME	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 03	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 5.7 acres					Latitude: 645488 Northing
Substrate: 3	Waterbody ID:				Longitude: 4604390 Easting
Marl?	Total # of Species: 32				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ASCINC	1			
CHARA	4			
CICBUL	1			
ECHCRU	1			
ECLPRO	1			
FIDCER	1			
FILALG	2			
HETDUB	1			
LEEORY	1			
LEMMIN	1			
LUDPAL	1			
LYSUNI	1			
MYRSPI	2			
NAJGUA	1			
NUPADV	2			
NYMTUB	2			
POLCOC	1			
POLLAP	1			
PONCOR	2			
POTAMP	1			
POTBER	2		1	
POTGRA	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 03	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 5.7 acres					Latitude: 645488 Northing
Substrate: 3	Waterbody ID:				Longitude: 4604390 Easting
Marl?	Total # of Species: 32				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POTILL	2			
POTNOD	1			
POTPEC	1			
SAGLAT	1			
SCIACU	1			
SCIPUN	1			
Spearmint	1			
SPIPOL	1			
TYPLAT	1			
VALAME	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 04	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 7.1 acres					Latitude: 645671 Northing
Substrate: 2	Waterbody ID:				Longitude: 4604530 Easting
Marl?	Total # of Species: 28				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CERDEM	1			
CHARA	3			
ELOCAN	1			
FILALG	3			
HETDUB	1			
IRIVIR	1			
LEEORY	1			
LEMMIN	1			
MYREXA	1			
MYRHET	1			
MYRSPI	2			
NAJFLE	1			
NAJGUA	1			
NAJMAR	1			
NIT sp.	2			
NUPADV	1			
NYMTUB	1			
PHAARU	1			
PONCOR	2			
POTAMP	2			
POTGRA	2			
POTILL	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 04	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 7.1 acres					Latitude: 645671 Northing
Substrate: 2	Waterbody ID:				Longitude: 4604530 Easting
Marl?	Total # of Species: 28				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POTNAT	1			
POTNOD	1			
POTPEC	2			
POTPUS	2		1	
SCIPUN	1			
VALAME	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 05	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 1.1 acres					Latitude: 645825 Northing
Substrate:	Waterbody ID:				Longitude: 4604520 Easting
Marl?	Total # of Species: 3				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 1	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CHARA	1			
FILALG	1			
POTILL	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 06	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 12.5 acres					Latitude: 645990 Northing
Substrate: 3	Waterbody ID:				Longitude: 4604460 Easting
Marl?	Total # of Species: 25				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ASCINC	1			
CERDEM	1			
CHARA	3			
DECVER	1			
ELOCAN	1			
FILALG	3			
LYTSAL	1			
MYRHET	1		1	
MYRSPI	3			
NAJFLE	1			
NAJMAR	1			
NIT sp.	1			
NUPADV	2			
NYMTUB	2			
PHAARU	1			
PONCOR	2			
POTAMP	2			
POTGRA	2			
POTILL	2			
POTPEC	2			
POTRIC	1		1	
POTZOS	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 06	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 12.5 acres					Latitude: 645990 Northing
Substrate: 3	Waterbody ID:				Longitude: 4604460 Easting
Marl?	Total # of Species: 25				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 2	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
SCIACU	1			
TYPLAT	1			
VALAME	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 07	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 22.7 acres					Latitude: 646229 Northing
Substrate: 5, 6	Waterbody ID:				Longitude: 4604230 Easting
Marl?	Total # of Species: 24				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 2	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CERDEM	1			
CHARA	2			
FILALG	2			
HETDUB	1			
MYREXA	1			
MYRHET	1		1	
MYRSPI	2			
NAJFLE	2			
NAJGUA	1			
NAJMAR	1			
NIT sp.	2			
NUPADV	1			
NYMTUB	1			
PONCOR	1			
POTAMP	2			
POTGRA	2			
POTILL	2			
POTPEC	1			
POTPUS	1		1	
SCIFLU	1			
SCIPUN	1			
TYPLAT	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
	SITE INFORMATION				**SITE COORDINATES**
Plant Bed ID: 07	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 22.7 acres					Latitude: 646229 Northing
Substrate: 5, 6	Waterbody ID:				Longitude: 4604230 Easting
Marl?	Total # of Species: 24				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 2	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
UTRVUL	1			
VALAME	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 08	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 2.6 acres					Latitude: 646336 Northing
Substrate: 6	Waterbody ID:				Longitude: 4603820 Easting
Marl?	Total # of Species: 11				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 2	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CHARA	2			
ELOCAN	1			
FILALG	2			
NAJFLE	2			
NAJMAR	1			
PHAARU	1			
POTFRE	1			
POTGRA	1			
POTILL	1			
POTPEC	1			
SCIPUN	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 09	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 8.3 acres					Latitude: 646163 Northing
Substrate:	Waterbody ID:				Longitude: 4603790 Easting
Marl?	Total # of Species: 25				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:	N:	F:	E:	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
BRASHR	1			
CERDEM	1			
DECVER	1			
FILALG	1			
HETDUB	1			
LEMMIN	1			
MYRHET	3			
MYRSPI	2			
NAJGUA	1			
NAJMAR	1			
NIT sp.	1			
NUPADV	1			
NYMTUB	1			
PONCOR	1			
POTAMP	2			
POTBER	1		1	
POTFRE	1		1	
POTGRA	2			
POTILL	2			
POTPEC	2			
POTPUS	1		1	
POTZOS	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 09	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 8.3 acres					Latitude: 646163 Northing
Substrate:	Waterbody ID:				Longitude: 4603790 Easting
Marl?	Total # of Species: 25				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S:	N:	F:	E:	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
SCIACU	1			
TYPLAT	1			
VALAME	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 10	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 8.2 acres					Latitude: 646055 Northing
Substrate: 2	Waterbody ID:				Longitude: 4603670 Easting
Marl?	Total # of Species: 11				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
BRASCH	1			
CHARA	4			
DECVER	1			
FILALG	2			
NAJFLE	2			
NYMTUB	1			
PONCOR	1			
POTGRA	2			
POTILL	1			
SCIACU	1			
SCIFLU	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 11	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 3.4 acres					Latitude: 645886 Northing
Substrate: 5, 6	Waterbody ID:				Longitude: 4603740 Easting
Marl?	Total # of Species: 31				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ASCINC	1			
BOECYC	1			
BRASCH	2			
CERDEM	1			
CHARA	3			
DECVER	1			
ELOCAN	1			
FILALG	2			
HETDUB	1			
LEMMIN	1			
MYRHET	2			
MYRSPI	2			
NAJFLE	1			
NAJMAR	1			
NELLUT	1			
NUPADV	2			
NYMTUB	2			
PONCOR	2			
POTAMP	2			
POTGRA	2			
POTILL	2			
POTNAT	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 11	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 3.4 acres					Latitude: 645886 Northing
Substrate: 5, 6	Waterbody ID:				Longitude: 4603740 Easting
Marl?	Total # of Species: 31				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POTPEC	1			
POTPUS	1		1	
POTZOS	1			
RANLON	1		1	
SCIPUN	1			
TYPANG	1			
TYPGLA	1			
TYPLAT	1			
VALAME	3			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 12	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 1.3 acres					Latitude: 645727 Northing
Substrate:	Waterbody ID:				Longitude: 4603810 Easting
Marl?	Total # of Species: 16				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
ASCINC	1			
CHARA	4			
FILALG	1			
LYTSAL	1			
NAJFLE	1			
NAJMAR	3			
NIT sp.	1			
NYMTUB	1			
PONCOR	1			
POTGRA	2			
POTILL	2			
POTPEC	1			
POTPUS	2		1	
SCIACU	1			
SCIPUN	1			
VALAME	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 13	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 3.2 acres					Latitude: 645613 Northing
Substrate: 2	Waterbody ID:				Longitude: 4603820 Easting
Marl?	Total # of Species: 39				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
AGRALB	1			
AGRALP	1			
ALISUB	1			
BIDCOM	1			
CERDEM	1			
CHARA	3			
CICBUL	1			
CIRARV	1			
CXCOMO	1			
ELEERY	1			
ELEPAL	1			
EQUARV	1		1	
FILALG	2			
IRIVIR	1			
JUN sp.	1			
LEEORY	1			
LEMMIN	1			
LEMTRI	1			
LYCUNI	1			
LYSNUM	1			
MYOSCO	1		1	
MYRHET	2			

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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 13	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 3.2 acres					Latitude: 645613 Northing
Substrate: 2	Waterbody ID:				Longitude: 4603820 Easting
Marl?	Total # of Species: 39				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 4	N: 1	F: 3	E: 2	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYRSPI	3			
NAJMAR	1			
NUPADV	2			
NYMTUB	2			
PONCOR	1			
POTAMP	3			
POTGRA	1			
POTNAT	2			
POTPEC	2			
SAGLAT	1			
SCIACU	1			
SCIPUN	1			
Spearmint	1			
SPIPOL	1			
TYPANG	1			
TYPLAT	1			
UTRVUL	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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: 8/2/06**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 14	Waterbody Name: Pretty Lake				Center of the Bed
Bed Size: 3.5 acres					Latitude: 645547 Northing
Substrate: 2	Waterbody ID:				Longitude: 4603980 Easting
Marl?	Total # of Species: 12				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				Latitude: NA
	S: 3	N: 1	F: 1	E: 1	Longitude: NA

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CHARA	3			
FILALG	1			
NAJFLE	1			
NAJGUA	1			
NIT sp.	2			
NYMTUB	1			
POTGRA	2			
POTILL	1			
POTPEC	1			
POTPUS	1		1	
SCIACU	1			
VALAME	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 sus
2 = Genus suspected
3 = Unknown

Voucher:
0 = Not Taken
1 = Taken, not varifiec
2 = Taken, varifi

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

APPENDIX G:

FISH SPECIES IDENTIFIED IN PRETTY LAKE BY THE INDIANA DEPARTMENT OF NATURAL RESOURCES DIVISION OF FISH AND WILDLIFE

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

Appendix G. Fish species present in Pretty Lake as observed by Indiana Department of Natural Resources Fisheries Biologists

Common Name	Scientific Name	1964	1973	1979	1983	1996
Black Bullhead	*Ictalurus melas*	x				
Black Crappie	*Pomoxis nigromaculatus*	x	x	x	x	x
Bluegill	*Lepomis macrochirus*	x	x	x	x	x
Bluegill-Redear Hybrid						x
Bowfin	*Amia calva*	x	x	x		x
Brook silversides	*Labidesthes sicculus*					x
Brook Stickleback	*Eucalia inconstans*	x				
Brown Bullhead	*Ictalurus nebulosus*	x	x	x	x	x
Brown Trout	*Salmo trutta*			x	x	
Golden Shiner	*Notemigonus crysoleucas*	x	x	x		x
Grass Pickerel	*Esox vermiculatus*	x	x	x		x
Green Sunfish	*Lepomis cyanellus*	x	x	x	x	x
Lake Chubsucker	*Erimyzon succetta*	x	x	x		x
Largemouth Bass	*Micropterus salmoides*	x	x	x	x	x
Northern Pike	*Esox lucius*	x	x	x	x	x
Pumpkinseed Sunfish	*Lepomis gibbosus*	x	x	x	x	x
Rainbow Trout	*Salmo gairdneri*	x	x	x	x	
Redear Sunfish	*Lepomis microlophus*	x	x	x	x	x
Rock Bass	*Ambloplites rupestris*	x	x	x	x	x
Smallmouth Bass	*Micropterus dolomeui*	x				
Walleye	*Sander vitreus*	x				x
Warmouth	*Chaenobryttus coronarius*	x	x	x	x	x
Yellow Bullhead	*Ictalurus natalis*	x	x	x	x	x
Yellow Perch	*Perca flavescens*	x	x	x	x	x

APPENDIX H:

POTENTIAL SHORELINE BUFFER SPECIES

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

Appendix H. Potential shoreline buffer species.

Common Name	Botanical Name	Approximate Location*
Arrow Arum	*Peltandra virginica*	Shallow water/water's edge
Big Blue Stem	*Andropogon gerardii*	Varies/broad range
Black-Eyed Susan	*Rudbeckia hirta*	Drier soils
Blue Flag Iris	*Iris virginica shrevei*	Shallow water/water's edge
Blue Joint Grass	*Calamagrostis canadensis*	Wet to mesic soils
Bottle Gentian	*Gentiana andrewsii*	Mesic to dry soils
Butterfly Milkweed	*Asclepias tuberosa*	Mesic to dry soils
Chairmakers rush	*Scirpus pungens*	Shallow water/water's edge
Common Bur Reed	*Sparganium eurycarpum*	Shallow water/water's edge
Compass Plant	*Silphium laciniatum*	Varies/broad range
Cream Wild Indigo	*Baptisia leucophaea*	Mesic to dry soils
Culver's Root	*Veronicastrum virginianum*	Varies/broad range
Cup Plant	*Silphium perfoliatum*	Wet to mesic soils
Early Goldenrod	*Solidago juncea*	Wet to mesic soils
False Dragonhead	*Physostegia virginiana*	Wet to mesic soils
Goats Rue	*Tephrosia virginiana*	Varies/broad range
Golden Alexanders	*Zizia aurea*	Wet to mesic soils
Great Blue Lobelia	*Lobelia siphilitica*	Wet soils
Halberd-leaved Rose Mallow	*Hibiscus laevis*	Shallow water/water's edge
Hard-stemmed Bulrush	*Scirpus acutus*	Shallow water/water's edge
Heart-Leaved Meadow Parsnip	*Zizia aptera*	Mesic to dry soils
Heath Aster	*Aster ericoides*	Wet to mesic soils
Illinois Sensitive Plant	*Desmanthus illinoensis*	Mesic to dry soils
Illinois Tick Trefoil	*Desmodium illinoiense*	Varies/broad range
Indian Grass	*Sorghastrum nutans*	Varies/broad range
Ironweed	*Vernonia altissima*	Wet to mesic soils
Little Blue Stem	*Andropogon scoparius*	Varies/broad range
Marsh Blazing Star	*Liatris spicata*	Wet to mesic soils
New England Aster	*Aster novae-angliae*	Wet to mesic soils
New Jersey Tea	*Ceanothus americanus*	Varies/broad range
Old-Field Goldenrod	*Solidago nemoralis*	Mesic to dry soils
Partridge Pea	*Cassia fasciculata*	Varies/broad range
Pickerel Weed	*Pontederia cordata*	Shallow water/water's edge
Prairie Bergamot	*Monarda fistulosa*	Varies/broad range
Prairie Cinquefoil	*Potentilla arguta*	Mesic to dry soils
Prairie Cord Grass	*Spartina pectinata*	Wet to mesic soils
Prairie Coreopsis	*Coreopsis palmata*	Mesic to dry soils
Prairie Dock	*Silphium terebinthinaceum*	Varies/broad range
Prairie Switch Grass	*Panicum virgatum*	Varies/broad range
Prairie Wild Rye	*Elymus canadensis*	Varies/broad range
Purple Coneflower	*Echinacea purpurea*	Mesic to dry soils
Rattlesnake Master	*Eryngium yuccifolium*	Varies/broad range

Common Name	**Botanical Name**	**Approximate Location***
Rosin Weed	*Silphium integrifolium*	Varies/broad range
Rough Blazing Star	*Liatris aspera*	Mesic to dry soils
Round-Head Bush Clover	*Lespedeza capitata*	Varies/broad range
Rushes	*Juncus* spp.	Depends upon the species
Saw-Tooth Sunflower	*Helianthus grosseserratus*	Wet to mesic soils
Sedges	*Carex* spp.	Depends upon the species
Showy Goldenrod	*Solidago speciosa*	Mesic to dry soils
Side Oats Grama	*Bouteloua curtipendula*	Mesic to dry soils
Sky-Blue Aster	*Aster azureus*	Mesic to dry soils
Smooth Aster	*Aster laevis*	Mesic to dry soils
Sneezeweed	*Helenium autumnale*	Wet to mesic soils
Softsem Bulrush	*Scirpus validus creber*	Shallow water/water's edge
Spider-Wort	*Tradescantia ohiensis*	Wet to mesic soils
Stiff Goldenrod	*Solidago rigida*	Varies/broad range
Swamp Loosestrife	*Decodon verticillatus*	Shallow water/water's edge
Swamp Rose Mallow	*Hibiscus palustris*	Shallow water/water's edge
Sweet Black-Eyed Susan	*Rudbeckia subtomentosa*	Wet to mesic soils
Sweet Flag	*Acorus calamus*	Shallow water/water's edge
Tall Coreopsis	*Coreopsis tripteris*	Wet to mesic soils
Thimbleweed	*Anemone cylindrica*	Mesic to dry soils
Virginia Mountain Mint	*Pycnanthemum virginianum*	Varies/broad range
White Wild Indigo	*Baptisia leucantha*	Varies/broad range
Wild Lupine	*Lupinus perennis*	Mesic to dry soils
Wild Quinine	*Parthenium integrifolium*	Varies/broad range
Wrinkled Goldenrod	*Solidago rugosa*	Wet to mesic soils
Yellow Coneflower	*Ratibida pinnata*	Varies/broad range

** These approximate locations are very general. Each species can have specific site conditions requirements (i.e. sun exposure, soil type, soil moisture). Consequently, site inspection should occur before determining an exact species list for a given site.*

APPENDIX I:

POTENTIAL FUNDING SOURCES

PRETTY LAKE DIAGNOSTIC STUDY
LAGRANGE COUNTY, INDIANA

Appendix I. Potential 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 Fish and Wildlife. 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. The LARE program also provides a maximum of $100,000 for the removal of sediment from a particular site on a lake and a cumulative total of $300,000 for all sediment removal projects on a lake. An approved sediment removal plan must be on file with the LARE office for projects to receive sediment removal funding. The LARE program will provide $100,000 for a one-time whole lake treatment to control aggressive, invasive aquatic plants. A cumulative total of $20,000 over a three year period may be obtained for additional spot treatment following the whole lake treatment. Additionally, aquatic plant management grants are available for up to $20,000 per year per lake for spot treatment when whole lake treatment is not appropriate. As with the sediment removal funding, an approved aquatic plant management plan must be on file with the LARE office for the lake association to receive funding. All approved projects require a 10 to 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 landowners who implement various BMPs. All of the LARE programs are recommended as a project funding source for the Pretty Lake watershed. More information about the LARE program can be found at http://www.in.gov/dnr/fishwild/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 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 Habitat 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