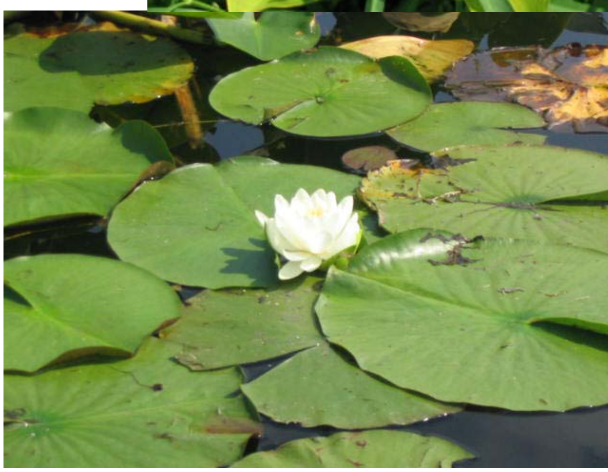
Dewart Lake Diagnostic Study

Kosciusko County, Indiana

May 13, 2005



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DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

EXECUTIVE SUMMARY

Dewart Lake is a 551-acre (223-ha) natural lake that lies in the headwaters of the St. Joseph River Basin southwest of Syracuse, Indiana. Dewart Lake's watershed encompasses approximately 5,000 acres (2,000 ha or 7.8 square miles). Most of the watershed (70%) is utilized for agricultural purposes (row crops, hay, and pasture). Remnants of the native landscape, including forested areas and wetlands, cover approximately 15% of the watershed, while residential and commercial land uses account for less than five percent of the watershed's total acreage. Dewart Lake itself covers 11% of the total watershed.

Dewart Lake has one primary tributary, Cable Run. Cable Run exhibited moderately good water quality during base flow, or "normal", conditions. The stream's biotic community integrity score reflected its moderately good water quality; Cable Run's biotic community fell in the "slightly impaired" category using the Indiana Department of Environmental Management's scoring criteria. During high flow events, the stream possessed elevated levels of pollutants. Of greatest concern was the stream's *E. coli* concentration, which was several orders of magnitude above the state standard following a storm event, and nitrate-nitrogen concentration which also exceeded the state standard following a storm event.

Dewart Lake itself is moderately productive. Historical data for the lake suggest that Dewart Lake's water quality has remained relatively stable for the past 15 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 mesotrophic in nature. However, Dewart Lake's phosphorus concentration has the potential to increase the lake's productivity. Dewart Lake supports a diverse submerged plant community that includes four state listed species. The lake offers good fishing opportunities. The Indiana Department of Natural Resources describes the lake's northern pike fishing opportunity as "excellent".

Continued good water quality in Dewart Lake will require both in-lake and watershed management. The lake possesses a moderate hydraulic residence time of 1.4 years. Thus, attention to 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. Dewart Lake's relatively small watershed area to lake area ratio of 8:1 suggests near shore residents have substantial control over influencing the health of their lake.

Recommended watershed management techniques include: ravine stabilization, homeowner best management practices, filter strip implementation, livestock fencing, wetland restoration, use of the Conservation Reserve Program and conservation tillage, and streambank stabilization. Within the lake itself, Dewart Lake stakeholders are encouraged to develop a comprehensive recreational use plan for the lake. This plan should include a rooted plant management section that considers the establishment of ecozones to protect the lake's health.

ACKNOWLEDGEMENTS

The Dewart Lake Diagnostic Study was made possible with funding from the Indiana Department of Natural Resources (IDNR) Division of Soil Conservation and the Dewart Lake Protective Association. The Dewart Lke Diagnostic Study was completed by JFNew and their subcontractor, Indiana University School of Public and Environmental Affairs. Contributors to this study included Cecil Rich with the IDNR Division of Soil Conservation, Jed Pearson with the IDNR Division of Fish and Wildlife, and Ron Helmich with the IDNR Division of Nature Preserves. Special thanks to the dedicated board directors and members of the Dewart Lake Protective Association for their initiative and assistance in getting this study completed. Dewart Lake residents who participated in the study included: Ken Brehob, who served as the primary liaison between JFNew and the Dewart Lake Protective Association; Gary Hogle, who, along with Ken Brehob, toured watershed sites with JFNew and hosted the project's public meetings; Betty Busch and Kathi Patty, who conducted a house count around the lake providing important information for the modeling component of the study; and Don Scearce, who navigated JFNew biologists around the lake during the rooted plant survey. John Hartmann from Elmhurst College reviewed historic water quality data, created an electronic database for the historic data, and compiled an annotated bibliography of historic fisheries studies on Dewart Lake. John Iverson of Earlham College and Geoff Smith of Denison University provided comments and shared an unpublished paper detailing their work with the Dewart Lake turtle population. Authors of this report included William Jones, Selena Medrano, Melissa Clark, Mark Lehman, Josh Tennen, Lisa Fascher, and Kim Vest at Indiana University and Marianne Giolitto, Sara Peel, John Richardson, Joe Exl, and Scott Namestnik at JFNew.

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DEWART LAKE DIAGNOSTIC STUDY
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1.0 INTRODUCTION

Dewart Lake is a 551-acre (223-ha) natural lake that lies in the headwaters of the St. Joseph River Basin southwest of Syracuse, Indiana (Figure 1). Specifically, the lake is located in Section 25 of Township 34 North, Range 6 East and Section 30 of Township 34 North, Range 7 East in Kosciusko County. The Dewart Lake watershed stretches out to the east and south of the lake encompassing just over 5,000 acres (2,000 ha or 7.8 square miles) (Figure 2). Water discharges through the lake's outlet in the northwest corner to Hammond Ditch. Water in Hammond Ditch flows through Waubee Lake and into Turkey Creek, a tributary of the Elkhart River. The Elkhart River transports water to the St. Joseph River which empties in Lake Michigan near St. Joseph, Michigan.

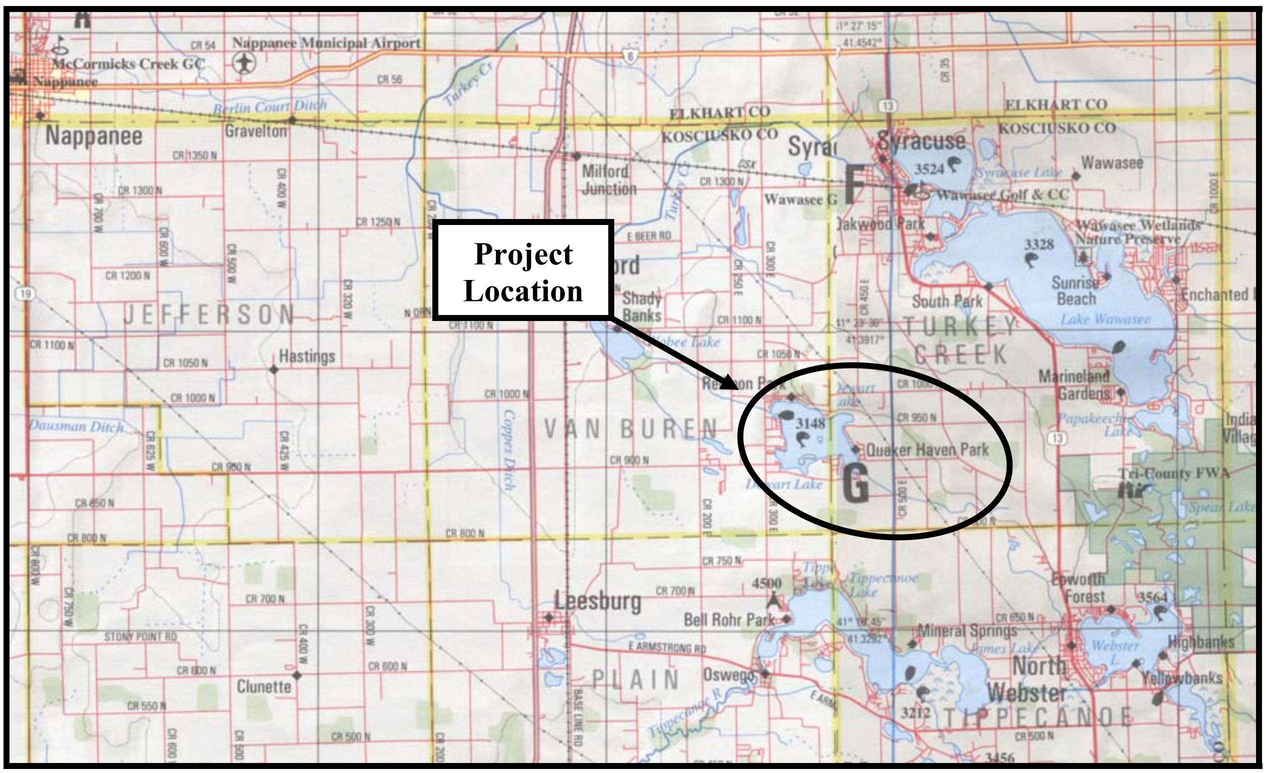

Figure 1. General location of the Dewart Lake watershed. Source: DeLorme, 1998.

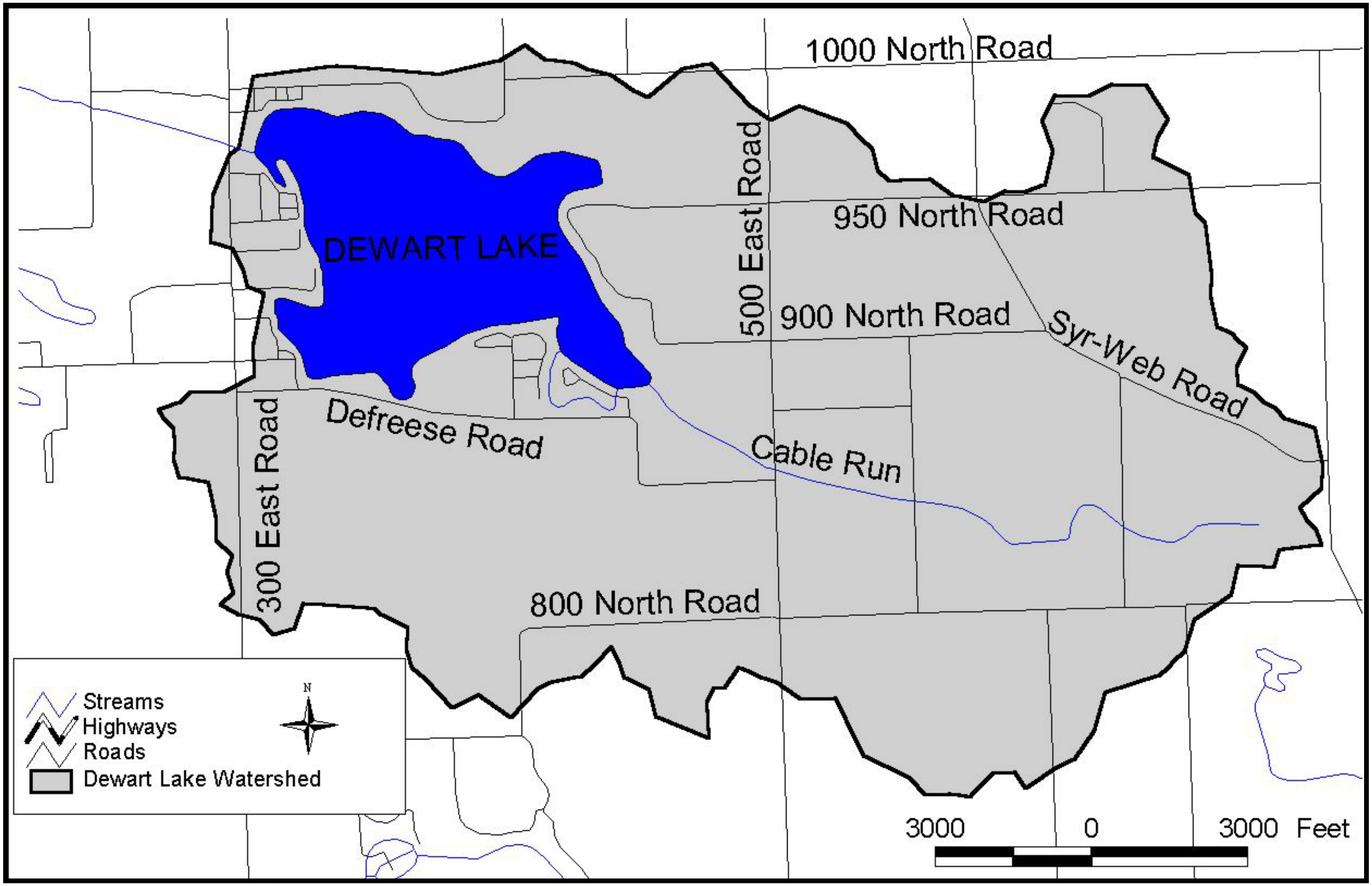

Figure 2. Dewart Lake watershed. Source: See Appendix A. Scale: 1”=3,000’.

Dewart Lake has historically exhibited good water quality. The lake's water clarity is excellent compared to many other lakes in the region. Historical records (Fink, 2003 and Indiana Clean Lakes Program files, 2002) from the past twenty years show the lake's Secchi disk transparency (a measure of water clarity) has been consistently greater than 7 feet (2.1 m) compared to a regional median of less than 6 feet (1.8 m) (Giolitto, unpublished data presented at the 2002 North American Lake Management Society annual meeting). Dewart Lake's nutrient levels have similarly remained relatively low over the past 20 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) in 1994 and 2000 were below 3μg/L.

In addition to exhibiting good water quality, Dewart Lake has been and continues to be a good lake for fishing. Early records of the area attest to Dewart Lake's popularity as a fishing destination. In notes from his 1899 survey of Dewart Lake, Blatchley (1900) states "As a fishing resort the lake is noted, and many people, even in a region where lakes are abundant, seek its waters to try their luck in pursuit of the finny tribe." Fisheries surveys conducted by the Indiana Department of Natural Resources (IDNR) show an improvement in the lake's fishing potential over the past 30 years (Fink, 2003). Gamefish dominate the total biomass of the lake's fishery accounting for 96% of the fishery by weight in 2003 compared to only 28% by weight in 1976. This means more of the lake's food source is going to support gamefish rather than non-sportfish. Fink (2003) describes Dewart Lake's northern pike fishery as "excellent". Current lake residents (personal communication) second Fink's assessment, claiming the lake is one of the best fishing lakes in Kosciusko County. The lake residents' claim is supported by the fact that the Indiana B.A.S.S Federation scheduled 13 angling tournaments on Dewart Lake in 2004 (Indiana B.A.S.S Federation, 2004).

Despite the lake's relatively good 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 water milfoil, appears to have expanded its coverage in the lake. Residents have also noted a decrease in the lake's water clarity after weekends of heavy boating use. These changes have negatively impacted the residents' enjoyment of the lake and increased their desire to protect the lake's health and future.

Dewart Lake residents have been proactive in protecting their lake's health. For example, property owners of the Limberlost Girl Scout Camp have worked with the Natural Resources Conservation Service to implement several best management practices on the camp property to reduce erosion. While these practices have slowed the import of sediment to Dewart Lake from this property, lake residents and members of the Dewart Lake Protective Association have identified additional areas of concerns. 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 Dewart Lake Protective Association 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 Dewart 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 Dewart 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 stream's 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

Dewart Lake is a headwater lake in the Great Lakes Basin. The lake and its 5,059-acre (2,049-ha) watershed lie immediately 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 Great Lakes Basin (land that drains north to the Great Lakes). As part of the Great Lakes Basin, water from the Dewart Lake watershed flows north through Waubee Lake into the Elkhart Creek. The Elkhart Creek flows into the St. Joseph River which eventually discharges into Lake Michigan near St. Joseph, Michigan.

The topography of the Dewart Lake watershed reflects the geological history of the watershed. The highest areas of the watershed lie along the watershed's southern and northern edges, where the Saginaw Lobe of the last glacial age left end moraines. Along the watershed's southern boundary, the elevation nears 950 feet (289.6 m) above mean sea level. The ridge along the watershed's northern boundary is higher and steeper, with elevations reaching over 1000 feet (304.8 m) above mean sea level. The highest point in Koscuisko County (1025 feet or 312.4 m above mean sea level) lies just north of Dewart Lake. Cable Run, an unnamed wetland complex south of Dewart Lake, and the unnamed intermittent stream/wetland complex east of Dewart Lake occupy lower elevation valleys in the watershed. Dewart Lake, elevation 868 feet (264.6 m) above mean sea level, is the lowest point in the watershed. Figure 3 presents a topographical relief map of the Dewart Lake watershed.

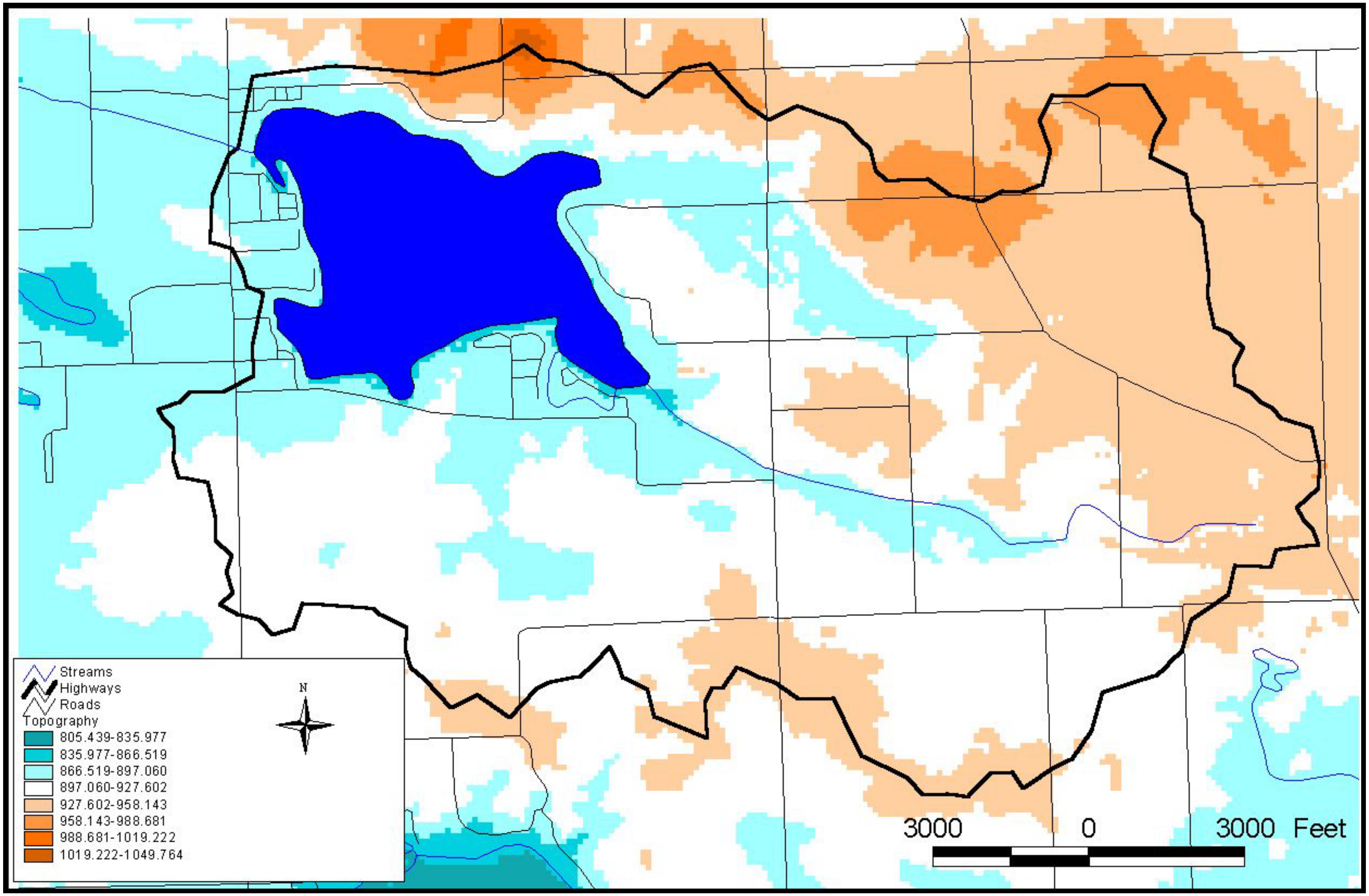

Figure 3. Topographical relief map of the Dewart Lake watershed. (Units in legend are feet.) Source: See Appendix A. Scale: 1"=3,000'.

Surface water drains to Dewart Lake via three primary routes. Cable Run drains approximately 2,160 acres (875 ha) southeast of the lake (Table 1). This stream empties into Dewart Lake at the lake's southeast corner. An unnamed intermittent stream/wetland system transports water from the eastern part of the watershed to Dewart Lake along the southern edge of the Limberlost Girl Scout Camp. This system drains less than 15% of the watershed. The remainder of the land in the Dewart Lake watershed (1,624 acres or 657 ha) drains directly to the lake. Figure 4 illustrates the boundaries of each of the three subwatersheds of Dewart Lake.

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

Subwatershed/Lake	Area (acres)	Area (hectares)	Percent of total watershed
Cable Run	2,158	874	43%
Unnamed Intermittent Stream/ Wetland Inlet	726	294	14%
Area adjacent to Dewart Lake	1,624	657	32%
Watershed draining to lake	**4,508**	**1,825**	**89%**
Dewart Lake	551	223	11%
Total Watershed	**5,059**	**2,049**	**100%**
Watershed to Lake Area Ratio	8.2:1		

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

Dewart Lake possesses a watershed area to lake area ratio of approximately 8.2:1. This is a fairly typical watershed area to lake area ratio for glacial lakes. This ratio is also relatively small compared to other lakes in the area. For example, Lake Tippecanoe's watershed area to lake area ratio is approximately 93:1. Lake Webster, which is similar in size to Dewart Lake, has a watershed area to lake area ratio of approximately 40:1. Both lakes have extensive watersheds compared to Dewart Lake. Big Chapman Lake, which is similar in size to Dewart Lake, has a watershed area to lake area ratio of approximately 7.6:1, indicating its watershed is close in size to Dewart Lake's watershed size.

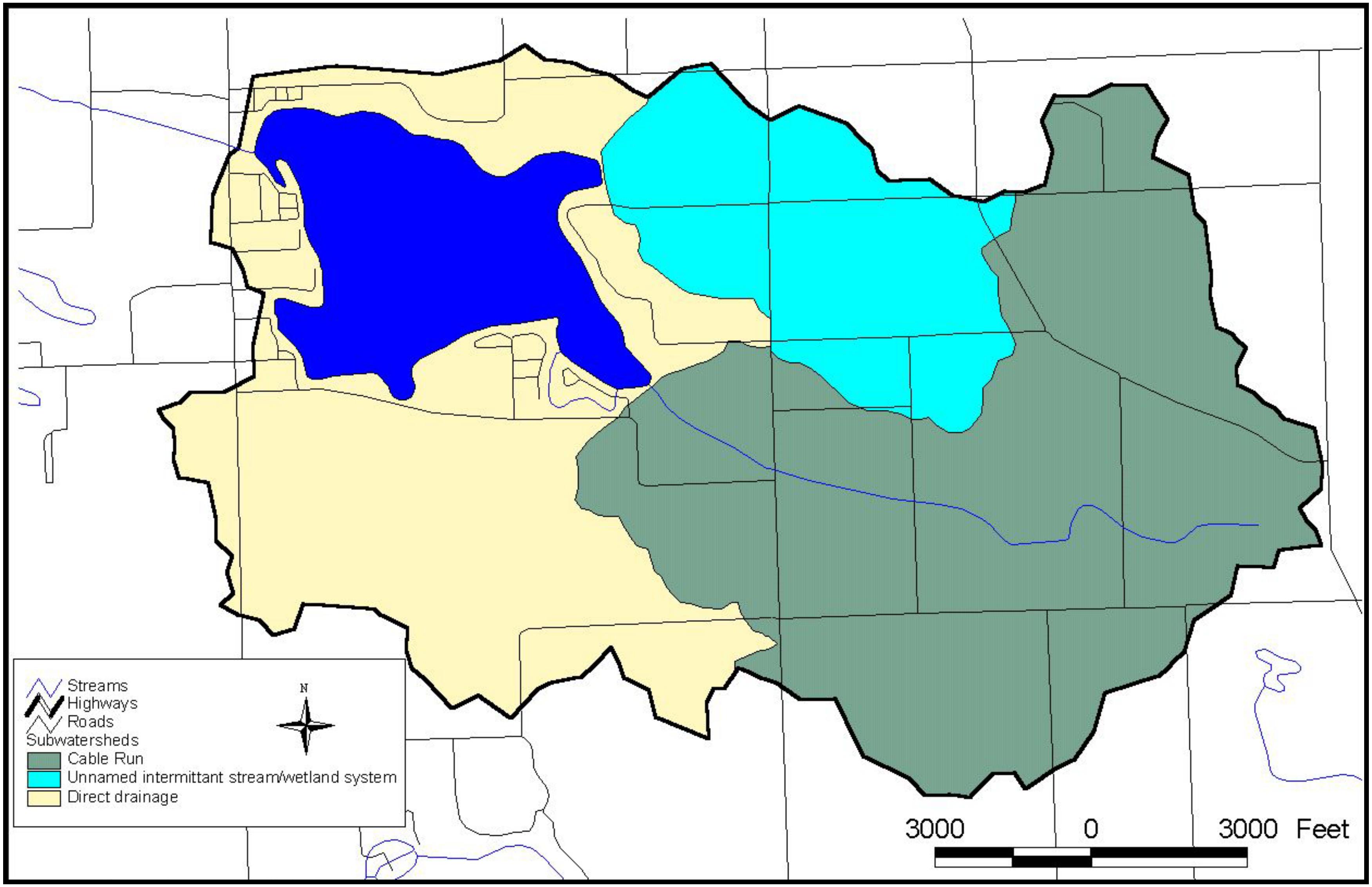

Figure 4. Subwatersheds within the Dewart Lake watershed. Source: See Appendix A. Scale: 1”=3,000’.

In terms of lake management, Dewart Lake's relatively small 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 Dewart Lake. Consequently, implementing best management practices along the lake's shoreline should rank high when prioritizing management options. Similarly, in-lake management, such as restricting high speed boating to the lake's deepest waters, should receive special attention. This does not mean that management of the watershed should be ignored. However, the relatively small watershed area to lake area ratio should be considered when prioritized 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.

Dewart Lake Watershed Climate

The climate of the Dewart Lake watershed is characterized as having four well-defined seasons of the year. Winter temperatures average 26º F (-3.3º C), while summers are warm, with temperatures averaging 70º F (21.1º C). The growing season typically begins in early April and ends in September. Annual rainfall averages 36.65 inches (93 cm). Winter snowfall averages about 26 inches (66 cm). During summers, relative humidity varies from about 60 percent in mid-afternoon to near 80 percent at dawn. Prevailing winds typically blow from the southwest except during the winter when westerly and northwesterly winds predominate. (All of the proceeding statistics, except for the annual rainfall average, were taken from Staley, 1989.) In 2004, more than 34 inches (86.4 cm) of precipitation (Table 2) was recorded at Warsaw in Kosciusko County. When compared with 30-year average for the area, the 2004 annual rainfall fell short of the average by approximately 2.4 inches (6.1 cm).

Table 2. Monthly rainfall data (in inches) for year 2004 as compared to average monthly rainfall. All data was recorded at Warsaw in Kosciusko County. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 at Warsaw.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2004	1.67	0.64	2.88	0.38	6.21	4.11	3.71	6.02	1.30	1.14	3.48	2.72	**34.26**
Average	1.85	1.45	2.08	3.36	3.83	4.51	3.67	4.05	3.22	3.04	2.97	2.62	**36.65**

Source: Purdue Applied Meteorology Group, 2004.

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 equaled the rate of glacial advance, add topographical relief to the landscape. Distinct glacial lobes, such as the Michigan Lobe, Saginaw Lobe, and the Erie Lobe, left several large, distinct end moraines, including the Valparaiso Moraine, the Maxinkuckee Moraine, and the Packerton Moraine, scattered throughout the northern portion of the state. Glacial drift and ground moraines cover flatter, lower elevation terrain in northern Indiana. Major rivers in northern Indiana cut through sand and gravel outwash plains. These outwash plains formed as the glacial meltwaters flowed from retreating glaciers, depositing sand and gravel along the meltwater edges. Lake plains, characterized by silt and clay deposition, are present where lakes existed during the glacial age.

Several glacial lobes rather than a single sheet of ice covered northern Indiana during the last glacial age. The Saginaw and Erie Lobes covered most of northeastern Indiana. The movement, stagnation, and melting of the Saginaw Lobe of the Wisconsin glacial age is largely responsible for the landscape covering the Dewart Lake watershed. The Saginaw glacial lobe moved out of Canada toward the southwest carrying a mixture of Canadian bedrock with it. The Packerton Moraine and the Maxinkuckee Moraine mark the extent of the Saginaw Lobe's coverage in northern Indiana. In addition to these major moraines, the Saginaw Lobe also deposited many unnamed end moraines during its retreat. The ridge that separates the Dewart Lake watershed from Lake Wawasee's watershed is part of an end moraine left by the Saginaw Lobe. The lower, less distinct ridge separating the Dewart Lake watershed from the Tippecanoe River Basin may also be part of an end moraine left by the glacial lobe. (Figure 3 shows the areas of greater relief (in orange and tan) associated with the end moraines along the watershed's nouthern and southern boundaries.) A complex mix of glacial till and outwash materials lies between the two ridges, while sand and gravel outwash materials dominate the very western edge of the Dewart Lake watershed.

Approximately 300-350 feet (91-107 m) of unconsolidated glacial materials cover most of the Dewart Lake watershed. In the southeastern portion of the watershed, the thickness of this unconsolidated glacial material decreases to 250-300 feet (76-91 m) (Indiana Geological Survey, undated). Antrim shale from the Devonian-Mississippian Period underlies the unconsolidated glacial material in the Dewart Lake watershed (Gutschick, 1966).

2.4 Soils

The Dewart Lake watershed's geological history described in the previous section determined the soil types found in the watershed and is reflected in the six major soil associations that cover the Dewart Lake watershed (Figure 5). The mixed till material of the two end moraines forming the northern and southern boundaries of the watershed consisted of silt, sand, and clay particles. The lowland between these two end moraines was covered by a complex mix of morainal till (silt, sand, and clay particles) and outwash materials (sand and gravel). As a result, the loamy to sandy loam soils developed from these terrains. On the extreme western edge of the watershed, outwash materials, primarily sand and gravel covered the landscape. Sandy soils developed from this parent material.

Before detailing the major soil associations covering the Dewart 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 Ormas-Kosciusko soil association consists primarily of Ormas loamy sand and Kosciusko sandy loam.

Six major soil associations cover the Dewart Lake watershed (Figure 5). These soil associations are the Riddles-Wawasee soil association, the Wawasee-Crosier-Miami soil association, the Crosier-Barry soil association, the Shipshe-Carmi soil association, the Ormas-Kosciusko soil association, and the Riddles-Ormas-Kosciusko soil association. The Riddles-Wawasee soil association covers the largest portion of the Dewart Lake watershed bordering much of Dewart Lake's shoreline and extending out to the east and south from the lake. The Riddles-Wawasee soil association is the third most common soil association found in Kosciusko County, covering approximately 10% of the county landscape. The Wawasee-Crosier-Miami soil association lies along the northern and western shorelines of Dewart Lake and the covers the headwaters of Cable Run along the eastern boundary of the watershed. The Wawasee-Crosier-Miami soil association is the most common soil association in Kosciusko County, covering approximately 28% of the county landscape. The Crosier-Barry soil association lies along the eastern and southern edges of the watershed. The three remaining soil associations, the Shipshe-Carmi soil association, the Ormas-Kosciusko soil association, and the Riddles-Ormas-Kosciusko soil association cover much smaller portions of the Dewart Lake watershed. The following discussion on soil associations in the Dewart Lake watershed relies heavily on the *Soil Survey of Kosciusko County* (Staley, 1989). Readers should refer to this source for a more detailed discussion of soil associations covering Kosciusko County.

The Riddles-Wawasee soil association covers the majority of the Dewart Lake watershed. Staley's (1989) description of the Riddles-Wawasee soil association as being "characterized by nearly level to strongly sloping topography dominated by broad ridges, knobs, and narrow depressions" mirror the actual topography of the Dewart Lake watershed. As noted earlier, Dewart Lake's watershed consists of two ridges separated by a narrow lowland drained by Cable Run and Dewart Lake. The Riddles-Wawasee soil association consists largely of Riddles (44%) and Wawasee (19%) soils. Both soils possess fine sandy loam surface layers that overlay fine sandy loam, sandy clay loam, and loam subsoil. Minor components of this association include Barry loam, Griswold loam, Martinsville sandy loam, Rensselaer loam, and Whitaker loam soils. Erosion is a concern with this soil association in sloping areas. The Riddles-Wawasee soil association is moderately limited for septic system usage.

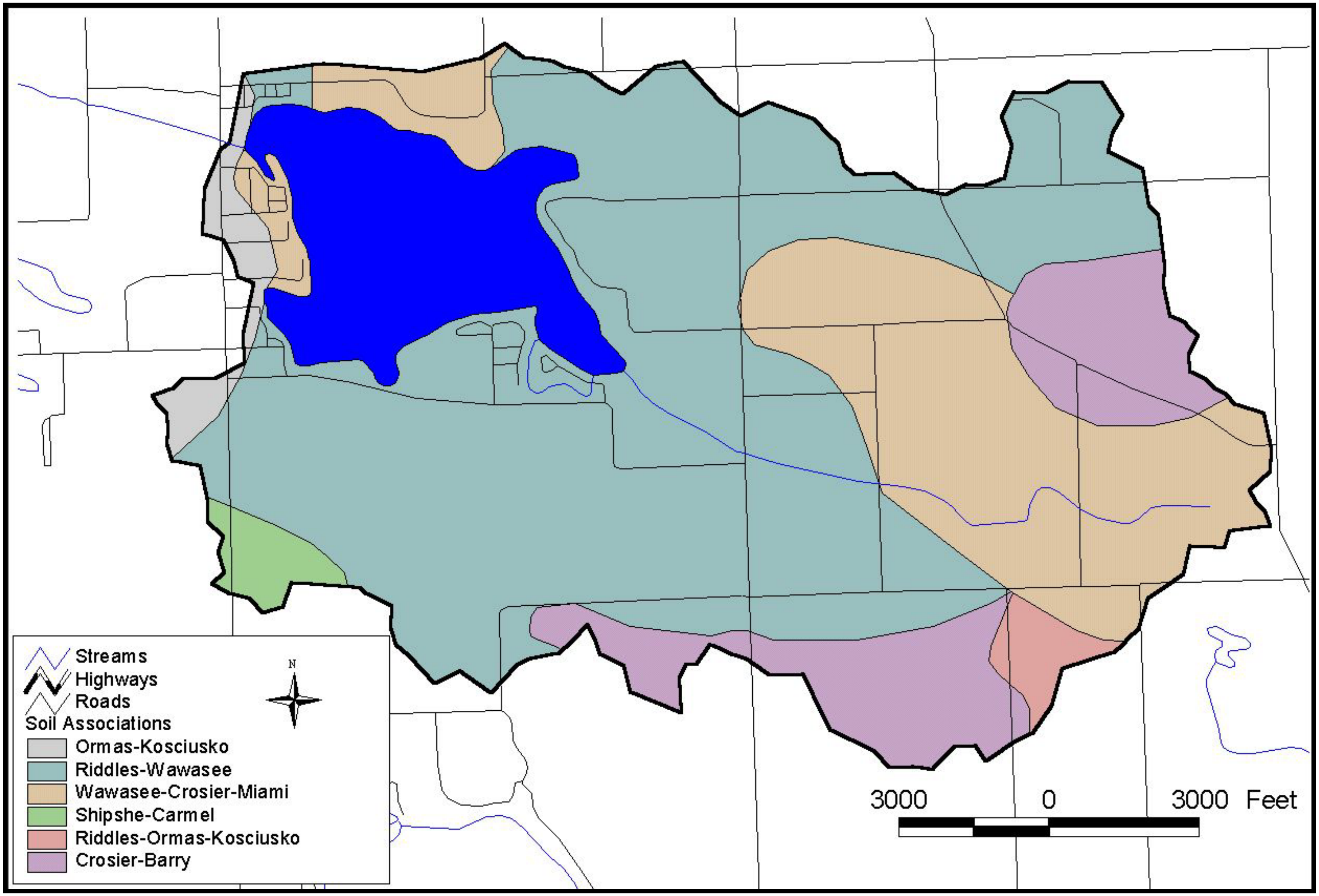

Figure 5. The major soil associations covering the Dewart Lake watershed. Source: See Appendix A. Scale: 1”=3,000’

The Wawasee-Crosier-Miami soil association lies along the northern and western shorelines of Dewart Lake. It also covers the headwaters of Cable Run in the southeastern portion of the watereshed. Wawasee soils comprise 30% of the soil association, while Crosier and Miami soils account for 26% and 24% of the association, respectively. Wawasee soils occur in well-drained, gently to strongly sloped areas along ridge tops and side slopes. Fine sandy loam soils overlay loam and sandy loam subsoils. Crosier soils are poorly drained soils found at lower elevations on the landscape below Wawasee soils. Well drained Miami soils occur on knobs and low ridges and in swells. Both soils possess loam and clay loam textured surface and subsurface layers which overlay loam layers. Aubbennaubbee sandy loam and fine sandy loam, Barry loam, Metea loamy sand and loamy fine sand, Rensselaer loam, Riddles fine sandy loam, and Washtenaw silt loam soils are minor components of the Wawasee-Crosier-Miami soil association. Like many of the other soils in the Dewart Lake watershed, erosion is a concern on sloped areas. Wetness and slow percolation severely limit the use of Crosier soils as septic system leach fields. Slope and slow percolation moderately to severely limit Wawasee and Miami soils for use as septic system leach fields.

A pocket of Crosier-Barry soil association lies along the eastern boundary of the watershed and another swath borders much of the southern boundary of the watershed. These soils formed in glacial till and are found on till plains and moraines. Crosier soils dominate this association accounting for approximately 54% of the soils. As noted above, Crosier soils are somewhat poorly drained and are found on side slopes along drainageways. Surface layers of Crosier soils are loamy in texture, while the subsoil is clay loam to loamy in texture. Barry soils account for 29% of the Crosier-Barry soil association. These soils are typically found along drainageways, on side slopes, and in swales. Barry soils are similar in texture to Crosier soils, but have sandy loam to loamy subsoils. Minor soil units in the Croiser-Barry soil association include Aubennaubbee sandy loam and fine sandy loam, Palms muck, Metea loamy fine sand, and Wawasee fine sandy loam. Wetness, ponding, and permeability severely limit use of soils in this association to serve as septic tank absorption fields.

The Riddles-Ormas-Kosciusko association is relatively uncommon in Kosciusko County, covering only 6% of the county. This association is found in the southeastern corner of the Dewart Lake watershed south of Cable Run. Well drained soils with moderately well defined surface drainage patterns characterize this soil association. Soils in this association are typically found on knobs, ridges, and in deep depressional areas. Riddles soils comprise 31% of the association, while Ormas soils and Kosciusko soils comprise 25% and 24%, respectively. Riddles soils are found on the tops of ridges and on the highest points across the landscape. Surface layers of Riddles soils are fine sandy loams with even finer textured (loams and clay loams) soils below the surface layer. Ormas soils are typically found at lower elevations on south and east facing slopes. Ormas soils consist of loamy sand over loamy sand and sand substratum. Kosciusko soils are found on lower elevation ridge tops than Riddles soils and on north and west facing slopes. Kosciusko soils consist of a sandy loam surface layer over gravelly sandy clay loam and gravelly loamy sand. Minor components in the Riddles-Ormas-Kosciusko association include Boyer loamy sand, Brady sandy loam, Gilford sandy loam, and Houghton muck soils. Producers should consider the erosion potential of this soil association when cultivating crops on sloped land in this soil association. Riddles soils are moderately limited for septic system development due to permeability, while poor filtering capacity limits Ormas and Kosciusko soils.

Two soils associations, the Shipshe-Carmi soil association and the Ormas-Kosciusko soil association, cover the extreme western edge of the Dewart Lake watershed. The sandy soils that dominate these soil associations reflect the sandy outwash parent materials covering this area of the watershed. In the Shipshe-Carmi soil association, Shipshe soils account for 69% of the association, while Carmi soils account for 30% of the association. The outwash origin of the Shipshe-Carmi soil association soils is revealed further by the texture of their subsurface layers. Very gravelly sandy loam and very gravelly clay sandy loam subsoils underlie the sandy loam surface layer of Shipshe soils, while sandy loam and gravelly sandy loam subsoils underlie the loam surface layer of Carmi soils. Shipshe and Carmi soils have severe limitation for use in septic absorption fields due to poor filtering capacity, which could lead to groundwater pollution.

The Ormas-Kosciusko soil association consists of well drained, nearly level sand and loam soils. In general, Ormas soils account for 33% of the soils in the association, while Kosciusko soils comprise 30% of the association. Minor components of the association include Boyer loamy sand, Riddles fine sandy loam, Homer sandy loam, Brady sandy loam, Gilford sandy loam, and Sebewa loam and mucky loam soils. Ormas and Kosciusko soils are severely limited for septic system development due to poor filtering capacity.

Soils in the watershed, and in particular their ability to erode or sustain certain land use practices, can impact a lake's water quality. The dominance of Wawasee, Riddles, Miami, and Kosciusko soils on steeply sloped areas across the Dewart Lake watershed suggests that large portions of the watershed are prone to erosion. Common erosion control methods should be implemented when the land is used for agriculture or during residential development to protect Dewart Lake and Cable Run. Similarly, many of these same soils lie under the residentially developed portions of the Dewart Lake shoreline and treat residential septic tank effluent. Unfortunately, these soils are moderately to severely limited in their ability to treat septic tank effluent. These limitations can impact Dewart Lake's water quality. A more detailed discussion how highly erodible soils and soils used to treat septic tank effluent impact Dewart Lake follows below.

2.4.1 Highly Erodible Soils

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

Highly erodible and potentially highly erodible are classifications used by the Natural Resources Conservation Service (NRCS) to describe the potential of certain soil units to erode from the landscape. The NRCS examines common soil characteristics such as slope and soil texture when classifying soils. The NRCS maintains a list of highly erodible soil units for each county. Table 3 lists the soil units in the Dewart Lake watershed that the NRCS considers to be highly erodible. As Figure 6 indicates, potentially highly erodible soils cover a substantial portion (2,162 acres (874.9 ha) or nearly 43%) of the Dewart Lake watershed. This acreage is spread throughout the watershed. Highly erodible soil exists on approximately 104 acres (42.1 ha) or approximately 2% of the watershed. Most of the highly erodible soil units are located within the vicinity of and bordering Dewart Lake.

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

Soil Unit	Status	Soil Name	Soil Description
BoC	PHES	Boyer loamy sand	6-12% slopes
ClC	PHES	Coloma loamy sand	6-12% slopes
KoB-KoC	PHES	Kosciusko sandy loam	2-12% slopes
KoE	HES	Kosciusko sandy loam	18-30% slopes
KxC3	HES	Kosciusko sandy clay loam	8-15% slopes, severely eroded
MbC	PHES	Metea loamy sand	6-12% slopes
MlB	PHES	Miami loam	2-6% slopes
MsB	PHES	Miami-Owosso-Metea complex	2-8% slopes
MsD	HES	Miami-Owosso-Metea complex	10-25% slopes
MzB	PHES	Morley-Glynwood complex	1-4% slopes
OrC	PHES	Ormas loamy sand	6-12% slopes
Pg	PHES	Pits, gravel	
RlB-RlD	PHES	Riddles fine sandy loam	2-18% slopes
RxB-RxC	PHES	Riddles-Ormas-Kosciusko complex	2-12% slopes
ShB	PHES	Shipshe sandy loam	2-6% slopes
WlB	PHES	Wawasee fine sandy loam	2-6% slopes
WlC2	PHES	Wawasee fine sandy loam	6-12% slopes, eroded
WlD2	HES	Wawasee fine sandy loam	12-18% slopes, eroded

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

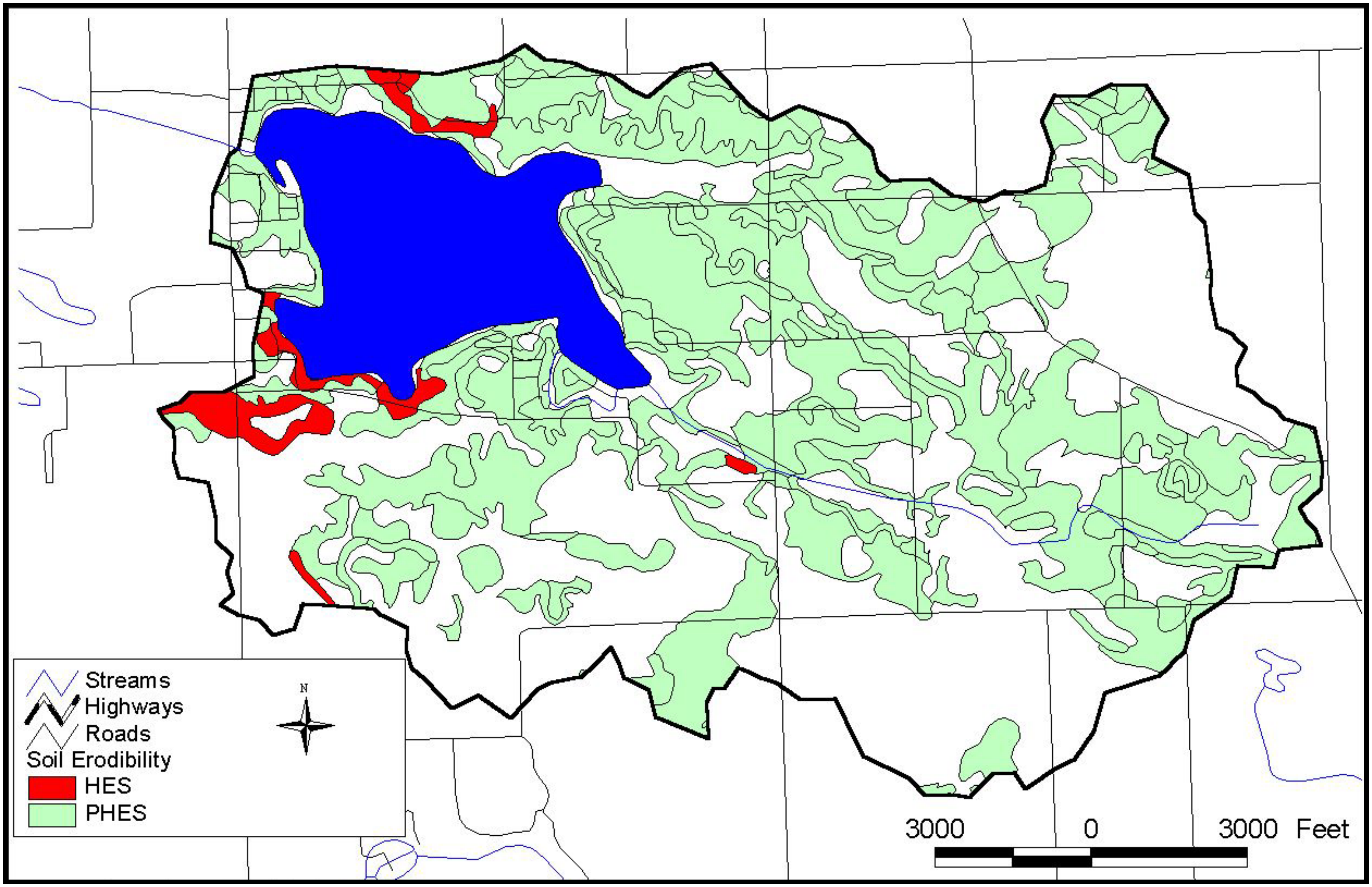

Figure 6. Highly erodible and potentially highly erodible soils in the Dewart Lake watershed. Source: See Appendix A. Scale: 1"=3,000'

2.4.2 Soils used for septic tank absorption fields

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

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

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

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

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

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

The Natural Resources Conservation Service has ranked each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields in moderately or severely limited soils generally requires special design, planning, and/or maintenance to overcome the limitations and ensure proper function. Soils classified as being severely limited for septic absorptions fields cover approximately 58% of the Dewart Lake watershed; those classified as moderately limited for septic absorption fields cover nearly 40% of the watershed (Figure 7).

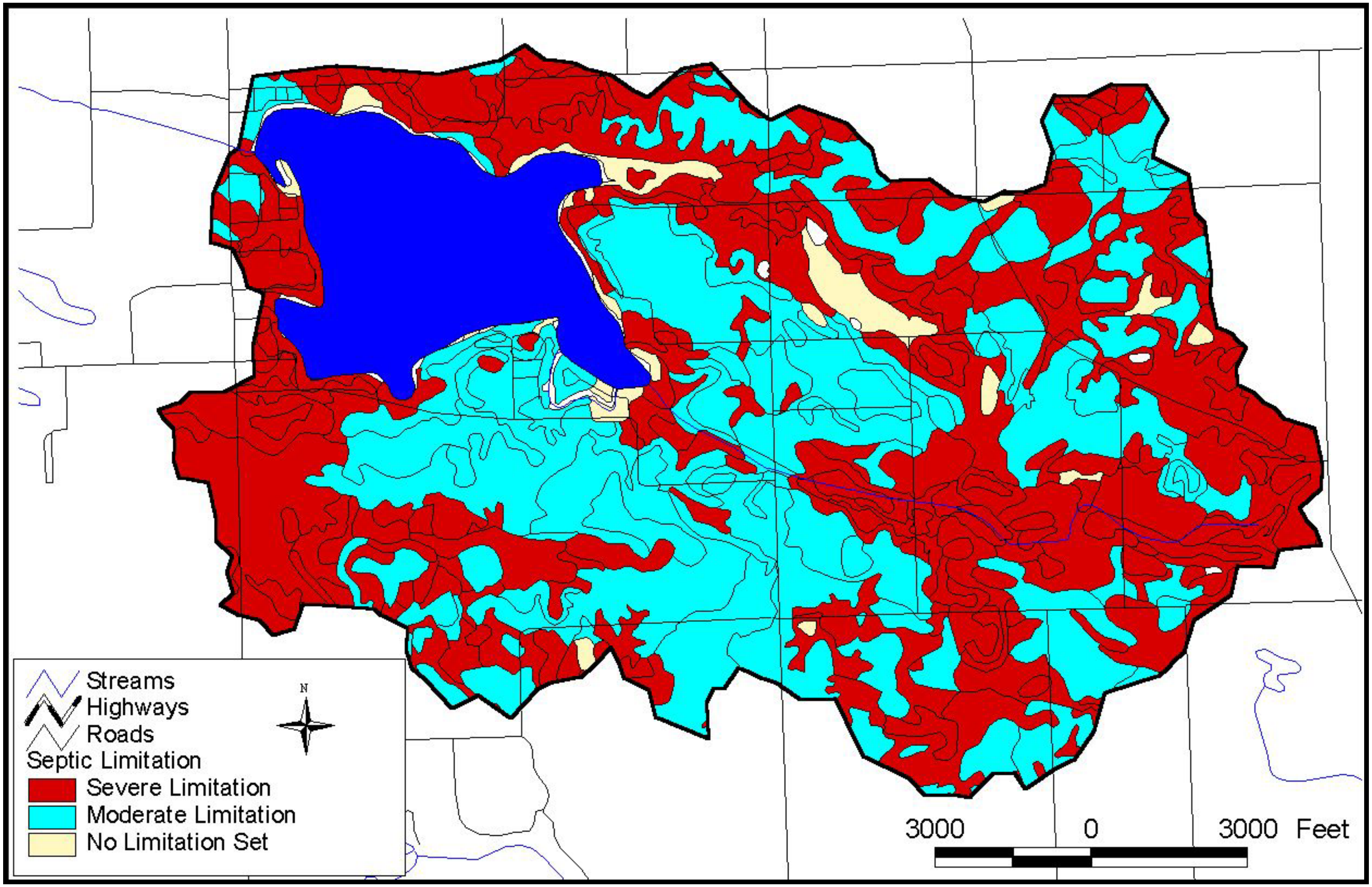

Figure 7. Soil limitations for use as septic tank absorption fields throughout the Dewart Lake watershed. Source: See Appendix A. Scale: 1"=3,000'.

While all septic system use in the Dewart Lake watershed has the potential to impact the water quality of the lake, the ability of the soil immediately adjacent to Dewart Lake to treat septic effluent has a more direct effect on Dewart Lake's water quality. Therefore the following discussion focuses on the soils adjacent to Dewart Lake. Figure 8 shows the soil units surrounding Dewart Lake, while Table 4 summarizes the soils' suitability for use as septic tank absorption fields. Following Table 4 is a short description of the soils listed in the table.

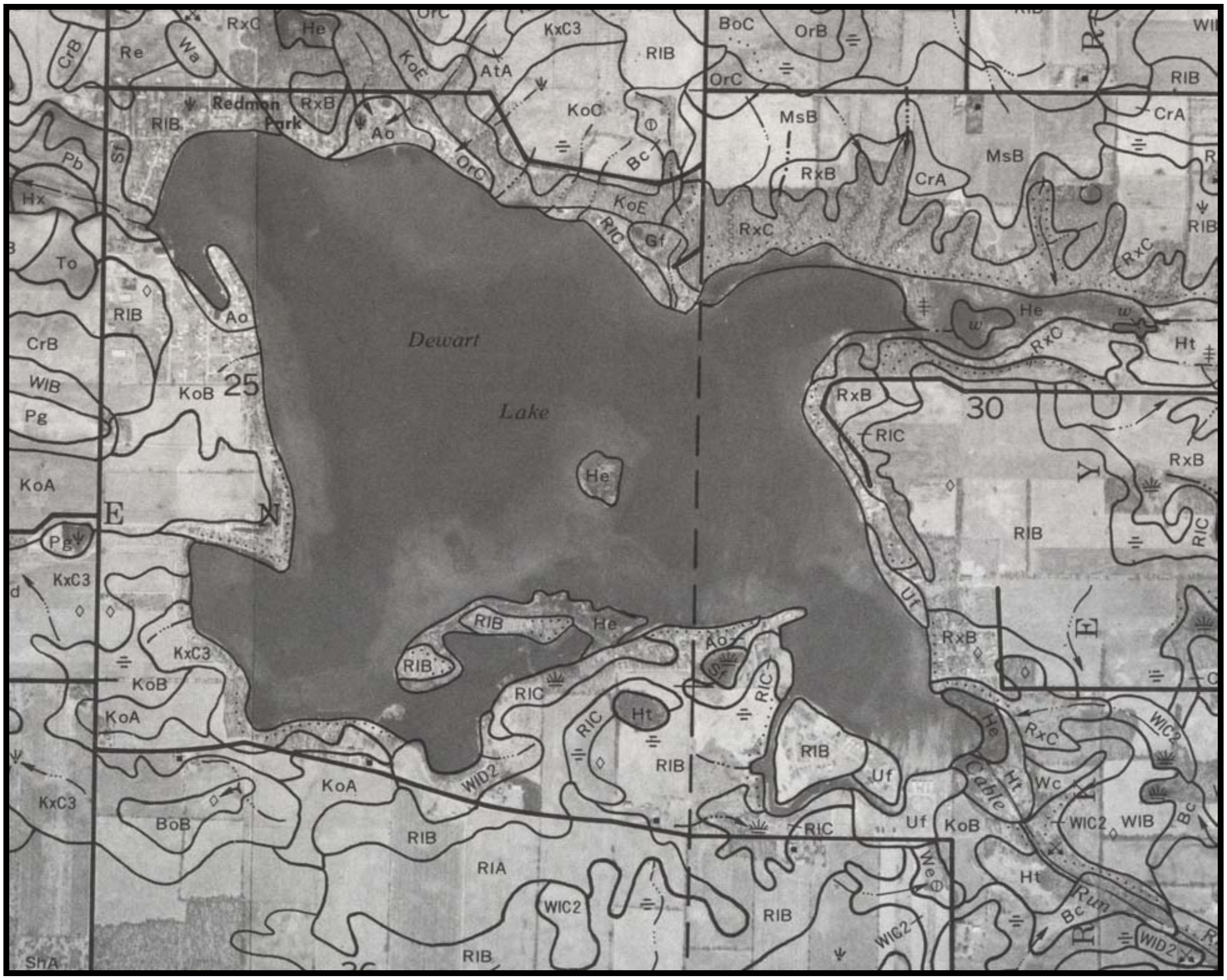

Figure 8. Soil series bordering Dewart Lake.
Source: Staley, 1989. Scale: 1"=1,667'

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

Symbol	Name	Depth to High Water Table	Suitability for Septic Tank Absorption Field
Ao	Aquents-Urban land complex	--	--
Gf	Gilford sandy loam	+0.5-1.0 ft.	Severe: ponding, poor filter
He	Histosols and Aquolls	--	--
Ht, Hx	Houghton muck	+1.0-1.0 ft.	Severe: subsides, ponding, percs slowly
KoA-KoE	Kosciusko sandy loam	>6 ft.	Severe: poor filter
KxC3	Kosciusko sandy clay loam	>6 ft.	Severe: poor filter
OrC	Ormas loamy sand	> 6 ft.	Severe: poor filter
RlB	Riddles fine sandy loam	>6 ft.	Moderate: percs slowly
RlC	Riddles fine sandy loam	>6 ft.	Moderate: percs slowly, slope
RxB	Riddles-Ormas-Kosciusko complex	>6 ft.	Moderate-Severe: percs slowly, poor filter
RxC	Riddles-Ormas-Kosciusko complex	>6 ft.	Moderate-Severe: percs slowly, poor filter, slope
Sf	Sebewa mucky loam	+1.0-1.0 ft.	Severe: poor filter, ponding
Uf	Udorthents-Urban land complex	--	--
WlD2	Wawasee fine sandy loam	>6 ft.	Severe: slope

Source: Staley, 1989.

Aquents-Urban land complex, rarely flooded (Ao) typically occurs on the edges of lakes, where marshes have been filled with soil material. This unit is rarely flooded, except for brief periods by stream or lake overflow. In many areas, it is ponded by runoff from the higher adjacent soils. The physical characteristics of the Aquents are highly variable, and suitability for use depends on the thickness and texture of the fill, depth to the seasonal high water table, and the nature of the underlying material. Because of the flooding, the soils are generally unsuitable as sites for buildings and septic tank absorption fields. Under current Indiana regulations, it is illegal to place septic systems in these soils. Small areas along the northern, northwestern, and southern portions of Dewart Lake's shoreline are mapped in this soil unit.

Gilford sandy loam (Gf) soils are very poorly drained soils. They are found in slight depressions on broad outwash plains and terraces, along small drainageways, and in depressions on till plains, terraces, and outwash plains. Because of the ponding, these soils are unsuitable for septic tank absorption fields. Only a small portion of Dewart Lake's shoreline is mapped in Gilford soils.

The Histosols and Aquolls (He) are very poorly drained soils frequently ponded by runoff from the higher adjacent soils or by lake or stream overflow. The water table is typically near or above the surface most of the year, which makes these soils generally unsuitable for septic tank absorption fields. This soil unit occurs primarily in the wetlands covering the northeast and southeast corners of the lake.

Houghton muck (Ht, Hx) soils are nearly level, very poorly drained soils found in broad depressions on outwash plains and around lakes. These soils are frequently ponded by runoff and/or by lake overflow. The availability water capacity is very high and runoff is very slow. The water table is near or above the surface most of the year. For these reasons, these soils are unsuitable for septic tank absorption fields.

Rapid permeability impairs ability of the Kosciusko and Ormas soil types found adjacent to Dewart Lake to serve as septic absorption fields. Kosciusko sandy loam (KoA-KoE) and Kosciusko sandy clay loam (KxC3) soils are well-drained soils. Permeability is moderate in the subsoil and very rapid in the underlying material. Ormas loamy sand (OrC) is a well-drained soil. Permeability rates are rapid to moderately rapid in the subsoil and very rapid in the underlying material. Due to the rapid permeability of these soil types, they do not provide adequate filtering capability for septic tank absorption fields and may pollute of the groundwater. Kosciusko and Ormas soils cover portions of the northern and western shorelines.

Riddles fine sandy loam (RlB-RlC) soils are well-drained soils with moderately slow permeability. These soils are found on till plains and on benches and the tops of ridges on moraines. They have moderate permeability, which makes them moderately limited as a site for septic tank absorption fields. Enlarged septic fields built within this soil type will better absorb effluent.

Riddles-Ormas-Kosciusko complex (RxB-RxC) soils are well-drained soils on moderate slopes. The moderate slopes limit septic field suitability. The Ormas component of the complex is a poor effluent filter and groundwater pollution may result when septic systems are built on this soil unit, especially if septic systems are situated near shallow wells.

Sebewa mucky loam (Sf) soils are poorly drained, organic soils found in depressional areas and on outwash plains. Typically, these soils cover only small areas located adjacent to lakes and streams. Shallow water generally covers them for some portion of the year. These soils are unsuited for sanitary facilities due to ponding and permeability issues. Because these soils generally occupy some of the lowest points on the landscape, pumping systems are necessary for adequate drainage.

The suitability of Udorthents (Uf) for septic tanks varies among locales. Udorthents are moderate to strongly sloping, well-drained soils typically found in disturbed areas. Septic suitability limitations can include restricted permeability, wetness, and steep slopes.

As shown in Table 4, all of the soils surrounding Dewart Lake, except Riddles fine sandy loam (RlB-RlC) soils, are severely limited in their use as a septic tank absorption field. Even the Riddles fine sandy loam soils are moderately limited in their use as a septic tank absorption field. Given these the limitations of the soil, residents in existing homes should take steps to properly care for their septic systems such as cleaning their septic tanks regularly, avoiding the disposal of household chemicals that may kill soil bacteria, and implementing water conservation measures to alleviate strain on the system. Lake residents should work with the county health department, the county zoning department, and developers to ensure the appropriate adjustments, such as installing large septic leach fields, are made to overcome any limitations posed by the soil when new homes or developments are constructed around the lake.

2.5 Land Use

The Dewart Lake watershed is located in the Northern Lakes Natural Region (Homoya et al., 1985). The Northern Lakes Natural Region occupies the north central and northeastern portion of Indiana. The Eel River marks the Northern Lakes Natural Region boundary on the southeast and the Maxinkuckee Moraine serves as the Region's western boundary. Prior to European settlement, the Northern Lakes Natural Region was a mixture of numerous natural community types including bog, fen, marsh, prairie, sedge meadow, swamp, seep spring, lake and deciduous forest (Homoya et al., 1985). Several of these natural community types likely covered the Dewart Lake watershed landscape in pre-settlement times. For example, upland forest dominated by red oak, white oak, black oak, shagbark hickory, and/or pignut hickory likely covered areas north and south of the lake. The lower elevation areas such as the corridor along Cable Run and the unnamed intermittent stream/wetland complex east of Dewart Lake were likely forested with tree species that are more tolerant of wet soil conditions. Common species may have included sycamore, American elm, red elm, green ash, silver maple, and red maple. Marsh habitat rather than open water may have been more common along the shallow edge of Dewart Lake in pre-settlement times.

Land use across the Dewart Lake watershed has changed over the past two centuries. Forested land has been cleared for agricultural and residential purposes. Table 5 and Figure 9 present current land use information for the Dewart Lake watershed. Land use data from the U.S. Geological Survey (USGS) forms the basis of Figure 9. The USGS data set was updated using 2003 orthophotography of the watershed. Some areas of the watershed were also field checked.

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

Land Use	Area (acres)	Area (hectares)	% of Watershed
Row Crops	3175.4	1285.6	62.8%
Open Water	556.6	225.4	11.0%
Deciduous Forest	512.2	207.4	10.1%
Pasture/Hay	363.4	147.1	7.2%
Woody Wetlands	220.5	89.3	4.4%
Low Intensity Residential	187.2	75.8	3.7%
Emergent Herbaceous Wetlands	33.3	13.5	0.7%
Evergreen Forest	4.1	1.7	0.1%
Urban Park Land	1.0	0.4	<0.1%
High Intensity Residential	2.2	0.9	<0.1%
High Intensity Commercial	2.3	0.9	<0.1%
Mixed Forest	0.4	0.1	<0.1%
Total	**5058.6**	**2048.1**	**100.0%**

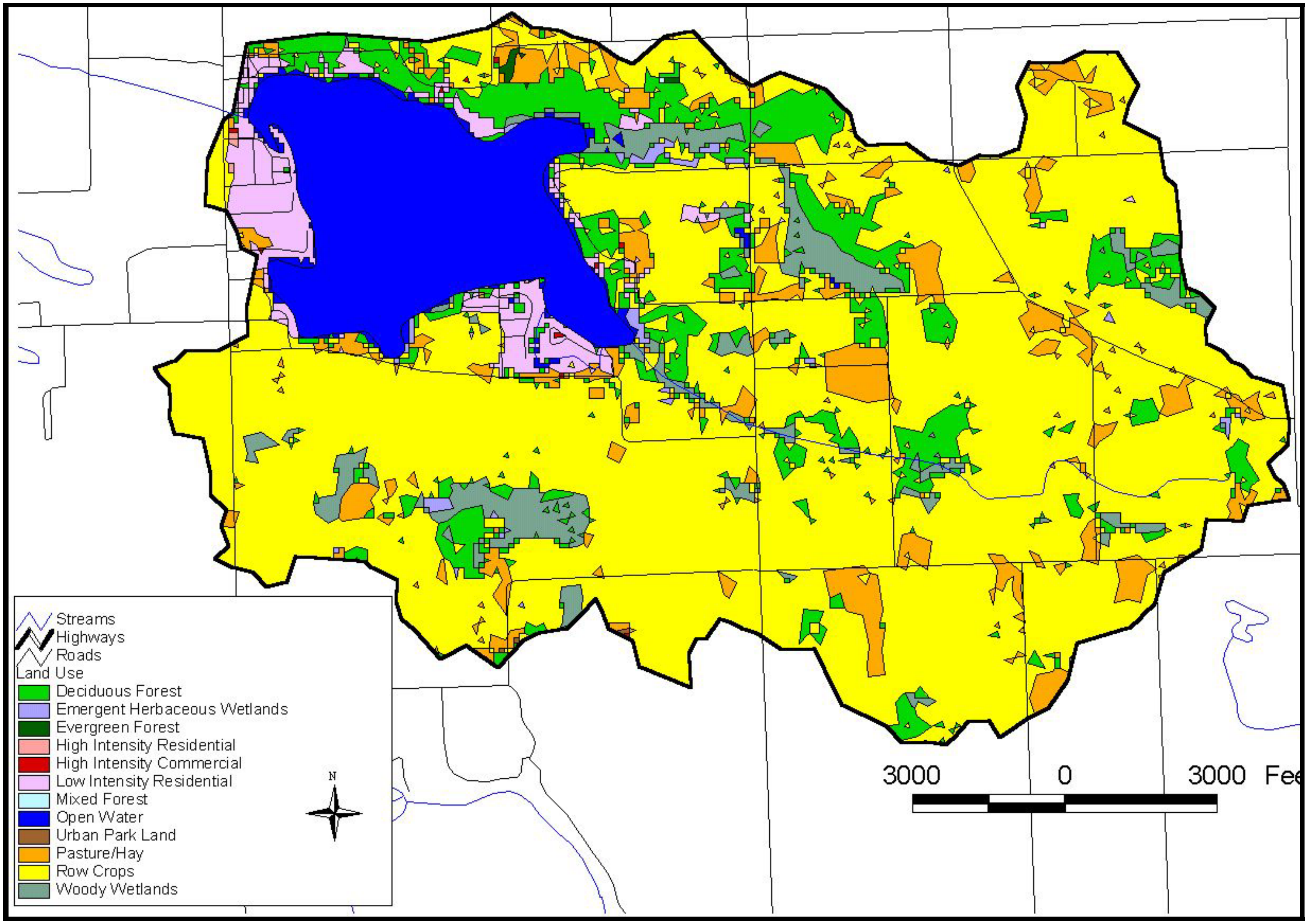

Figure 9. Land use in the Dewart Lake watershed. Source: See Appendix A. Scale: 1"= 3,000'.

Agricultural land use dominates the Dewart Lake watershed. Approximately 63% of the watershed is in row crop agricultural production. Another 7% is used to grow hay or as pastureland. A dominance of agricultural land use is typical in Kosciusko County. Staley (1989) reports "Most of the acreage in the county is farmed." Corn and soybeans are the main crops grown in Kosciusko County and the Dewart Lake watershed.

Remnants of the native landscape, including forested areas and wetlands, cover approximately 15% of the watershed. Most of these natural areas are contained in forested tracts around Dewart Lake in the northwest and north central portions of the watershed. Remnant emergent wetlands can be found along the southern shoreline of Dewart Lake. Several small wetlands border Cable Run as well. Three relatively large woody wetlands exist near Dewart Lake to the east and south. Smaller woody wetlands are scattered throughout the watershed. Dewart Lake itself covers 11% of the total watershed.

Nearly 200 acres (80.9 ha) of the watershed is used for residential or commercial purposes. Much of the residential and commercial development is focused along the Dewart Lake shoreline. Low intensity residential areas accounts for a majority of the residential and commercial development within the watershed. (In the Indiana Land Cover Data Set, the USGS defines low intensity residential areas consist largely of single-family homes; hardscape covers only 30-80% of the landscape.)

Land use can have a significant impact on water quality since different land use types receive different pollutants and have different capabilities for retaining and/or assimilating pollutants. For example, residential areas are often subject to high rates of fertilizer application, whereas forests often receive little human-applied fertilizer. Residential areas do not have the same capacity as forests to assimilate pollutants reaching the landscape. Forests and other vegetated landscapes assimilate nutrients that reach these areas via plant growth. Land uses with high amounts of impervious surfaces have reduced or, in extreme cases, no ability to retain or assimilate pollutants.

Pollutants that cannot be assimilated by the landscape leave the landscape during rain events. Researchers have examined the pollutant loss from different landscapes and developed pollutant export coefficients for different landscapes. Pollutant export coefficients are a measure of the rate a pollutant is lost from a landscape per unit area of the landscape. To illustrate how different land types assimilate pollutants, Table 6 presents some mid-range phosphorus export coefficients for different land use types. (Phosphorus was selected for this illustration since it is one of the pollutants of critical concern in lakes. Phosphorus is the nutrient that typically controls algae and rooted plant growth in aquatic ecosystems.) As shown in Table 6, high and low density residential land, commercial land, agricultural land, and golf courses have relatively high phosphorus export rates compared to more natural landscapes such as wetlands, forests, and old fields. The export coefficients provided in Table 6 are simply estimates. The use of best management practices, such as filter strips on agricultural land or stormwater infiltration trenches on commercial land, can reduce the export of pollutants to adjacent waterways or lakes.

Table 6. Mid-range phosphorus export coefficients.

Land Use	Phosphorus Export Coefficient (kg/ha-yr)
Agricultural	1.0
EM/SS Wetland	0.1
Emergent Wetland	0.1
Forested	0.2
High Density Residential	2.5
Low Density Residential	0.6
Open Water	0
High Density Commercial	2.5
Low Density Commercial	1.5
Old Field	0.2
Golf Course	1.5

Source: Reckhow et al. 1980 and Reckhow and Simpson, 1980.

2.6 Wetlands

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

In general wetlands, including lake or ponds, cover 16% to 18.5% of the Dewart Lake watershed. The USGS Land Cover Data Set suggests that wetlands cover approximately 5% of the Dewart Lake watershed and open water covers an additional 11% of the watershed (Table 5). The United States Fish and Wildlife Service's (USFWS) National Wetland Inventory Map (NWI) (Figure 10) shows that wetlands cover approximately 18.5% of the Dewart Lake watershed. (Table 7 presents the acreage of wetlands by type according to the National Wetland Inventory.) The differences in reported wetland acreage in the Dewart Lake watershed between the USGS and the USFWS data sets reflect the differences in project goals and methodology used by the different agencies to collect land use data.

Table 7. Acreage and classification of wetland habitat in the Dewart Lake watershed.

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed
Lacustrine	531.0	215.1	10.5%
Palustrine emergent	114.9	46.5	2.3%
Palustrine forested	206.1	83.5	4.1%
Palustrine scrub/shrub	73.7	29.9	1.5%
Palustrine submergent	5.8	2.3	0.1%
Ponds	5.3	2.2	0.1%
Total	**936.9**	**379.4**	**18.5%**

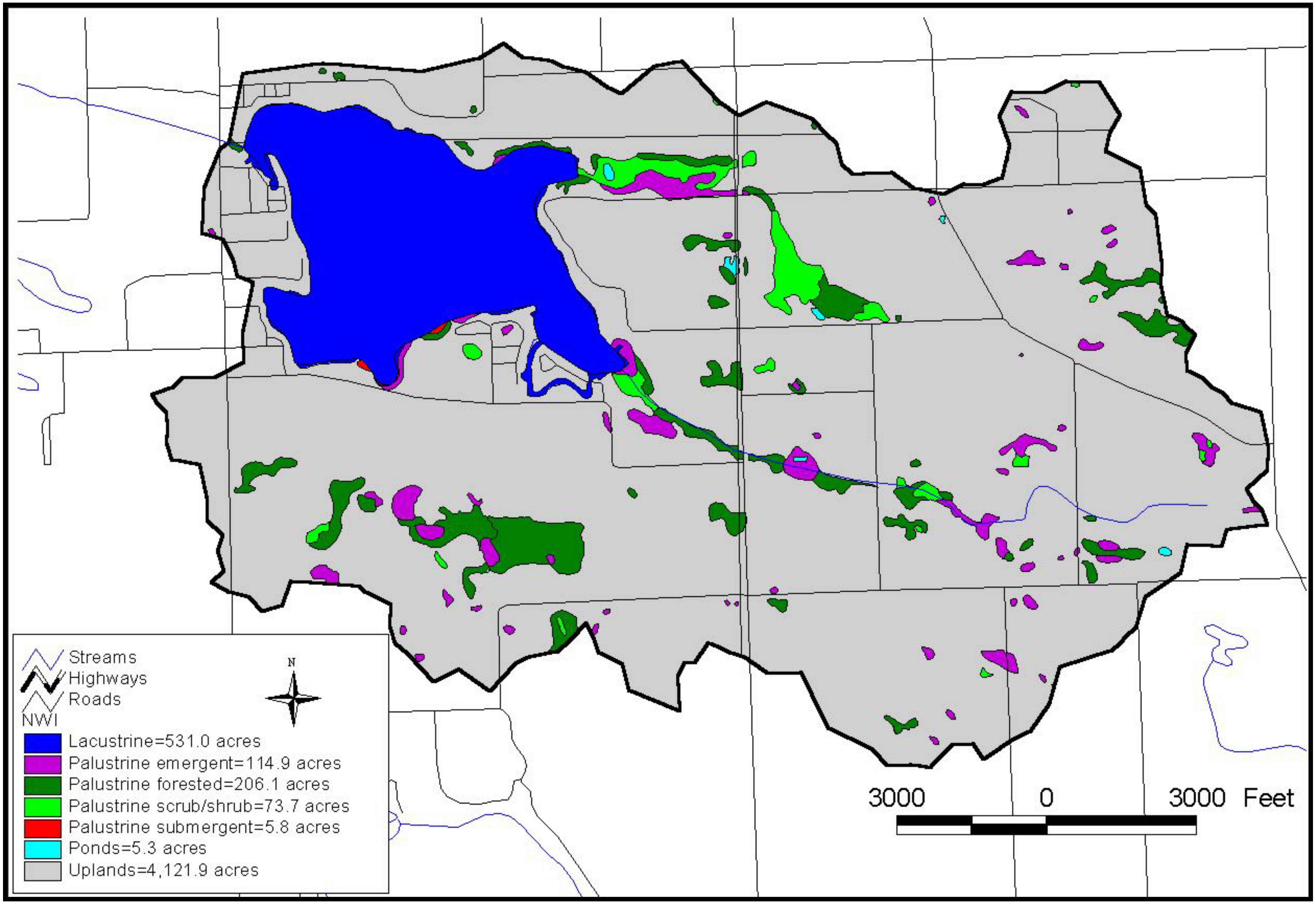

Figure 10. Wetlands in the Dewart Lake watershed. Source: See Appendix A. Scale: 1”=3,000’.

The IDNR estimates that approximately 85% of the state's wetlands have been filled (Indiana Department of Natural Resources, 1996). The greatest loss has occurred in the northern counties of the state. 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 and residential purposes altered much of the natural hydrology, eliminating many of the wetlands. The 1978 Census of Agriculture found that drainage is artificially enhanced on 38% of the land in Kosciusko County (cited in Hudak, 1995). Shoreline development around lakes has also significantly reduced wetland acreage.

To estimate the historical coverage of wetlands in the Dewart Lake watershed, hydric soils in the watershed were mapped in Figure 11. (This map is based on the Natural Resources Conservation Service criteria for hydric soils and is not field checked.) Because hydric soils developed under wet conditions, they are a good indicator of the historical presence of wetlands. Comparing the total acreage of wetland (hydric) soils in the watershed (1,124.8 acres or 455.2 ha) to the acreage of existing wetlands, excluding Dewart Lake (405.9 acres or 164.3 ha) suggests that roughly 36% of the original wetland acreage exists today. Compared to other watersheds in Kosciusko County and throughout northern Indiana, the Dewart Lake watershed has experienced less wetland loss than typical. Much of the loss occurred within the eastern and southern portions of the watershed.

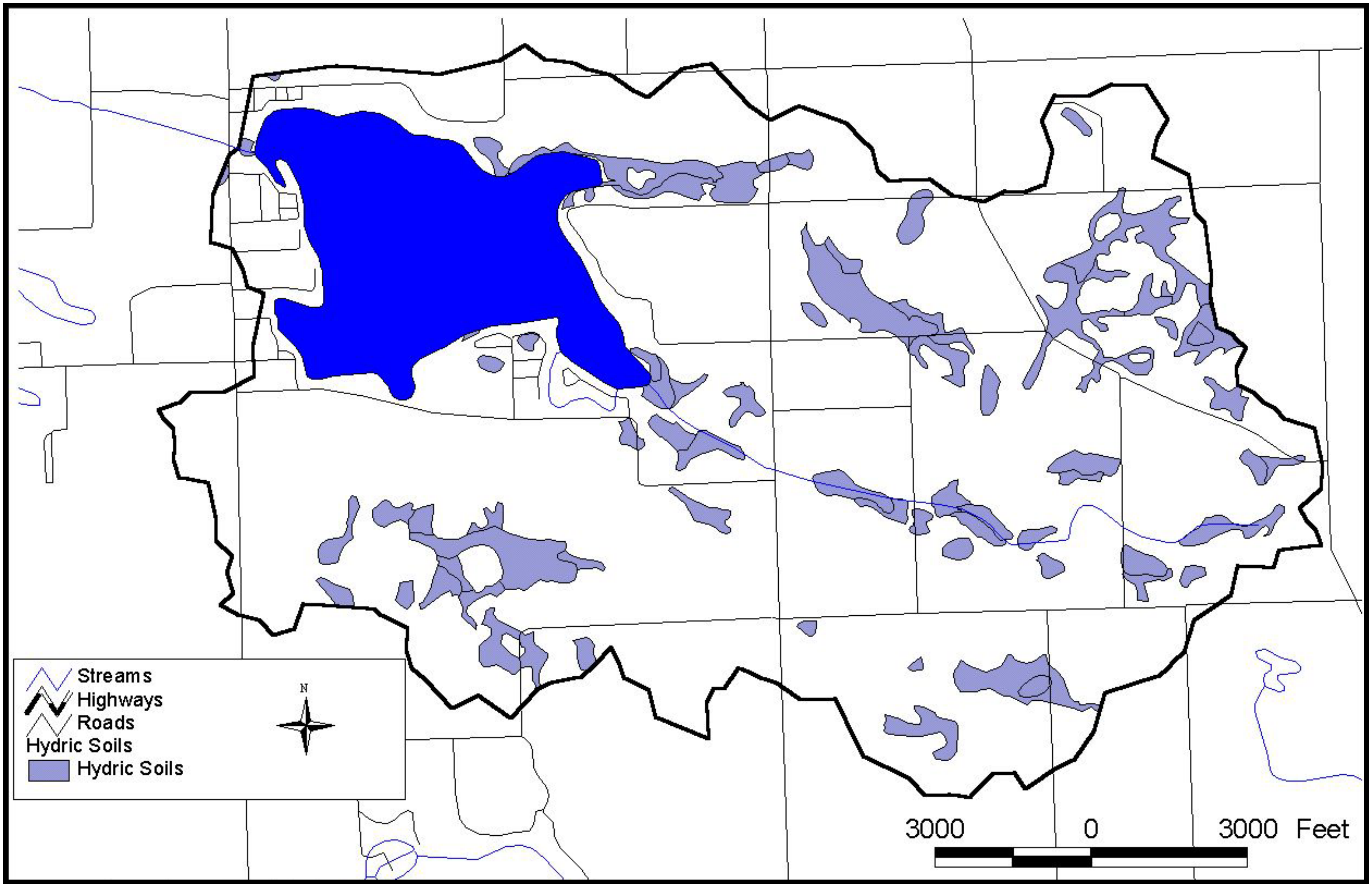

Figure 11. Hydric soil in the Dewart Lake watershed. Source: See Appendix A. Scale: 1"=3,000'.

2.7 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 B presents the results from the database search for the Dewart Lake watershed. (The ETR list in Appendix B includes additional species; however these species sightings actually occurred outside of the Dewart Lake watershed boundaries. For additional reference, Appendix C provides a listing of endangered, threatened, and rare species (ETR) documented in Kosciusko County.) No federally listed endangered, threatened, and rare species are known to exist in the watershed, although several state listed species inhabit the Dewart Lake and its 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.
- *Threatented*: 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.

According to the database, habitat within the Dewart Lake watershed supports, or at least historically supported, five state endangered species (two birds, two turtles, and an aquatic plant). The black tern (*Chlidonias niger*) was noted in the western/northwestern edge of Dewart Lake in 1949. A nest belonging to a least bittern (*Ixobrychus exilis*) was documented in 1950 along the southwest edge of Dewart Lake. Both of these areas are now developed for residential use making the presence of these species unlikely today. The spotted turtle (*Clemmys guttata*) and Blanding's turtle (*Emydoidea blandingii*) were observed more recently (1984 and 1997, respectively) near the southeast corner of Dewart Lake. Beck's water-marigold (*Bidens beckii*), listed as state endangered, was documented in Dewart Lake in 1941. (Beck's water-marigold is now listed as state threatened.) Beck's water-marigold, as well as the state threatened species, Fries' pondweed (*Potamogeton friesii*), and state rare species, flatleaf pondweed (*Potamogeton robbinsii*) and Richardson's pondweed (*Potamogeton richardsonii*), were observed during the aquatic plant survey conducted as part of this diagnostic study.

3.0 STREAM ASSESSMENT

3.1 Stream Assessment Introduction

To better understand the transport of nutrients and other pollutants to Dewart Lake from its watershed, this study included an evaluation of the water quality of Cable Run, Dewart Lake's only inlet stream. The water quality evaluation consisted of the collection of water samples from the stream. 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.

Cable Run's biological community was 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 plan a larger role in shaping the stream's fish community than water quality in some instances.

To provide a complete assessment of Cable Run's water quality, 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 12. The stream's biological community 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 Cable Run 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.

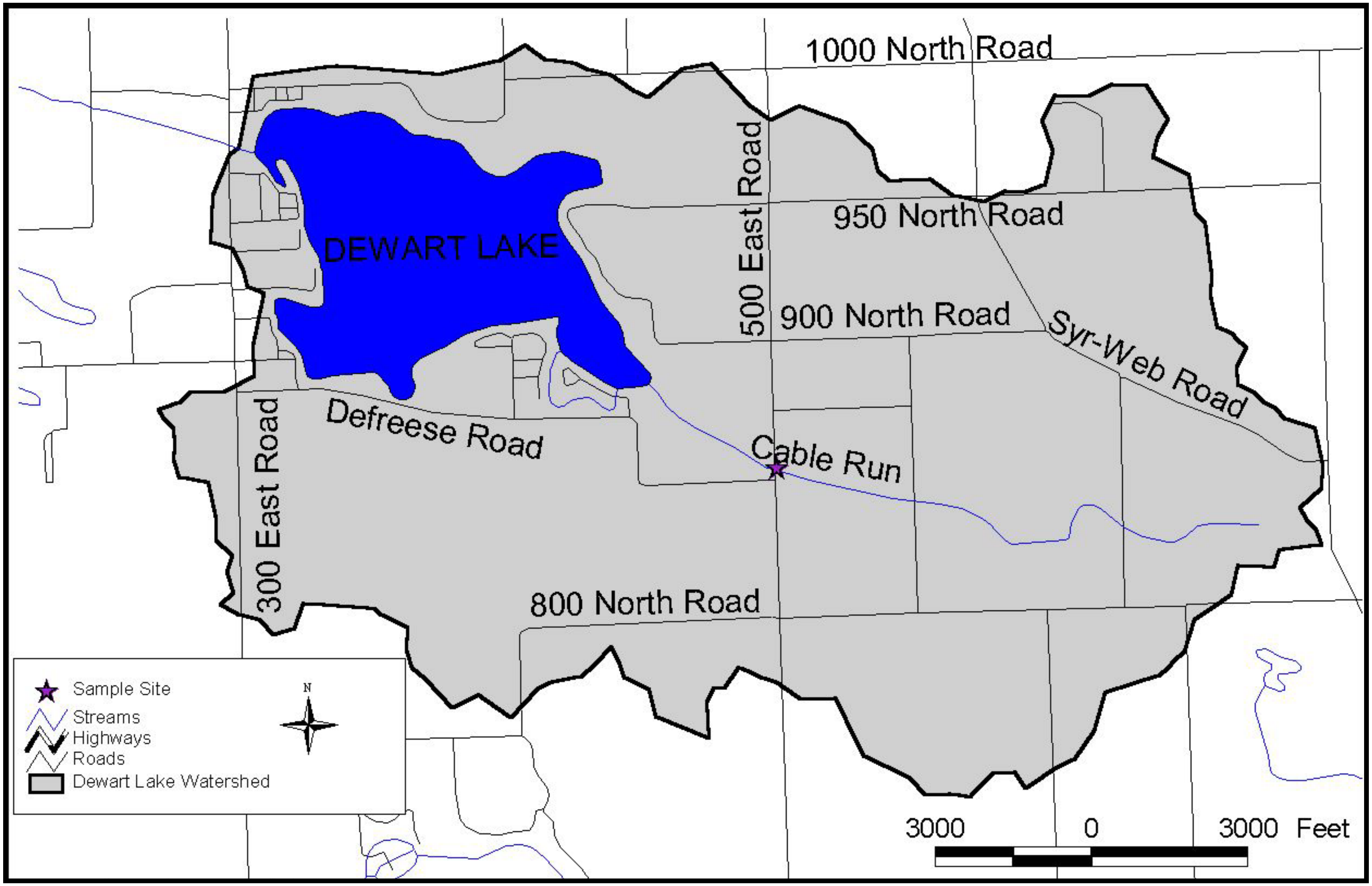

Figure 12. Stream sampling site in the Dewart Lake watershed. Source: See Appendix A. Scale: 1”=3,000’.

3.2 Stream Assessment Methods

3.2.1 Water Chemistry

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).

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 ^{o}F (32.2 ^{o}C).

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

Conductivity. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low discharge, conductivity is higher than during high discharge 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 0.033 mg/L in streams (USEPA, 2000b). Dodd et al. (1998) suggest the dividing line between moderately (mesotrophic) and highly (eutrophic) productive streams is a total phosphorus concentration of 0.07 mg/L. The Ohio EPA recommended a total phosphorus concentration of 0.08 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 Cable Run may not fit the WWH definition, 0.08 – 0.1 mg/L is a good goal for the creek.

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 0.30 mg/L and 0.24 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 Cable Run and its tributaries. The IAC sets only nitrate-nitrogen and ammonia-nitrogen standards for waterbodies in Indiana. The Indiana Administrative Code requires that all waters of the state have a nitrate-nitrogen concentration of less than 10 mg/L, which is the drinking water standard for the state. The IAC standard for ammonia-nitrogen depends upon the water's pH and temperature, since both can affect ammonia-nitrogen's toxicity. None of the samples collected from Cable Run violated the state standard for either nitrate-nitrogen or ammonia-nitrogen.

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

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

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

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

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 Dewart Lake, macroinvertebrates were collected during base flow conditions on August 11, 2004 from Cable Run using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). The macroinvertebrate samples were processed according to the protocol detailed in the QAPP. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al., 1984, Ferraro and Cole, 1995, Marchant, 1995, Bowman and Bailey, 1997, Waite et al., 2000).

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

3.2.3 Habitat

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

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

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

A stream's buffer, which includes the riparian zone and 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 QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation (IDEM, 2000).

3.3 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 Cable Run are presented in Table 9. The stream cross-section, determined while measuring discharge, is shown in Figure 13. Cable Run possesses a box shaped channel profile with relatively steep side slopes. This box shaped channel profile is characteristic of streams that have been straightened to improve drainage. Water flowing through the stream channel has cut a low flow channel within the general box shaped structure of the channel. Stream discharges measured during base and storm flow conditions are shown in Figure 14. Storm flow discharge was higher than base flow, as expected. Comparing this year's discharge data to historical sampling of the stream suggests the storm flow sampling occurred when the stream was close to its maximum discharge. Cable Run's rather low base flow discharge suggests very low flow is normal for this stream. Lake residents (personal communication) report that Cable Run is often dry by August. Heavier than normal rains throughout the summer of 2004 likely helped maintained water flow in Cable Run.

Table 9. Physical characteristics of Cable Run on June 11, 2004 (storm flow) and August 11, 2004 (base flow).

Site	Date	Event	Flow (cfs)	Temp (°C)	DO (mg/L)	DO Sat (%)	TSS (mg/L)	Turbidity (NTU)
Cable Run	8/11/2004	base	0.025	15.5	8.7	87.5	2.25	1.4
	6/11/2004	storm	8.370	17.0	8.6	88.2	16.9	-

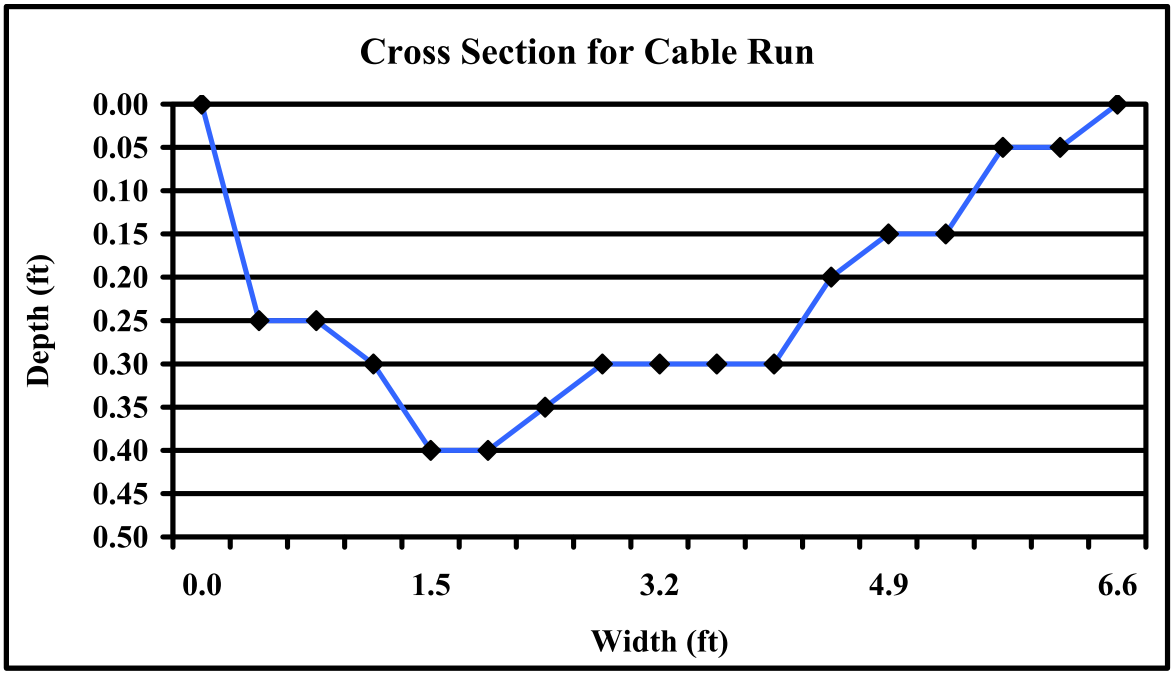

Figure 13. Physical dimensions at the Cable Run sample location.

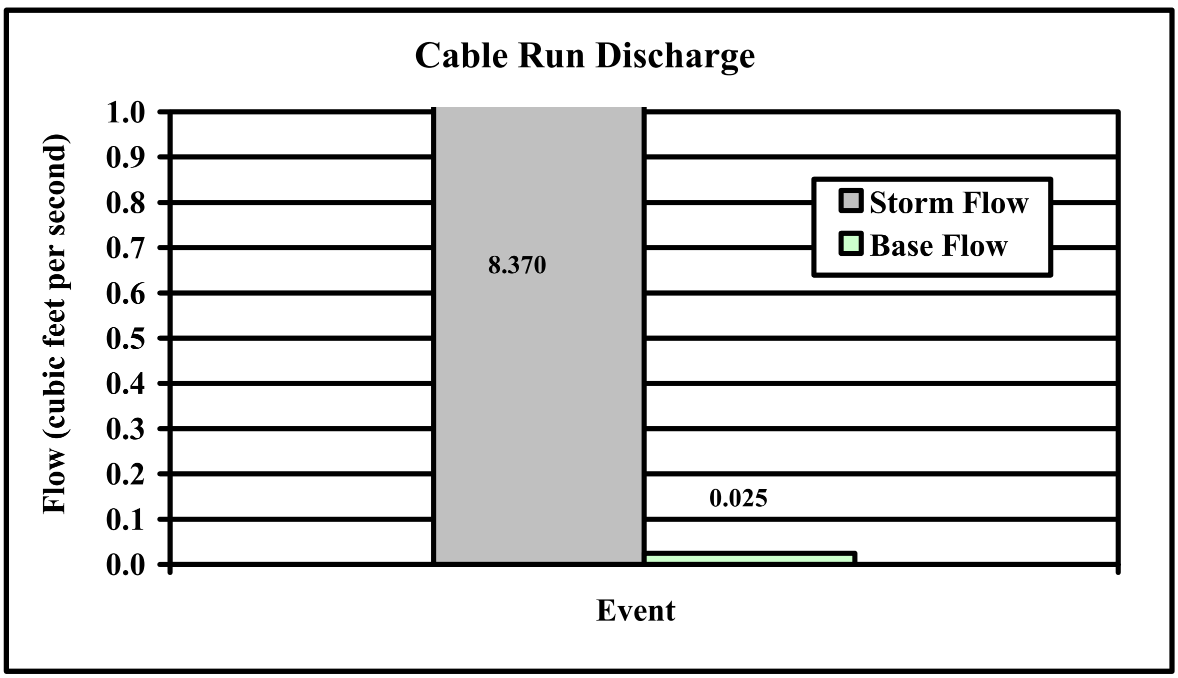

Figure 14. Discharge measurements during base and storm flow sampling of Cable Run.

Temperature and dissolved oxygen concentration within Cable Run during both base and storm flow events were normal for Indiana streams and were sufficient to support aquatic life. The water temperature was warmer during storm flow than during base flow despite the fact that base flow sampling occurred later in the summer. The lower base flow temperature reflects the influence of groundwater, which is typically cooler than surface water, in maintaining flow within Cable Run. Surface water discharge, which is generally warmer since stormwater runoff gains heat from the warmer land surface before entering streams, likely contributes more to the stream's flow during rain events resulting in a higher water temperature. The dissolved oxygen concentration in the Cable Run stream was nearly identical for both sampling events and was well above the 5 mg/L minimum required by most aquatic fauna for respiration.

Cable Run's base flow total suspended solid concentration and turbidity were relatively low. During the storm flow sampling event, Cable Run exhibited a total suspended solid concentration more than seven times higher than the total suspended solid concentration observed during base flow. 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.

The results of the stream sampling conducted during this study are generally consistent with the results from sampling conducted by the Kosciusko County Health Department (KCHD, 1997, 1998, 1999, 2000, 2001). In sampling conducted from 1996 to 2001, the KCHD did not observe any violations of the state standards for temperature, dissolved oxygen, or pH in Cable Run. (This diagnostic study utilized the same sampling point on Cable Run as the KCHD uses in its yearly sampling of county streams.) Although the KCHD does not specifically report which samples were collected during storm flow conditions and which samples were collected during base flow, the KCHD documents higher turbidity in Cable Run during periods of higher discharge, which is similar to the results obtained in this study.

Chemical and Bacterial Characteristics
Table 10 shows the chemical and bacterial characteristics of Cable Run. 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), soluble reactive phosphorus (0.010 mg/L), and total phosphorus (0.022 mg/L) (Clark et al., 2000). Except for one instance, namely the base flow ammonia concentration, nutrient concentrations within Cable Run all exceeded these median concentrations. Some parameters exceeded the median concentrations by one to three orders of magnitude.

Table 10. Chemical and bacterial characteristics of Cable Run on June 11, 2004 (storm flow) and August 11, 2004 (base flow).

	Date	Event	pH	NH_3	NO_3	TKN	TP	SRP	*E. coli*
Concentration	8/11/04	base	--	0.019	4.925	0.227	0.057	0.083	490
	6/11/04	storm	7.0	0.747	11.066	1.943	0.347	0.260	>70000
Load	8/11/04	base	--	0.001	0.30	0.014	0.003	0.005	--
	6/11/04	storm	--	15.29	226.47	39.76	7.10	5.32	--

Note: All concentration parameters were measured in mg/L except E. coli, which was measured in colonies/100 mL. All loading parameters are in kg/d.

Cable Run exhibited high pollutant concentrations during storm flow conditions. The nitrate-nitrogen concentration exceeded the state standard. The 11 mg/L concentration is also well above the 3-4 mg/L threshold concentration found by the Ohio EPA to impair aquatic life. Cable Run's total phosphorus concentration is also well above target concentrations recommended by various agencies to protect aquatic life. Finally, the stream's *E. coli* concentration is extremely high. The *E. coli* concentration observed in Cable Run during storm flow sampling is over 300 times the state standard.

Fortunately, Cable Run exhibited much lower nutrient and bacteria concentrations during base flow conditions. Base flow conditions are more representative of "normal" conditions in the stream. They provide an idea of typical inputs to Dewart Lake. Phosphorus, ammonia-nitrogen, and total Kjeldahl nitrogen concentrations observed during base flow in Cable Run were all relatively good for a stream in a largely agricultural setting. The stream's nitrate nitrogen concentration was still high during base flow and again exceeded the 3-4 mg/L threshold concentration found by the Ohio EPA to impair aquatic life. The stream's base flow *E. coli* concentration violated the state standard but well within the range that is typical for a northern Indiana stream.

3.3.2 Macroinvertebrates and habitat

Table 11 presents the results of the macroinvertebrate sampling of Cable Run. (Appendix D includes a complete list of macroinvertebrate found during the Cable Run sampling.) Overall, Cable Run possessed a mIBI score of 5.3, suggesting the stream's biotic community is only slightly impaired. The stream supports an above average species richness and the dominant taxa only accounted for 27% of the community composition. Many of the taxa in Cable Run exhibited only moderate tolerance to pollution. This is reflected in the fairly low HBI score of 4.4. 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 Cable Run. A dominance of members of the *Chiromidae* family is typically associated with degraded water quality.

Cable Run's biotic community also exhibited some negative attributes. For example, the stream community has only two taxa from the more sensitive *Ephemeroptera*, *Plecoptera*, and *Trichoptera* or EPT orders. Members of these two taxa, Heptageniidae and Hydropsychidae, tend to be much more tolerant of pollution compared to other members of the EPT orders. No stoneflies were observed in Cable Run. Stoneflies are arguably the most sensitive to pollution. Finally, while reflecting moderate taxa richness, three taxa comprised 75% of the sample.

Despite these negative attributes, Cable Run's overall mIBI indicates water quality is fairly 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 slightly impaired category, this would not be sufficient for IDEM to consider Cable Run as not meeting the requirements of the Clean Water Act.

Table 11. Classification scores and mIBI score for Cable Run, August 11, 2004.

Metric	Value	Metric Score
HBI	4.40	6
No. Taxa (family)	14	6
% Dominant Taxa	27.0	6
EPT Index	2	0
EPT Count	58	4
EPT Count/Total Count	0.46	4
EPT Abundance/Chironomid Abundance	19.33	8
Chironomid Count	3.00	8
mIBI Score		**5.3**

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

Table 12 presents the Qualitative Habitat Evaluation Index (QHEI) score for Cable Run and includes the maximum possible score for each metric evaluated. (Appendix D contains the QHEI data sheet.) Cable Run's QHEI score was fairly low (40). The Indiana Department of Environmental Management characterizes QHEI scores less than 51 as non-supporting of aquatic life uses in Indiana (IDEM, 2002). The low QHEI score is due in large part to the stream's history. Judging by the stream's straight profile (Figures 15 and 16) and the prevalence of hydric soils along the stream's corridor, Cable Run was likely dug through historic wetlands to facilitate drainage for agricultural purposes. The stream's straight profile and the corridor's lack of gradient limit the development of pool/riffle sequences. Combined, these characteristics help to lower the stream's QHEI score.

Figure 15. Cable Run sampling site, August 11, 2004.

Figure 16. Cable Run downstream of the sampling site, August 11, 2004.

Table 12. QHEI Scores for the Cable Run, August 11, 2004.

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**
Cable Run	14	7	8	6	0	3	2	**40**

At the sampling point, Cable Run possesses a fairly narrow (approximately 15 feet or 4.6 m) riparian zone on its northern bank and a wider (approximately 120 feet or 37 m) riparian zone on its southern bank. Further upstream and downstream of the sampling site, Cable Run's riparian corridor is wider on the northern bank. Trees dominant the riparian vegetation, although the understory is well vegetated with herbaceous species. Beyond the riparian zone, row crop agricultural is the dominate floodplain land use. A residential lot lies immediately adjacent to the sampling point.

The stream banks were in good shape; little or no bank erosion was observed throughout the sampling reach. In-stream cover at the site was sparse and consisted mainly of overhanging vegetation, aquatic macrophytes, and woody debris. Cobble and gravel are the primary substrate types through the sampling reach.

Due to Cable Run's relatively poor habitat score, it is difficult to determine with any certainty whether the slight 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, nitrate-nitrogen concentrations observed during both storm and base flow conditions were above the threshold at which the Ohio EPA found to impair a stream's biotic community. Thus, it is likely that both poor habitat and water quality are impairing the stream's biotic community.

4.0 LAKE ASSESSMENT

4.1 Morphology

Figure 17 presents Dewart Lake's rather complex morphology. The lake consists of four or five distinct deep basins separated by shallower water. The lake's main basin lies in the western half of the 551-acre lake. Here, the lake extends to it maximum depth of 82 feet (25 m) (Table 13). Two shallower basins lie in the southeast and southwest corners of the lake. The southeastern basin (the "Kettle") has a maximum depth of 36 feet (11 m), while the maximum depth in the southwestern basin is approximately 30 feet (9.1 m). Water as shallow as 20-25 feet separates these two basins from the other parts of the lake. A third basin (or pair of basins) lies in the eastern third of the lake. Water depths extend to 47 and 53 feet (14.3 and 16.2 m) at two points in this basin. The water separating this basin from the main lake basin is approximately 30-35 feet deep (9.1-10.7 m).

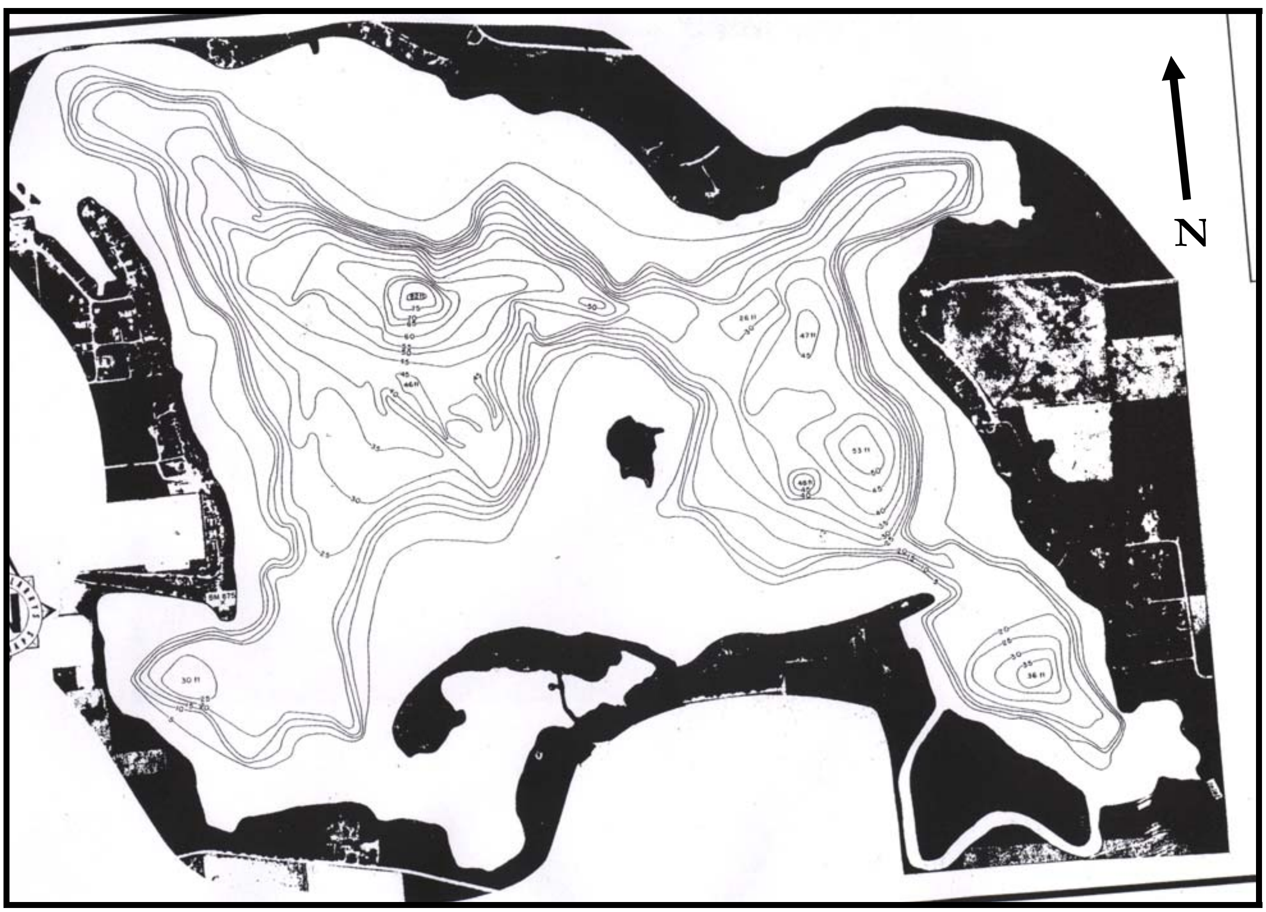

Figure 17. Dewart Lake bathymetric map. Source: IDNR, 1963.

Table 13. Morphological characteristics of Dewart Lake.

Characteristic	Value
Surface Area	551 acres (223 ha)
Volume	8,629 acre-feet (34,938,210m^3)
Maximum Depth	82 feet (25 m)
Mean Depth	16.3 feet (5.0 m)
Shallowness Ratio	0.44
Shoalness Ratio	0.63
Shoreline Length*	31,700 feet (9,665 m)
Shoreline Development Ratio	1.8

* Including the shoreline of Blueberry Island.

Dewart Lake possesses vast expanses of shallow water. According to its depth-area curve (Figure 18), nearly 250 acres (101.2 ha) of the lake is covered by water less than 5 feet (1.5 m) deep and approximately 350 acres (141.6 ha) of the lake is covered by water less than 20 feet (6.1 m) deep. This translates into a very high shallowness ratio of 0.44 (ratio of area less than 5 feet (1.5 m) deep to total lake area) and a high shoalness ratio of 0.63 (ratio of area less than 20 feet (6.1 m) deep to total lake area) (Table 13), as defined by Wagner (1990). Very little of the lake's acreage (approximately 10 acres or 4.0 ha) covers the water deeper than 55 feet (16.8 m).

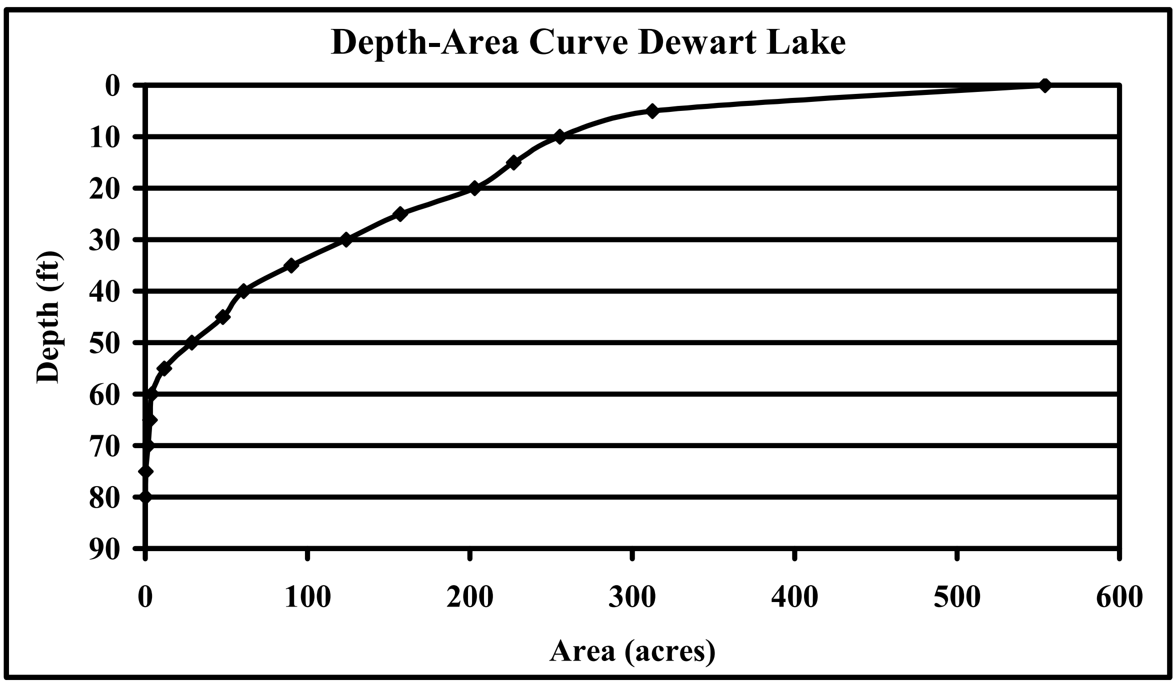

Figure 18. Depth-area curve for Dewart Lake.

Given the lake's high shallowness ratio, water level fluctuations of only 5 feet (1.5 m) can significantly alter the size of Dewart Lake. Historical reports and anecdotal evidence indicate that the lake has been subjected to such water level fluctuations several times over the past 100 years. During Blatchley's surveys of Indiana lakes conducted in 1899 (Blatchley, 1900), Blatchley estimates Dewart Lake to be approximately 300 acres (121.4 ha) in size but notes that the lake level had recently been lowered, cutting the lake's total size in half. Figure 19 is a sketch of Dewart Lake as Blatchley found it in the fall of 1899. Comparing this figure to the current bathymetric map of the lake (Figure 17) suggests Dewart Lake was about five to ten feet lower in the fall of 1899 than it is currently, giving the lake a much different shape than it possesses today. A low level rock and earthen dam was constructed in the late 1920s (Dewart Lake resident, personal communication), raising the lake's water level to close to the level it is today. Following several disputes among watershed residents over the lake's water level, the Kosciusko County Circuit Court set Dewart Lake's legal lake level in 1929 at 867.70 feet (264.5 m) mean sea level (msl). Several years of drought in the early 1960s lowered the lake's water level again, reducing the lake's size (Figure 20). An IDNR fisheries report from the 1970's (Shipman, 1977) documented that the lake had still not regained its full size. Shipman (1997) states that Dewart Lake covered 357 acres (144.5ha) in 1976, nearly 200 acres (81 ha) less than the lake's current size of 551 acres (223 ha).

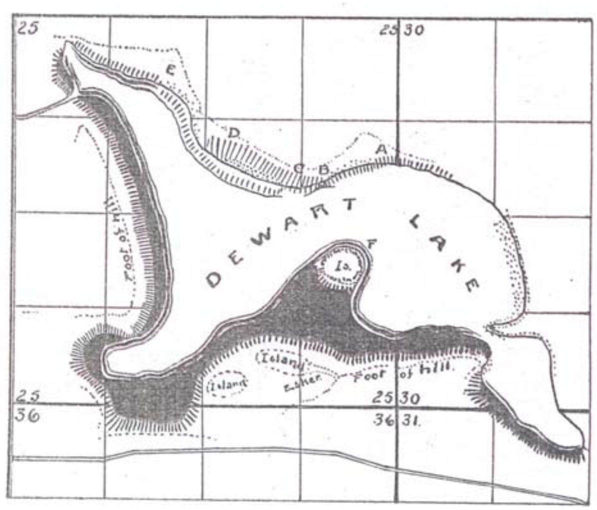

Fig. 46. Map of Dewart Lake, Kosciusko County, Ind.

Figure 19. Dewart Lake as mapped by Blatchley (1900).

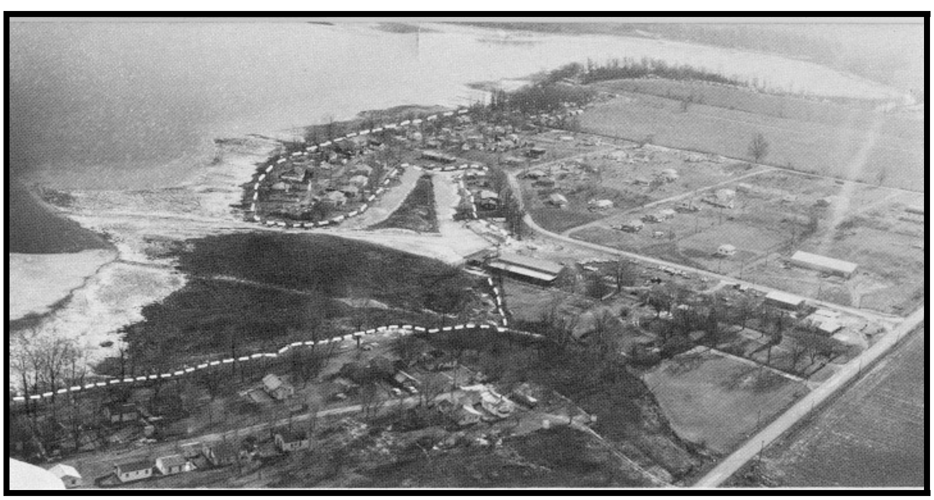

Figure 20. Dewart Lake's northwestern corner in 1965. Note the water is some distance from the shoreline. (Photo appeared in February 1965 edition of Outdoor Indiana. A scanned copy of the photo was provided by Jed Pearson, IDNR Division of Fish & Wildlife.)

Dewart Lake holds approximately 8,629 acre-feet (34,938,210m^3) of water. As illustrated in the depth-volume curve (Figure 21), most of the lake's volume is contained in the shallower areas of the lake. Nearly 90% 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 40 feet (12.2 m). Below 40 feet (12.2 m), the steep curve indicates a greater change in depth per unit volume.

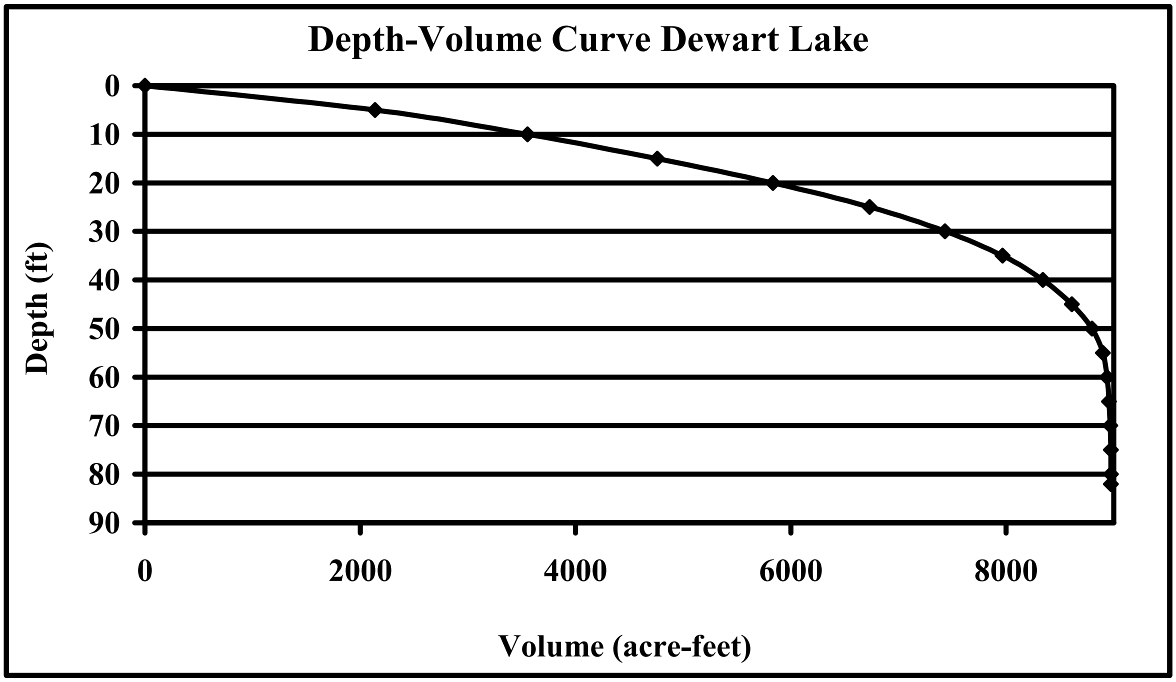

Figure 21. Depth-volume curve for Dewart Lake.

A lake's morphology can play a role in shaping the lake's biotic communities. For example, Dewart Lake's extensive shallow area coupled with its excellent clarity suggests the lake is capable of supporting a large rooted plant community. Based on the lake's clarity, Dewart 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 28 feet (8.5 m). Referring to Dewart Lake's depth-area curve (Figure 18), this means that the lake's littoral zone is approximately 425 acres (172 ha) in size or approximately 75% of the lake. This large 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.

A lake's morphology can also influence the lake's water quality. Some lakes with multiple deep holes like Dewart Lake exhibit anoxia in these deep holes that is not necessarily due to eutrophication. Hypolimnetic (bottom water) anoxia is often associated with eutrophication. However, mesotrophic and oligotrophic lakes can experience anoxia in their hypolimnia if the shape of the lake does not allow for complete mixing of lake layers during turnover. This was observed in Lake Maxinkuckee, an oligotrophic-mesotrophic lake, even in the early part of the 1900's (Evermann and Clark, 1920 and Crisman, 1986). Historical data from the 1970's (Fink, 2003 and ISPCB, 1986: Table 14) show Dewart Lake often exhibits hypolimnetic anoxia despite possessing relatively good water quality.

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 Dewart Lake (551 acres or 223 ha) would have a circumference of 17,367 feet (5,295 m). Dividing Dewart Lake's shoreline length (31,700 feet or 9,665 m) by 17,367 feet yields a ratio of 1.8:1. This ratio is moderately low. The channel dug through wetland habitat to create the Blueberry Island development and the creation of the point east of the public boat launch increased the length of Dewart Lake's shoreline. However, Dewart Lake lacks extensive shoreline channeling observed on other popular Indiana lakes such as lakes in the Barbee Chain and Lake Tippecanoe. 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.

4.2 Shoreline Development

Dewart Lake has long been a popular destination for anglers, and consequently development of the lake's shoreline started much earlier compared to many other lakes in northeastern Indiana. Blatchley (1900) records Dewart Lake's popularity in his notes, stating that "As a fishing resort the lake is noted, and many people, even in a region where lakes are abundant, seek its waters to try their luck in pursuit of the finny tribe." Blatchley notes the presence of a several structures, including a boathouse located just west of the Limberlost Girl Scout Camp, around the lake during his 1899 survey of the lake.

Early aerial photography of the lake (1938) shows the presence of a few piers and several houses around the lake. These structures are located along the eastern shoreline, near the Redmond Park area, and northwest of the wetland that would become Blueberry Island. The 1938 photography also documents the presence of wetland habitat in areas that would be developed for residential use in future years. These areas include Blueberry Island, the point immediately east of the public boat launch, and the subdivision along EMS Lanes 10-12.

By 1965, aerial photography documents significant development of the shoreline compared to 1938. Houses and mobile units populate the western, northern, and eastern shorelines. The emergent wetland community immediately east of public boat launch has been filled and shaped to accommodate lakeside homes. The channel around Blueberry Island was complete or nearly complete in 1965. Individuals had also built homes off shore. This so called second and third tier development is common around lakes with completely developed shorelines.

Shipman (1977) describes the shoreline development around Dewart Lake as "extensive" in 1976, commenting that only the areas of shoreline not developed are wetland habitat. His data sheets record the presence of 483 homes, 431 boats, one marina and two camps around Dewart Lake. In his study of Kosciusko County lakes, Hippensteel (1989) confirms the popularity of Dewart Lake, noting that only Lake Wawasee, Lake Tippecanoe, and Webster Lake have more homes around them. IDNR fisheries reports (Pearson, 1982, 1984, 1985 and 1995) suggest the lake's shoreline has reached its maximum capacity.

Dewart Lake residents took a census of development around the lake as part of this study. Lake residents counted a total of 273 homes lying directly along the shoreline. Of these homes, they estimated that 63% were utilized full time. Lake residents recorded the presence of another 93 homes located across the street from the shoreline and estimated that half of these homes were used full time. Finally, the residents counted another 227 homes around the lake that did not lie directly on the lakeshore or across the street from the lakeshore. Most (73%) of these homes are utilized full time. Totaling these counts yields an estimate of close to 600 single-family residence homes.

The resident census also included a count of motor homes, mobile homes, and cabins in the two campgrounds on Dewart Lake. Crowl's Campground has 20 motor home, mobile homes, or cabins. Crowl's Landing on the west end of the lake has 57 mobile homes or motor homes that seem more or less permanent. According to information provided by Crowl's Landing personnel, all residents of Crowl's Landing are supposed to use the toilet/shower facilities in the building located on site. Campers use both campgrounds seasonally, typically from May through September.

Given the tiered development of Dewart Lake's shoreline, it is unlikely that each property owner has direct access or an easement giving him or her access to the lake. Dewart Lake has a recently paved public boat launch in the northwest corner of the lake. The boat launch has parking capacity for approximately 30 vehicles. The IDNR established this public access point in 1985. Prior to 1985, boaters could access the lake for a fee through the Dewart Lake Marina.

Much of the lake's natural shoreline has been altered as a result of the residential development around Dewart Lake's perimeter. Concrete seawalls have replaced the natural emergent vegetation along much of the lake's northern and western shorelines (Figure 22). Concrete seawalls are also common along a portion of the eastern shoreline and around Blueberry Island. Rock seawalls line some of the properties in the southwestern corner of the lake, while seawalls are absent along the Limberlost Girl Scout Camp or the Quaker Haven properties. Only a very short portion of Dewart Lake's shoreline remains in a natural condition. A portion of the cove adjacent to the Limberlost Girl Scout Camp, the southern corner of the Kettle Cove, and the central portion of the southern shoreline still support a healthy fringe of emergent vegetation, mimicking what was likely the natural condition of the entire Dewart Lake shoreline.

Figure 22. Type of seawall bordering Dewart Lake.

4.3 Historical Water Quality

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana Stream Pollution Control Board, the Indiana Department of Environmental Management (IDEM), the Indiana Clean Lakes Program (CLP), and citizen volunteers participating in the Indiana CLP Volunteer Monitoring Program have conducted various water quality tests on Dewart Lake. Table 14 presents a summary of some selected water quality parameters from these assessments of Dewart Lake. Appendix E contains detailed data tables from the comprehensive CLP and IDEM assessments of the lake in 1988, 1994, and 2000.

Based on the data presented in Table 14, water quality in Dewart Lake has remained stable or even improved slightly over the past 30 years. Water clarity is relatively good for the region. Since 1976, Secchi disk transparency (a measure of water clarity) has ranged from 7 feet (2.1 m) to 13.4 feet (4.1 m). Water clarity has been variable over the years with no distinct trend toward increasing or decreasing clarity. Data collected by a citizen volunteer on the lake confirms that water clarity has remained stable over the past 15 years (Figure 23). Total phosphorus concentrations have been generally low, ranging from less than 0.03 mg/L to 0.06 mg/L. This exception to this is data collected in 1988 when Dewart Lake's epilimnion (upper water) exhibited a very high total phosphorus concentration. This reading appears to be an outlier, as such a high epilimnetic concentration was not observed in any other year, including this year's results. The lake's algae (plankton) density reflects the relatively low nutrient levels. Nutrients (phosphorus and nitrogen) promote the growth of algae and rooted plants; thus, lakes with high nutrient levels are expected to support dense algae and/or rooted plant populations. The lake's overall trophic index (TSI) score has dropped from 36 in 1976 to 22 in 1994 and 2000. These scores suggest the lake's trophic state has changed from being slightly eutrophic in the 1970s to mesotrophic in the 1990s. (Please see the following sections for a more detailed discussion of lake water quality parameters and trophic states.)

Table 14. Summary of historic data for Dewart Lake.

Date	Secchi (m)	Mean TP (mg/L)*	Percent Oxic (%)	Plankton Density (#/L)	TSI score (based on means)	Data Source
1972	1.8		30%			Fink, 2003
1976	1.7-1.8	<0.03	36%		36**	IDEM, 1986
1976	2.4		37%			Fink, 2003
1982	4.1		30%			Fink, 2003
1988	2.1	0.06				Hippensteel, 1989
1988	2.7	0.15	27%	843	25	IDEM 1988
1994	2.3	0.052	37%	7213	22	CLP, 1994
1995	2.5		100%			Fink, 2003
2000	2.2	0.036	26%	3148	22	CLP, 2000
2003	3.0		30%			Fink, 2003
2004	2.9	0.086	29%	729	24	Present Study

* ISPCB TP data is a water column average; Hippensteel TP data may be an epilimnetic sample (methods are not documented in the study); CLP and IDEM TP data are means of epilimnion and hypolimnion values.
** Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.

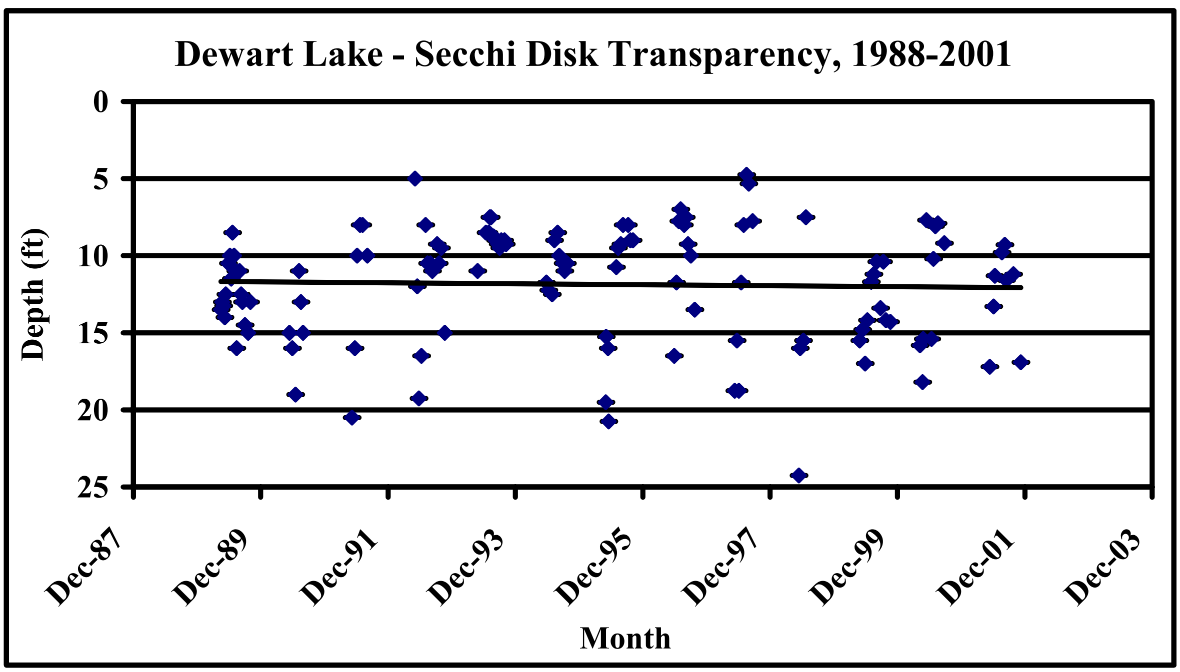

Figure 23. Historical volunteer-collected Secchi disk transparencies for Dewart Lake.

While much of the data presented above suggest Dewart Lake is only moderately productive, the historical percent oxic results are more typical of a eutrophic (productive) lake. This lack of oxygen in the lake's water column may be more of a reflection of Dewart 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. See Appendix E.) But the lake's morphology, specifically, its relatively steep drop offs at depths below 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 Dewart 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 Dewart 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 21), approximately 70% 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 Dewart Lake's hypolimnion can also affect the lake's chemistry. 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 algae growth. Historical records show higher levels of soluble reactive phosphorus in Dewart Lake's hypolimnetic water samples, suggesting internal phosphorus release is occurring in Dewart Lake (Appendix E).

4.4 Lake Water Quality Assessment

4.4.1 Lake Water Quality Assessment Methods

The water sampling and analytical methods used for Dewart 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 Dewart Lake on August 11, 2003 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: Prescott (1982), Ward and Whipple (1959), Wehr and Sheath (2003), and Whitford and Schumacher (1984).

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

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

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

Conductivity. Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 µmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 µmhos per mg/L 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 or stream. Algae and rooted plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy lake or stream. Complete elimination of algae and/or rooted plants is neither desirable nor even possible and should, therefore, never be the goal in managing a lake or stream. Algae and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a lake or stream. Limnologists commonly measure nutrient concentrations in aquatic ecosystem evaluations to determine the potential for such nuisance growth.

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

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

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

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

It is important to remember that none of the threshold or recommended concentrations listed above are state standards for water quality. They are presented here to provide a frame of reference for the concentrations found in Dewart 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 Dewart 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 <u>rate</u> 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 poorer water quality. The USEPA recommended a numeric criterion of 2.6 μg/L as a target concentration for lakes in Aggregate Nutrient Ecoregion VII (USEPA, 2000a).

4.4.2 Lake Water Quality Assessment Results

The results from the Dewart Lake water quality assessment are included in Tables 15 and 16 and Figure 24.

Table 15. Water quality characteristics of Dewart Lake, August 11, 2004.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
Conductivity	304 μmhos	299 μmhos	-
Secchi Depth Transparency	2.9 meters	-	0
Light Transmission @ 3 ft.	60 %	-	2
1% Light Level	23 feet	-	-
Total Phosphorous	0.030 mg/L	0.141 mg/L	3
Soluble Reactive Phosphorous	0.022 mg/L	0.156 mg/L	3
Nitrate-Nitrogen	0.013* mg/L	0.013* mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.678 mg/L	1
Organic Nitrogen	0.630 mg/L	1.376 mg/L	2
Oxygen Saturation @ 5ft.	95 %	-	0
% Water Column Oxic	29 %	-	3
Plankton Density	729 #/L	-	0
Blue-Green Dominance	68.3%	-	10
Chlorophyll *a*	3.33 μg/L	-	-

* Method Detection Limit **TSI score** **24**

Table 16. The plankton sample representing the species assemblage on August 11, 2004.

Species	Abundance (organisms/L)
Blue-Green Algae (Cyanophyta)	
Anabaena	37
Microcystis	46
Oscillatoria	129
Aphanocapsa	286
Green Algae (Chlorophyta)	
Pediastrum	55
Diatoms (Bacillariophyta)	
Fragilaria	65
Other Algae	
Ceratium	18
Mallomonas	9
Zooplankton	
Filinia	9
Keratella	55
Nauplii	10.6
Daphnia	1.9
Cyclopoid	5.3
Calanoid	1.3
Bosmina	0.2

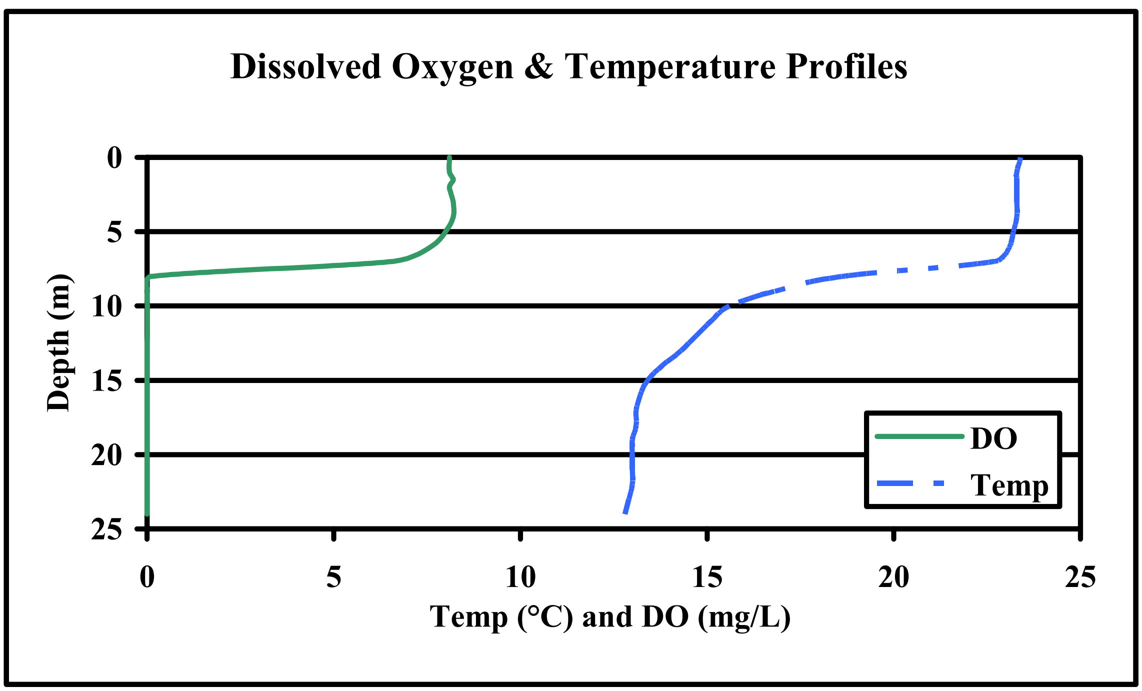

Figure 24. Temperature and dissolved oxygen profiles for Dewart Lake, August 11, 2004.

The temperature profile for Dewart Lake shows that the lake was stratified at the time of sampling (Figure 24). During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the well-mixed epilimnion by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth, is called the *metalimnion*. At the time of our sampling, the epilimnion was confined to the upper 23-26 feet (7-8 m) of water. The sharp decline in temperature between about 26 and 33 feet (8 and 10 m) defines the metalimnion or transition zone. The hypolimnion occupied water deeper than 33 feet (10 m).

The dissolved oxygen profile (Figure 24) for Dewart Lake is consistent with the findings of previous examinations of the lake. (Appendix E contains historic water quality data.). At the time of sampling, the upper 20-23 feet (6-7 m) of the water column was well oxygenated. Dissolved oxygen saturation in this portion of the water column was approximately 95%. The water's oxygen content began to diminish rapidly below 23 feet (7 m). Water below 29 feet (9 m) was considered anoxic (D.O. < 1.0 mg/L) and did not have sufficient oxygen content to support fish and other aquatic organisms.

Dewart 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 9.5 feet (2.9 m). This result is consistent with the measurement taken during the aquatic macrophyte survey on August 3, 2004. Light transmission at 3 feet (0.9 m) reflects the lake's good water clarity. Sixty percent of the incident light was measured at 3 feet (0.9 m) below the lake's surface.

Dewart Lake's rather large littoral and photic zones also highlight the lake's good water clarity. In previous sections of this report, Dewart 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 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, Dewart 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, Dewart 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 18, this would mean that Dewart Lake's littoral zone is approximately 374 acres (151 ha) in size and covers 68% of the lake's surface area. A previous section of this document suggests Dewart Lake's littoral zone is approximately 425 acres (172 ha) in size and covers 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 345 acres (140 ha) of the lake as observed during the rooted plant survey. Regardless of which estimate is used, Dewart 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 Dewart Lake's depth-volume curve (Figure 21), more than 6,400 acre-feet of Dewart Lake (71% of total lake volume) lies above the 23-foot 1% light level. This volume constitutes the lake's photic zone.

Nutrient concentrations in Dewart Lake remained low relative to other regional lakes, although some nutrient concentrations were higher than concentrations observed during the 1994 and 2000 CLP assessments of the lake. At the time of sampling, nitrate-nitrogen concentrations in Dewart Lake were below the laboratory detection limit in both the epilimnion and hypolimnion. The ammonia-nitrogen concentration in the lake's epilimnion 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 in 1994 and 2000 indicating that the rate or amount of decomposition has not changed significantly over the years.

Despite being relatively low, Dewart Lake's total phosphorus and soluble reactive phosphorus concentrations were slightly higher in both the epilimnion and hypolimnion compared to concentrations observed in 1994 and 2000. Higher levels of phosphorus *could* translate into greater rooted plant and algae growth. The lake's eplimnetic total phosphorus concentration of 0.03 mg/L is at the threshold at which algae blooms can occur. Interestingly, Dewart Lake's epilimnetic soluble reactive phosphorus concentration was above the laboratory detection limit. 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 high epilimnetic soluble reactive phosphorus concentration coupled with its relatively low plankton density suggest something other than nutrients may be limiting algae growth in the lake. Dewart Lake's hypolimnetic soluble reactive phosphorus concentration was relatively high, suggesting that the lake is releasing phosphorus from its bottom sediments.

Dewart Lake's relatively low plankton density reflects the relatively low nutrient concentrations in the lake. Dewart Lake exhibited a chlorophyll *a* concentration of 3.33 μg/L. While this concentration is slightly higher than the chlorophyll *a* concentrations observed in 1994 and 2000, it is still low relative to other lakes in the region and only slightly higher than the USEPA's recommended target concentration of 2.6 μg/L.

Dewart Lake's plankton density was similar to the density observed in 1988 and lower than the plankton densities observed in 1994 and 2000 (Table 16). At the time of the current sampling effort, *Aphanocapsa*, a blue-green algae, dominated the sample, accounting for 40% of the plankton density. Oscillatoria, another blue-green algae, was also common in Dewart Lake. In total, 68.3% of the Dewart Lake plankton community consisted of blue-green algae. This is consistent with the findings of previous assessments on Dewart Lake. In three comprehensive examinations of the lake (CLP, 1988, 1994 and 2004), blue-green algae accounted for 63% to 70% of the lake's plankton density.

The presence of blue-green algae is typical in many lakes in late summer. However, a dominance of blue-green algae is usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they: 1) may form extremely dense nuisance blooms; 2) may cause taste and odor problems; and 3) are unpalatable as food for many zooplankton grazers.

One should use caution, however, when interpreting the results of the plankton sampling. While blue-green algae dominate the Dewart Lake plankton community, this dominance is slight compared to other regional lakes. In several other regional lakes, blue-green algae accounted for 80-90% of the plankton density or more. In addition, Dewart Lake's overall plankton density (729 organisms/L) is low. Considering these factors, dominance of blue-green algae in Dewart Lake's plankton community does not necessarily mean the lake's water quality is degraded.

Dewart Lake's overall trophic state index score of 24 is similar to TSI scores observed in 1988, 1994, and 2000. This year's score as well as scores from previous years place the lake in the mesotrophic (moderately productive) category. This is consistent with the lake's productivity levels as expressed through plankton density and chlorophyll *a* concentrations. The dominance of blue-green algae in the lake's plankton community keeps the lake squarely within the mesotrophic category. This year, as in 1988, 1994, and 2000, 10 eutrophy points were added to the lake's score due to the dominance of blue-green algae.

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 Dewart 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 the Table 17. 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.

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

Table 17. 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	-

Dewart Lake's total phosphorus concentration (mean of 0.085 mg/L) was similar to lakes in Vollenweider's eutrophic category, while the lake's total nitrogen and chlorophyll *a* concentrations (1.0 mg/L (mean) and 3.3 µg/L, respectively) suggest that Dewart Lake is more mesotrophic in nature, using Vollenweider's criteria.

Comparison with Other Indiana Lakes

The Dewart Lake results can also be compared with other Indiana lakes. Table 18 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 18. 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
Dewart	**9.5**	**0.013**	**0.348**	**1.35**	**0.09**	**0.085**	**3.33**	**729**	**68.3**

All of the nutrient concentrations and the chlorophyll a concentration in Dewart Lake were below the median values measured for the set of Indiana lakes. Additionally, Dewart Lake's Secchi disk transparency depth was deeper than the median observed in the set of Indiana lakes. This suggests Dewart Lake possessed better water quality than most Indiana lakes at the time of the August 11, 2004 sampling. Stated another way, Dewart Lake exhibited better water clarity (Secchi disk) and lower nutrient levels than most Indiana lakes. The lake also was less productive (chlorophyll *a*) than most Indiana lakes.

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 19 shows the point values assigned to each parameter.

Table 19. The Indiana Trophic State Index.

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

V. Ammonia (ppm)

A.	At least 0.3	1
B.	0.4 to 0.5	2
C.	0.6 to 0.9	3
D.	1.0 or more	4

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

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

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

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

VIII. Light Penetration (Secchi Disk)

A.	Five feet or under	6

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

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

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

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

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

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

Four of these categories correspond to the qualitative lake productivity categories described earlier. The fifth category, dystrophic, is for lakes that possess high nutrient concentrations, but have limited rooted plant and algal productivity (IDEM, 2000). A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening, while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI 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 August 11, 2004 sampling, Dewart Lake possessed an Indiana Trophic State Index value of 24. This value places Dewart Lake in the mesotrophic range. This conclusion is generally consistent with results obtained from the comparison of the lake data to Vollenweider's data (Table 17), which suggested the lake was mesotrophic to eutrophic in nature. As will be described later in this section, the Indiana TSI score for Dewart 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 25 illustrates the change in Dewart Lake's ITSI score over time. Figure 25 shows a decline in Dewart Lake's ITSI score from 1976 to 1988. (A decline in ITSI score indicates a decrease in productivity of a lake and generally an improvement in water quality.) ITSI scores have remained fairly stable since 1988, with variations of 3 or fewer eutrophy points among the years. This suggests water quality in Dewart Lake has remained fairly stable over the past 15 years.

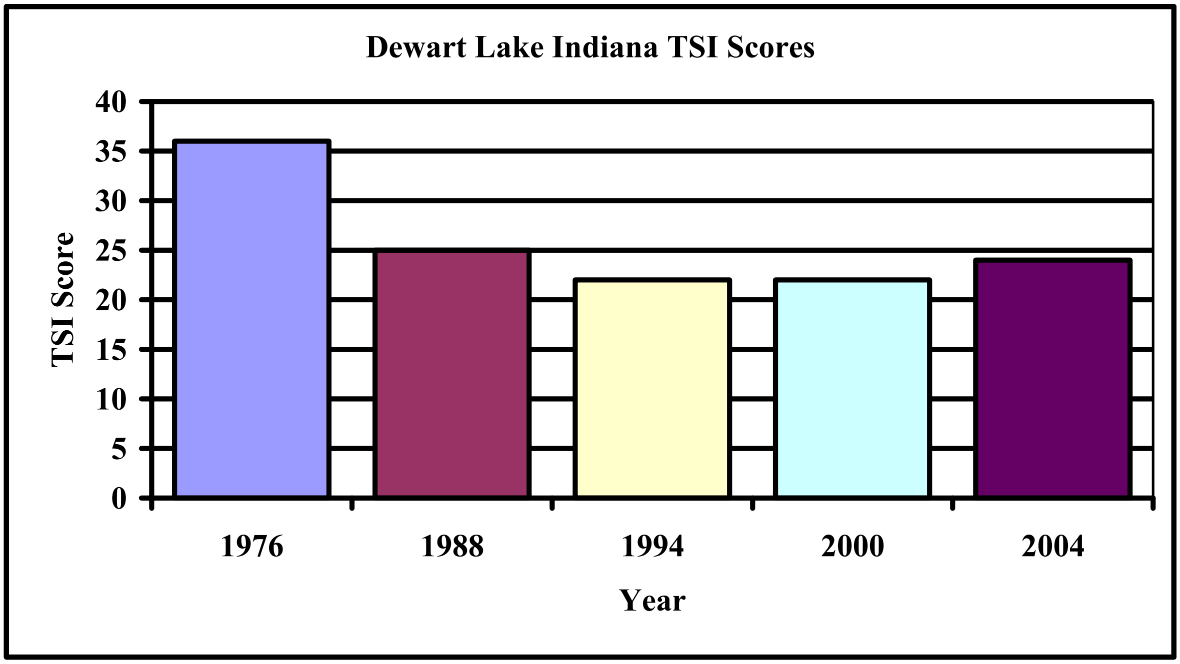

Figure 25. Indiana Trophic Index State scores for Dewart Lake from 1976 to 2004.

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 26).

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.

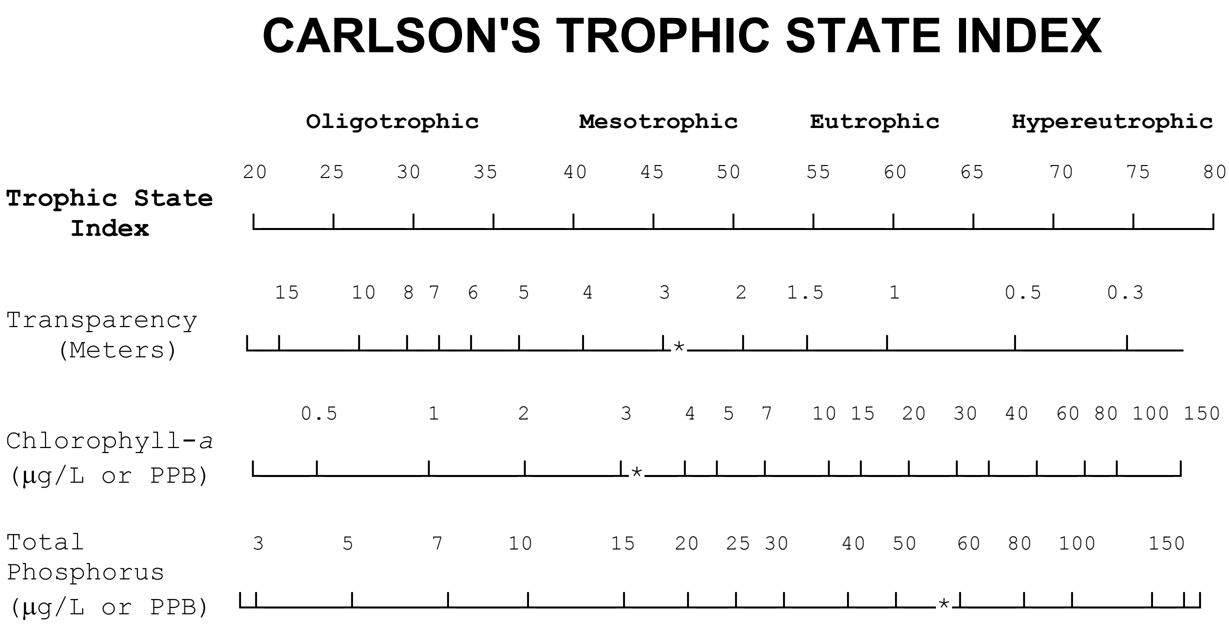

Figure 26. Carlson's Trophic State Index with Dewart Lake results indicated by asterisks.

Analysis of Dewart Lake's total phosphorus, transparency, and chlorophyll *a* data using to Carlson's TSI suggests that the lake is mesotrophic to eutrophic/hypereutrophic (Figure 26). Dewart Lake's transparency and chlorophyll *a* concentration place the lake in the mesotrophic category, while its total phosphorus concentration places it on the border between the eutrophic and hypereutrophic categories. This analysis is consistent with the results obtained when comparing the Dewart Lake data to Vollenweider's data. Both analyses suggest that Dewart Lake possesses sufficient phosphorus to support a greater level of productivity than the level suggested by the lake's relatively low 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 Dewart Lake, Carlson's TSI scores using transparency and chlorophyll *a* concentration are roughly equal (TSI (SD) = 44.7 and TSI (chl *a*) = 42.4). However, Carlson's TSI score for total phosphorus concentration is slightly higher (TSI (TP) = 58). When TSI (SD) = TSI (chl *a*) < TSI (TP), something other than phosphorus is limiting algae growth. Potential limiting factors zooplankton grazing and/or nitrogen. In the case of Dewart 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. Finally, all of Dewart Lake's total phosphorus may not be available to the algae within the photic zone. Dewart Lake's complex morphology may prevent the lake from achieving a complete turnover. Thus, the lake's bottom waters, which contain the most phosphorus, may not completely mix with the lake's upper waters, where most of the algae live. 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.

4.5 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 water milfoil, white stem pondweed, and large leaf pondweed, all of which prefer clear water, dominate the plant community, one is more likely to conclude that the lake is typically clear and its current state of turbidity is due to the storm rather than being its inherent nature.

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

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

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

Conditions for Growth

Like terrestrial vegetation, aquatic vegetation has several habitat requirements that need to be satisfied in order for the plants to grow or thrive. Aquatic plants depend on sunlight as an energy source. The amount of sunlight available to plants decreases with depth of water as algae, sediment, and other suspended particles block light penetration. Consequently, most aquatic plants are limited to maximum water depths of approximately 10-15 feet (3-4.5 m), but some species, such as Eurasian water milfoil, have a greater tolerance for lower light levels and can grow in water deeper than 32 feet (10 m) (Aiken et al., 1979). Hydrostatic pressure rather than light often limits plant growth at 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. Dewart Lake possesses better water clarity than the average Indiana lake. The Secchi disk depth measured during the plant survey was 9.3 feet (2.8 m). (This measurement was consistent with the Secchi disk depth measured for the lake during the in-lake sampling portion of the study.) As a general rule of thumb, rooted plant growth is restricted to the portion of the lake where water depth is less than or equal to 2-3 times the lake's Secchi disk depth. This is true in Dewart Lake, where rooted plants were observed in water deeper than 25 feet, which is nearly 3 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 water milfoil, may increase macrophyte density rather than decrease it. Boating activity may be increasing the size and density of the Eurasian water milfoil stands in Dewart Lake.

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

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

Aquatic vegetation also serves as substrate for aquatic insects, the primary diet of insectivorous fish. Waterfowl and shorebirds depend on aquatic vegetation for nesting and brooding areas. Numerous waterfowl were observed utilizing Dewart Lake as habitat during the macrophyte survey. Aquatic plants such as pondweed, coontail, duckweed, water milfoil, 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 Dewart Lake on August 3, 2004 according to the Indiana State Tier One sampling protocol (Shuler and Hoffmann, 2002). 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 during the in-lake sampling effort.) At the time of sampling, Dewart Lake's Secchi disk depth was 9.3 feet (2.8 m); thus, its 1% light level was estimated to be approximately 28 feet (8.5 m). Consequently, JFNew sampled that area of Dewart Lake that is less than 28 feet deep (8.5 m).

A survey crew, consisting of one aquatic ecologist, one botanist, and a citizen volunteer boat driver, surveyed Dewart Lake in a clockwise manner, starting at the public boat launch. The survey crew drove their boat in a zig-zag pattern across the littoral zone of the lake while visually identifying plant species. The crew maintained a tight pattern to ensure the entire zone was observed. Most of the estimated littoral zone of the lake was shallow. This shallowness coupled with the lake's good water clarity allowed for visual identification of plant species. In areas of dense plant coverage, rake grabs were performed to ensure all species were identified.

Rake grabs were also conducted along bed edges to determine the depth limit of rooted plant growth.

Rooted plants ring Dewart 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

Dewart Lake supports an extensive rooted plant community. The community extends from the lake's shoreline to water that is over 25 feet (7.6 m) deep. This is consistent with the estimated extent of the littoral zone based on the lake's Secchi disk depth of 9.3 feet (2.8 m), measured at the time of the aquatic plant survey. (Three times the Secchi disk depth is 28 feet (8.5 m).) Dewart Lake's aquatic plant community can be roughly divided into nine beds that differ in community composition and structure. Figure 27 shows the approximate location and extent of each bed.

In total, approximately 44 aquatic plant species inhabit the water and shoreline of Dewart Lake. 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.

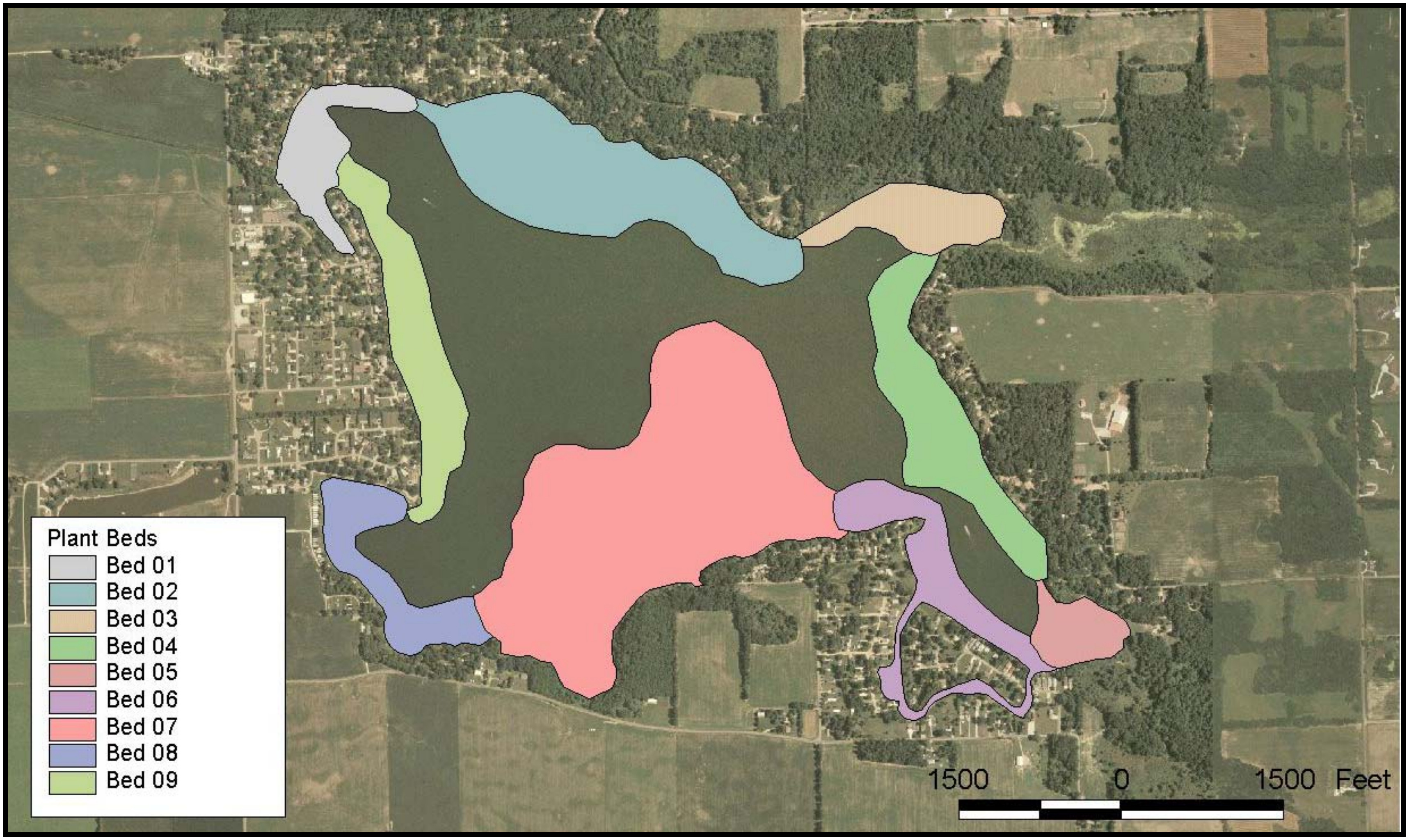

Figure 27. Dewart Lake plant beds as surveyed August 3, 2004.
Source: See Appendix A. Scale: 1”=1,500’.

Of the 44 species observed in Dewart Lake, more than half (23) were submerged plant species. Additionally, of the 23 submerged species, more than half of those (12) 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 nine plant beds in Dewart Lake. In all but one bed, chara covered at least 20% of the plant bed's canopy. In three of the nine beds, chara covered more than 60% of the plant bed's canopy. Large leaved pondweed and northern water milfoil are also common in Dewart Lake. Large leaved pondweed was observed in each plant bed and generally represented 2-20% of the bed's canopy. Northern water milfoil inhabited seven of the nine plant beds and it usually covered 20-60% of the bed' canopy. Coontail, flatstem pondweed, water star grass, and Illinois pondweed are also important components of the Dewart Lake submerged community.

Four of the 23 submerged species in Dewart Lake are state listed species. Fries pondweed, a state rare species, was found throughout the lake. Beck's water marigold, a state threatened species, was observed in three fairly protected areas of the lake, the cove adjacent to the Limberlost Girl Scout Camp and the coves in the southeast and southwest corners of the lake. Richardson's pondweed, a state rare species, also grows in the cove adjacent to the Limberlost Girl Scout Camp. Robbins' pondweed, a state threatened species, was found in the northwest corner of the lake. (See the **Endangered, Threatened, and Rare Species** section for definitions of state listing categories.)

The species richness of the emergent and floating strata was less than the submerged strata. Fifteen emergent species were noted bordering Dewart Lake's edges, and only six 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 water willow, arrow arum, and cattails. Water willow was observed in each plant bed, although it tended to be very sparse in the bed. Arrow arum and cattails were each observed in two thirds of the plant beds. The most common floating species are white water lilies, which was found in eight of the nine beds, and spatterdock, which was found in five of the nine beds.

Dewart Lake's plant community covers over 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 ranges from a low of about 20% in Bed 05 to complete (100%) canopy cover in several beds. 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 (six) beds, the floating species cover less than 20% of the bed. In Bed 01, however, canopy coverage of the floating species was greater than 60%.

The following paragraphs detail each of the nine plant beds in Dewart 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 the most diverse plant bed on the lake. Located in the northwest corner of Dewart Lake, an area that included the public boat launch, Bed 01 supports over 30 species, including 17 submerged species. Submerged and floating species dominate the plant bed each covering over 60% of the bed's surface area. Chara is the most common submerged species, while spatterdock and white water lilies are the most common floating species. Large leaved pondweed, common waterweed, coontail, flat stem pondweed, southern naiad, and northern water milfoil are also common in Bed 01. Both curly leaf pondweed and Eurasian water milfoil, two exotic invasive submerged species, grow in Bed 01. While Bed 01 supports the greatest number of emergents (10) compared to the other plant beds, collectively emergent plant species are only a small component of Bed 01. Most of the shoreline surrounding Bed 01 consists of concrete seawalls, limiting the growth of emergent vegetation. The exotic invasive species, purple loosestrife, is one species in the emergent component of Bed 01.

Bed 02

Bed 02 occupies the shallow water in front of Dewart Lake's the northern shoreline. Bed 02's lack of floating and emergent strata separates Bed 02 from Bed 01. Bed 02 also lacks the species richness observed in Bed 01. Bed 02 supports only 18 species. Bed 02's most distinguishing feature is the dense mat of Eurasian water milfoil located approximately 700 feet (213 m) off shore. Northern milfoil is mixed in with the Eurasian water milfoil in this mat. It is likely that hybrid plants also exist in this mat. The dense mat was marked by buoys at the time of the survey. Outside the buoys, chara covers much of the lake bottom in Bed 02. Northern water milfoil and Illinois pondweed were also common in Bed 01 outside of the buoyed area. Despite the relatively disturbed nature of Bed 02, it supports two state listed species: Robbins' pondweed (state rare) and Fries' pondweed (state threatened). Additionally, purple loosestrife was not observed along the shoreline adjacent to Bed 02.

Bed 02's current condition may be the result of human impact over the years. Early photography of the lake suggests the northern shoreline was wetland and forested habitat. Large stands of emergent vegetation are evident in a 1938 aerial photograph of this section of the lake. By 1965, the northern shoreline had been developed for residential use. Today a sparse stand of hardstem bulrush grows in Bed 02, but much of the emergent vegetation that likely once filtered runoff water is gone. As northern shoreline residents navigate their boats through Bed 02 to take advantage of the lake's deeper waters, the shallowness of this area increases the likelihood of propeller damage the submerged plants. A combination of intentional plant removal during development, inadvertent propeller damage to the plants, and a decrease in water quality due to the change in the adjacent land use, decreased Bed 02's richness and diversity (only a few species are abundant) and facilitated the establishment of Eurasian water milfoil.

Bed 03

Bed 03 covers the cove near the Limberlost Girl Scout Camp. An increase in species richness and diversity as well as an increase in emergent plant cover marks the transition between Beds 02 and 03. Although a portion of the natural shoreline has been altered, the majority of the shoreline bordering Bed 03 remains in its native condition. Combined, emergent and floating vegetation cover over 20-30% of the plant bed's surface area. Dominant emergent and floating species include water willow, spatterdock, and white water lily. Submerged species cover over 60% of Bed 03's surface area. Northern milfoil, flat stem pondweed, long leaved pondweed, large leaved pondweed, and chara are the most common submerged species in Bed 03. Bed 03 supports two state listed species: Beck's water marigold (state threatened) and Richardson's pondweed (state rare). Richardson's pondweed was not found anywhere else in the lake.

Bed 04

Bed 04 occupies the water in front of the eastern shoreline of Dewart Lake. Single family homes and the Quaker Haven camp lie adjacent to the lake along the eastern shoreline. The reduction in emergent plant coverage compared to Bed 03 reflects the change in shoreline land use. Emergent species cover less than 2% of the total plant bed. Floating species are nearly absent from Bed 04. Only a few white water lilies were observed scattered throughout the bed. Submerged species dominate Bed 04. The bed supports large stands of Eurasian water milfoil, chara, and water star grass. Large leaved pondweed and Illinois pondweed are also important components of Bed 04. Purple loosestrife was observed in scattered locations along Bed 04.

Bed 05

Bed 05 includes the emergent wetland in the southeastern corner of Dewart Lake. Unlike other plant beds on the lake, Bed 05 has a relatively even coverage distribution among the three strata (emergent, floating, and submerged). Cattails dominate the wetland portion of Bed 05, although purple loosestrife, water willow, swamp loosestrife, and willows were also observed in the wetland. Floating species, including spatterdock, white water lilies, small duckweed, water meal and giant duckweed, are an important component of Bed 05, covering over 20% of the bed's surface area. Submerged species also cover over 20% of Bed 05's surface area. The most common submerged species in Bed 05 are northern water milfoil, chara, flat stem pondweed, and coontail. The state threatened Beck water marigold was also observed in Bed 05.

Bed 06

The lack of emergent and floating vegetation set Bed 06 apart from Beds 05 and 07. Bed 06 lies in the southeast corner of the lake, west of the emergent wetland. Bed 06 includes the channel around Blueberry Island. Concrete seawalls line most of the shoreline around Bed 06 and only a few scattered emergent or floating plants grow in front of these seawalls. Submerged species, primarily chara, dominate the plant bed. Other common submerged species in Bed 06 include large leaved pondweed, water star grass, and northern water milfoil.

Bed 07

Bed 07 is the largest plant bed on Dewart Lake. Bed 07 extends out from the south central shoreline to encompass the island in the middle of the lake. Scattered stands of cattails and hardstem bulrush grow in the shallow water between the central island and the shoreline. Anecdotal evidence (lake residents, personal communication), aerial photography, and historical accounts (Blatchley, 1900) suggest that these scattered stands once formed a contiguous, thicker stand of vegetation between the southern shoreline and the central island. At certain times in the past 150 years, Dewart Lake's water level was significantly lower and this shallow area was actually wetland habitat rather than open water. Periods of low water likely facilitated the growth of bulrush and cattails lakeward. Higher water levels may have restricted the further expansion of these plants. Dominant submerged vegetation, primarily chara and northern water milfoil, covers the lake bottom around the hardstem bulrush. Several large patches of floating vegetation, mostly spatterdock and white water lilies, exist throughout Bed 07.

Bed 08

Bed 08 occupies the water in front of the residentially developed southwestern corner of Dewart Lake. A decrease in species richness and diversity and lack of emergent vegetation separates Bed 08 from Bed 07. Thick mixed pockets of northern milfoil, Eurasian water milfoil, and likely hybrids of the two characterize Bed 08. Outside of these pockets, chara covers a large portion of the bed. White water lilies and large leaved pondweed are also common species in Bed 08.

Bed 09

Bed 09 parallels Dewart Lake's western shoreline. This bed supports the fewest number of species. Emergent vegetation is nearly absent, with most of the shoreline consisting of concrete seawalls. Floating vegetation is nearly absent as well. The absence of these two stratum reflect the alteration of the shoreline for residential use. Like other parts of Dewart Lake, chara dominates the submerged component of the bed. Southern naiad, variable leaved pondweed, and large leaved pondweed are also common in Bed 09.

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. Dewart Lake's rooted plant data is no exception. The survey and analysis of Dewart 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 Dewart Lake possessed relatively good water clarity. The Secchi disk transparency depth recorded during the rooted plant survey extended beyond 9 feet (2.8 m) which is deeper than the statewide median Secchi disk transparency depth. Historical Secchi disk data suggest that Dewart Lake has maintained this good water clarity over the last 15 years. Earlier data indicate the water quality may have been even better.

Dewart Lake's rooted plant community reflects this good water clarity. Several of Dewart Lake's dominant submerged plant species, including large leaved pondweed, northern water milfoil, and flatstem 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 Robbins pondweed and variable leaved pondweed, are also characteristic of clear northeastern lakes (Davis and Brinson, 1980). While Dewart 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.

Dewart Lake also exhibits moderate nutrient concentrations rather than high nutrient concentrations observed in many other lakes in the region. Dewart Lake's diverse rooted plant community is a reflection of this 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 Dewart Lake (JFNew 2000a, 2000b, 2001, 2004a, and 2004b). Additionally, in lakes with high total phosphorus concentrations, species tolerant of eutrophic water such as Eurasian water milfoil, 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, Dewart Lake supports a rooted plant community more similar to Big Chapman Lake, which also possesses relatively moderate nutrient levels. Both Dewart Lake and Big Chapman Lake exhibit good species richness and dominant species include species such as large leaved pondweed which is less tolerant of eutrophic conditions (JFNew, 2001 and Chapman Lake Conservation Association et al., unpublished data).

Dewart 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 by lake residents 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 Dewart Lake's plant community by 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 balance community to one dominated by species tolerant of eutrophic water conditions. It is not surprising that the lake's densest populations of Eurasian water milfoil, a species more likely to be found in more eutrophic water, occur in front of developed shorelines (Beds 02 and 04).

Despite some areas of nuisance exotic species growth, Dewart Lake generally supports a healthy, relatively high quality rooted aquatic plant community. Dewart Lake supports a rich submerged community that includes 11 species of pondweed. More than fifty percent of the lake's littoral zone is vegetated and rooted plants are observed in water deeper than 20 feet (6 m). Additionally, several high quality, sensitive species live in Dewart 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, no data detailing Dewart Lake's historical rooted plant community exists for comparison to the current data. Current data, however, suggest Dewart Lake's rooted plant community may be in the middle of a shift from a relatively healthy plant community to a less healthy plant community. The paucity of Beck's water marigold in the lake may be evidence of a shift. Beck's water marigold is considered an indicator species. Borman et al. (1997) report that Beck's water marigold "may be one of the first (submerged) plants to disappear from a lake when water quality declines". Such declines are reported in the literature (Crum and Bachman, 1973; Stuckey, 1971) as lakes are subjected to various environmental pressures over time.

The presence of Beck's water marigold in the Dewart Lake is a good sign. However, very few individual plants were observed during the macrophyte survey, suggesting the plant may be declining and nearing extinction from Dewart Lake. If this plant species is indeed declining or in the process of being eliminated from the lake, it may be a warning of changes in the lake's water chemistry.

Other species that should be monitored in Dewart Lake to determine if the plant community is signaling a larger change in water quality include large leaved pondweed, long leaved pondweed, variable leaved 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 Dewart Lake might indicate an increase in eutrophication of Dewart Lake.

In the past, IDNR fisheries biologists conducted cursory vegetation surveys as a part of their general fisheries surveys. 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 to document any of the changes described above.

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 Dewart Lake. The plant survey revealed the presence of two submerged, aggressive exotics: Eurasian water milfoil (Figure 28) and curly leaf pondweed (Figure 29). It also supports two emergent exotic plant species: purple loosestrife (Figure 30) and reed canary grass. As nuisance species, these species have the potential to proliferate if left unmanaged.


Figures 28. Eurasian water milfoil (*Myriophyllum spicatum*) and 29 Curly leaf pondweed (*Potamogeton crispus*).

Figure 30. Purple loosestrife (Lythrum salicaria).

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

Depending upon water chemistry curly leaf pondweed can be less aggressive than Eurasian water milfoil. Despite this, its presence in the lake is still of concern. Like many exotics, curly leaf pondweed gains a competitive advantage over native submerged species by sprouting early in the year. The species can do this because it is very tolerant of cooler water temperature compared to many of the native submerged species. Curly leaf pondweed experiences a die back during early to mid summer. This die back can degrade water quality by releasing nutrients into the water column and increasing the biological oxygen demand.

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

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

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

4.6 Fisheries

The Indiana Department of Natural Resources' (IDNR) first survey of Dewart Lake occurred in 1972 to assess the lake's potential of supporting a coldwater fishery. Warm water temperatures and low dissolved oxygen levels precluded Dewart Lake from being considered for any further trout stocking (Taylor, 1972). The IDNR conducted its first comprehensive fishery survey of Dewart Lake in 1976. Additional IDNR surveys occurred in 1982, 1983, 1995, and 2003. Appendix G contains an annotated bibliography of the fishery surveys from 1972 to 1995.

Dewart Lake supports a diverse fish community with a total of 31 species being observed at some point in the past 30 years. On average, 22 species have been observed each survey year (Appendix H). The Centrachid, or sunfish, family has been the dominant family inhabiting Dewart Lake with nine species being represented. Bluegill, a member of the sunfish family, have accounted for the greatest number of fish collected in each of the IDNR surveys. Figure 31shows that bluegill percent community composition has ranged from a low of 33.9% in 1983 to a high of 79.1% in 2003. Largemouth bass populations have been relatively stable as shown in Figure 31. Pearson (1995), however, indicates that Dewart Lake's fish community had changed substantially over the past 19 years. He noted an increase in northern pike numbers and a decline in common carp and other nongame fish species (Figure 31). Nongame fish made up approximately 72% of the weight in the 1976 survey and only 16% in 1995. This trend continued in 2003, with sportfish accounting for 93% of the catch by weight (Fink, 2003). Prior to the 1980's, northern pike were not found in Dewart Lake (Appendix H). Pearson (1995) hypothesized that northern pike entered Dewart Lake from nearby Waubee Lake where northern pike stockings were extensive. Despite the increase in northern pike numbers, bluegill, largemouth bass, and to a lesser extent yellow perch numbers have been fairly consistent. However, it should be noted that yellow perch often display cyclical trends in population numbers.

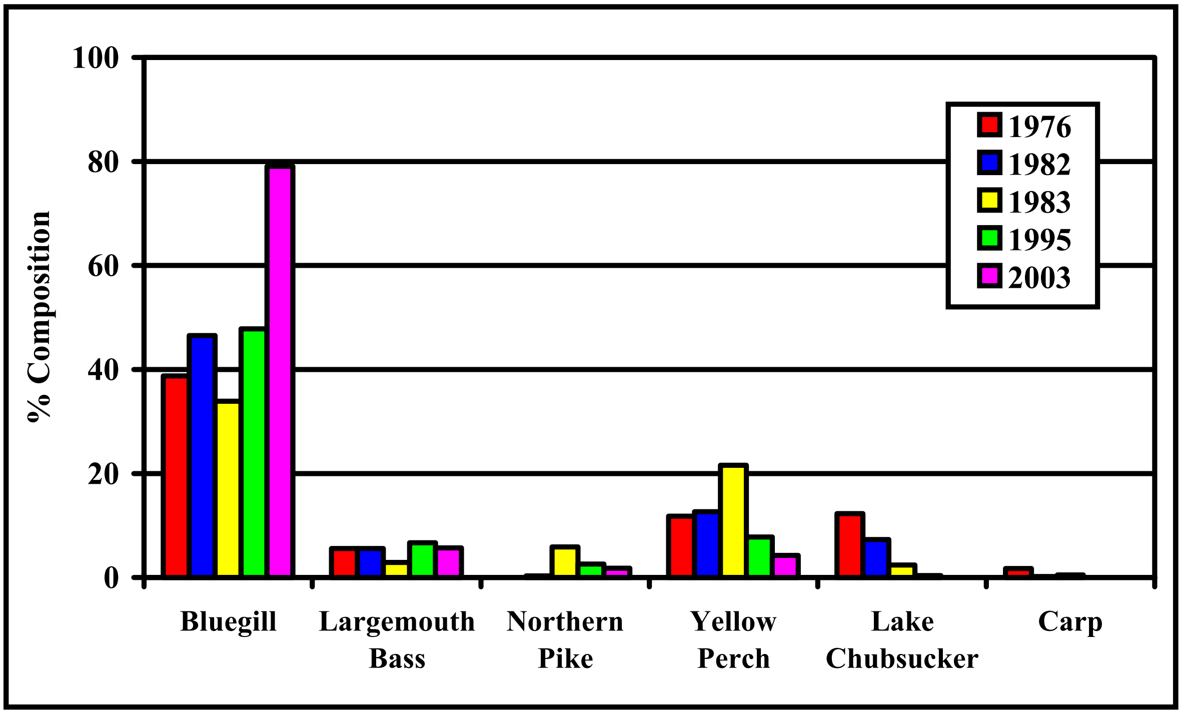

Figure 31. Percent community composition by number of fish collected for Dewart Lake.

A number of attempts have been made by the IDNR to create a walleye fishery in Dewart Lake. Although not native to the northeast natural lakes area, walleye are one of the most requested fish for stocking efforts (Pearson, 1982). Dewart Lake was first stocked with fingerling walleye in the summer of 1982 by the IDNR. Additional stockings occurred in 1983 and 1986-1990 by the IDNR and the Dewart Lake Association. A number of size classes and seasonal stocking strategies were implemented to create the walleye fishery. Annual surveys, however, revealed that most of the stockings were unsuccessful (Pearson, 1982, 1984, 1985, 1987, 1995). Some success was found in 1987 by stocking advanced fingerlings in October at a rate of 16 advanced fingerlings per hour. However, the IDNR has determined that the cost and difficulty of raising advanced fingerlings to maintain a Walleye fishery in Dewart Lake was prohibitive. Walterhouse (1990) indicated that some of the possible reasons for stocking failure may include: the fish were too small to utilize the available forage base, poor fish health, and vulnerability to predation during the time of stocking. The Dewart Lake Association and others renewed stocking efforts in 2000. In 2000, 2002, and 2003, they released a combined total of nearly 5,000 walleye fingerlings (6-8-inch and 8-10-inch classes). Unfortunately, Fink (2003) reports poor survival of the stocked fingerlings from 2002. Pearson points to the abundance of walleye predators as one plausible reason for the poor success of the walleye stocking program.

4.7 Zebra Mussels

Zebra mussels are an exotic species of concern for many lakes and rivers throughout the state and for the Dewart Lake as well. 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 Dewart Lake in the early to mid-1990s. Pearson (1995) reports the presence of zebra mussels in Dewart Lake during his 1995 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 atttaching 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 even 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 32).
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 32. Adult zebra mussel.

5.0 MODELING

5.1 Water Budget

Inputs of water to Dewart Lake are limited to:

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

Water leaves Dewart Lake from:

1. discharge from the outlet channel
2. evaporation
3. groundwater

There are no discharge gages in the watershed to measure water inputs and the limited scope of this study did not allow the determination of annual water inputs or outputs. Therefore, the water budget for Dewart 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 Tippecanoe River near North Webster, Indiana (Stewart et al., 2002). The 16-year (1986–2002) mean annual runoff for this watershed is 13.32 inches. With mean annual precipitation of 35.52 inches (Staley, 1989), this means that on average, 37.5 % of the rainfall falling on this watershed runs off of the land surface.
- No groundwater records exist for the lake so it was assumed that groundwater inputs equal outputs or groundwater effects are insignificant compared to surface water impacts. It is unlikely that the latter is true for Dewart Lake.
- Evaporation losses were estimated by applying evaporation rate data to the lake. Evaporation rates are determined at six sites around Indiana by the National Oceanic and Atmospheric Administration (NOAA). The nearest site to the Dewart Lake

watershed is located in Valparaiso, Indiana. Annual evaporation from a 'standard pan' at the Valparaiso site averages 28.05 inches per year. Because evaporation from the standard pan overestimates evaporation from a lake by about 30%, the evaporation rate was corrected by this percentage, yielding an estimated evaporation rate from the lake surface of 19.95 inches per year. Multiplying this rate times the surface area of each lake yields estimated volume of evaporative water loss from Dewart Lake.

The water budget for Dewart Lake, based on the assumptions discussed above, is shown in Table 20. Dividing the volume of water flowing out of Dewart Lake by the lake's volume yields a *hydraulic residence time* of 1.41 years. This means that on average, water entering the lake stays in the lake for nearly one and half years before it leaves. This hydraulic flushing rate is typical for glacial lakes in this part of the country. In a study of 95 north temperate lakes in the U.S., the mean hydraulic residence time for the lakes was 2.12 years (Reckhow et al., 1980). A lake's hydraulic residence time is strongly correlated with its watershed size to lake surface area ratio. Dewart Lake possesses a watershed size to lake surface area ratio of approximately 8 to 1. This too is consistent with studies that show most glacial lakes have a watershed area to lake surface area ratio of around 10:1 (Vant, 1987). Thus, the water budget estimate is likely reasonable.

Table 20. Water budget calculations for Dewart Lake.

Parameter	**Data**
Watershed size (ac)	5059
Mean Watershed Runoff (ac-ft/yr)	5609
Lake Volume (ac-ft)	8974
Runoff Estimates	
Closest gauged stream	Tippecanoe River at North Webster
Stream watershed (mi^2)	49.3
Stream watershed (acres)	31,552
Mean annual Q (cfs)	48.32
Mean annual Q (ac-ft/yr)	34,982
Mean precipitation (in/yr)	35.52
Mean watershed precipitation (ac-ft/yr)	93,394
Watershed C	0.37456
Evaporation Estimates	
Pan evaporation (in/yr)	28.05
Pan evaporation coefficient	0.70
Lake Surface Area (acres)	554
Estimated lake evaporation (ac-ft)	907
Direct precipitation to lake (ac-ft)	1604
Runoff from watershed (ac-ft)	5609
Evaporation (ac-ft)	907
TOTAL LAKE OUTPUT (ac-ft)	6343
Hydraulic Residence Time (yr)	1.41
Watershed Area:Lake Area	8.2:1

5.2 Phosphorus Budget

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

The limited scope of this study did not allow for the outright determination of phosphorus inputs and outputs. Therefore, a standard phosphorus model was utilized to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies. They used these phosphorus loss rates to calculate phosphorus export coefficients for various land uses. Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. Table 21 shows the phosphorus export coefficients developed by Reckhow and Simpson (1980).

Table 21. Phosphorus export coefficients (units are kg/hectare except the septic category, which are kg/capita-yr).

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

Source: Reckhow and Simpson, 1980.

To obtain an annual estimate of the phosphorus exported to Dewart Lake from the lake's watershed, the export coefficient for a particular land use was multiplied by the area of land in that land use category. Mid-range estimates of phosphorus export coefficient values for all watershed land uses (Table 5) were used in this calculation.

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

Adding the phosphorus export loads from the watershed, septic systems, and precipitation, yielded an estimated 1,586 kg of phosphorus loading to Dewart Lake annually (Table 22).

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):

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

Table 22. Phosphorus model results for Dewart Lake.

INPUT DATA		**Unit**	**DATE:**	10/24/2004
Area, Lake	554	acres		
Volume, Lake	8,974	ac-ft		
Mean Depth	16.2	ft		
Hydraulic Residence Time	1.41			
Flushing Rate	0.71	1/yr		
Mean Annual Precipitation	0.90	m		
[P] in precipitation	0.03	mg/L		
[P] in epilimnion	0.03	mg/L		
[P] in hypolimnion	0.141	mg/L		
Volume of epilimnion	6,800	ac-ft		
Volume of hypolimnion	2,174	ac-ft		
Land Use (in watershed)	**Area**		**P-export Coefficient**	
Deciduous Forest	211.7	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	13.7	hectare	0.1	kg/ha-yr
Evergreen Forest	1.7	hectare	0.15	kg/ha-yr
High Intensity Residential	1.0	hectare	2.5	kg/ha-yr
High Intensity Commercial	0.9	hectare	2.5	kg/ha-yr
Low Intensity Residential	25.0	hectare	0.6	kg/ha-yr
Mixed Forest	0.2	hectare	0.175	kg/ha-yr
Urban Park Land	0.4	hectare	0.5	kg/ha-yr
Pasture/Hay	175.5	hectare	0.4	kg/ha-yr
Row Crops	1,303.6	hectare	1.0	kg/ha-yr
Woody Wetlands	89.6	hectare	0.1	kg/ha-yr
Septic Systems	--------	--------	0.50	kg/ha-yr
Total	1,823.3			
Other Data				
Soil Retention coefficient	0.75	--------		
# Permanent Homes	172	homes		
Use of Permanent Homes	1.0	year		
# Seasonal Homes	101	homes		
Use of Seasonal Homes	0.25	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	1,451.7	kg/yr		
P load from precipitation	60.67	kg/yr		
P load from septic systems	73.97	kg/yr		
Total External P load	1,586.35	kg/yr		
Areal P loading	0.708	g/m2-yr		
Predicted P from Vollenweider	0.052	mg/L		
Back Calculated L total	0.768	g/m2-yr		
Estimation of L internal	0.061	g/m2-yr		
% of External Loading	92.1	%		
% of Internal Loading	7.9	%		

During the August 11, 2004 sampling of Dewart Lake, the mean volume weighted phosphorus concentration in the lake was 0.057 mg/L. It is useful to determine how much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.057 mg/L in Dewart Lake. Plugging this mean concentration of 0.057 mg/L along with the lake's mean depth and flushing rate into Vollenweider's phosphorus loading model and solving for L yields an areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 0.768 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.057 mg/L in Dewart Lake, a total of 0.768 grams of phosphorus must be delivered to each square meter of lake surface area per year.

Total phosphorus loading (LT) is composed of external phosphorus loading (LE) from outside the lake (watershed, septic systems, and precipitation) and internal phosphorus loading (LI). Since LT = 0.768 g/m^2-yr and LE = 0.708 g/m^2-yr (estimated from the watershed loading in Table 30), internal phosphorus loading (LI) equals 0.061 g/m^2-yr. Thus, internal loading accounts for about 8% of total phosphorus loading to Dewart Lake.

It is important to check this conclusion that internal phosphorus loading accounts for 8% of total phosphorus loading to Dewart Lake with the data collected on August 11, 2004. There is evidence in Dewart Lake that soluble phosphorus is being released from the sediments during periods of anoxia. For example, the concentration of soluble phosphorus in Dewart Lake's hypolimnion on August 11 was 4.7 times higher than concentration in the epilimnion (0.141 mg/L vs. 0. 030 mg/L). The source of this hypolimnetic phosphorus is primarily internal loading in most lakes. This internal loading can be a major source of phosphorus in many productive lakes. In the case of Dewart Lake, the high hypolimnetic phosphorus concentration is balanced by the fact that Dewart Lake's hypolimnion is small relative to its epilimnion. Thus, the estimate that internal phosphorus loading accounts for only 8% of the total phosphorus loading to the lake may be realistic

The significance of Dewart Lake's phosphorus areal loading rate is better illustrated in Figure 33 in which areal phosphorus loading is plotted against the product of mean depth times flushing rate. Overlain on this graph is a curve, based on Vollenweider's model, which represents an acceptable loading rate that yields a phosphorus concentration in lake water of 30 µg/L (0.03 mg/L). Dewart Lake's areal phosphorus loading rate is above the acceptable line.

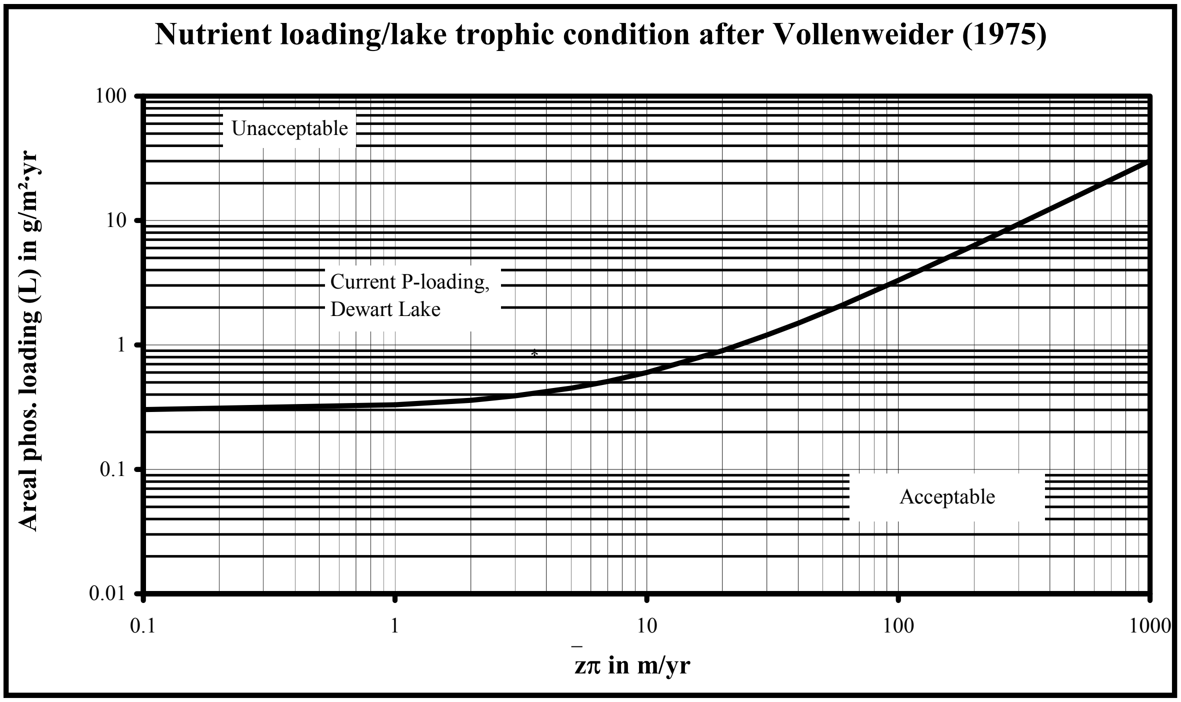

Figure 33. Phosphorus loadings to Dewart Lake compared to acceptable loadings determined from Vollenweider's model. The dark line represents the upper limit for acceptable loading.

This figure can also be used to evaluate management needs. For example, areal phosphorus loading to Dewart Lake would have to be reduced from 0.768 g/m^2-yr to 0.405 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 0.363 g/m^2-yr to the lake, which is equivalent to a total phosphorus mass loading reduction of nearly 813 kg/yr or 47% of the current total phosphorus loading to the lake. Eliminating internal phosphorus loading (136 kg/yr) alone will not meet this reduction need. A significant reduction in watershed phosphorus loading will be required to reduce the trophic state of Dewart Lake.

6.0 MANAGEMENT

The preceding sections of this report detailing Dewart Lake's current condition indicate that the lake possesses good water quality, particularly in comparison to other lakes in the region and throughout the state. The lake has good clarity with a Secchi disk depth of over 9 feet (2.7 m). Nutrient concentrations are lower than the state medians. The lake's volume weighted total phosphorus concentration places the lake in the eutrophic category based on Carlson's TSI, but a much of this phosphorus is in the lake's hypolimnion where it is not accessible to algae. The lower than average nutrient levels present in Dewart Lake result in a moderate productivity level. The lake's chlorophyll *a* concentration, Indiana TSI score, and Secchi disk depth suggest Dewart Lake is mesotrophic in nature.

The lake's relatively healthy biological communities reflect the lake's good water quality. Dewart Lake supports a diverse submerged plant community including several state listed rooted plants. Beck's water marigold, an indicator of good water quality, was found in several places throughout the lake. IDNR fisheries biologists describe Dewart Lake's fisheries community as healthy. The popularity of the lake for fishing tournaments supports this assessment.

While Dewart Lake historically has exhibited and currently exhibits good water quality, there is some evidence that this trend may not continue into the future. The phosphorus modeling shows that more phosphorus is entering the lake from the watershed than can be absorbed by the lake and still maintain only a moderate level of productivity. Similarly, the 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 relatively high concentration of ammonia in Dewart Lake's hypolimnion suggests decomposition rates may be the primary reason for the oxygen consumption. Based on this evidence, the rate of organic material input to the lake may be exceeding the level that the lake can effectively process without compromising water quality.

To date, Dewart Lake's relatively large capacity (volume) had likely helped offset the effects of the phosphorus and organic matter loading from the lake's watershed. Thus, despite relatively high phosphorus inputs, the lake's productivity (algae, plant, and fish populations) is more typical of moderately productive lakes. However, the lake cannot continue to absorb phosphorus and organic matter indefinitely without a concurrent change in its water quality. It is likely that Dewart Lake will 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 included more algae blooms, poorer water clarity, and shifts in the rooted plant and fish community to a dominance of less desirable species.

To prevent, or at least delay, degradation of Dewart Lake's water quality and biological communities, Dewart Lake residents and other watershed stakeholders are strongly encouraged to actively manage their lake and watershed. Management efforts should focus on reducing phosphorus loading to the lake. Dewart 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 ravines, individual residential properties and campground areas should be prioritized. Cable Run's high nitrate 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 recommended for Dewart Lake and its watershed. For the sake of clarity, the techniques are separating into two categories: watershed management techniques and in-lake management techniques.

6.1 Watershed Management

6.1.1 Ravine Management

A series of steep ravines cover the landscape north of Dewart Lake (Figure 34). Within the Limberlost Girl Scout property and along County Road 1000 North, ravine slopes exhibit grades of 10% or higher. Many of the soil units in these areas are considered highly or potentially highly erodible (Figure 6). Given these site conditions, it is not surprising that several of the ravines are actively eroding (Figure 35). Active headcuts at the top of some of these ravines and slumping side slopes were observed during site inspections conducted during the course of this study. Additionally, coarse, sandy material that appeared to have originated from the ravines was noted along the shallow edge of Dewart Lake in the cove adjacent to the Girl Scout property.

Figure 34. View of a typical ravine on the Limberlost Girl Scout property.

Figure 35. Actively eroding ravine on the Limberlost Girl Scout property.

Sediment reaching Dewart 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. During a public meeting conducted this year, residents complained of poor water clarity following weekends of heavy use. Sediment from actively eroding ravines 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 ravines is natural. The landscape's steep slopes coupled with the sandy soil naturally predispose the ravine area to erosion. However, erosion rates within the ravines were likely slower in pre-settlement times. In pre-settlement times, forest likely covered the landscape north of Dewart 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 captures 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 leaves the forest floor as overland runoff. This low stormwater runoff volume and consequently low flow rate translates into lower potential for soil erosion.

At some point during settlement of the Dewart 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 top of the ravines 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 ravines as the water drains toward the lake. The increased volume and rate of stormwater runoff increases the erosion within the ravines.

While the shift from forested land to agricultural land use likely accelerated erosion within the ravines north of Dewart Lake, the conversion of agricultural and/or forested land to residential land use that is occurring today presents an even greater concern for erosion in the ravines. While stormwater runoff volumes and rates are greater on agricultural land compared to forested land, they are even higher on residential land. Residential land can have a significant amount of impervious surface (roads, sidewalks, driveways, houses, etc.) associated with it. Impervious surface provides no infiltration of stormwater. Even if common stormwater management practices are utilized, the potential is high for increased erosion in ravines that released stormwater runoff from residential areas.

The Limberlost Girl Scout Camp has taken steps to address the erosion concerns associated with the ravines on their property. The Camp has worked with the Kosciusko County Soil and Water Conservation District to construct water and sediment control basins, detention basins, and a sediment trap on the parcel (Figure 36). Additionally, the Camp has installed a grassed waterway along an eroding gully. The Camp has also retired active agricultural land and planted these areas to trees and prairie habitat.

Figure 36. Sediment trap at the bottom of one of the ravines on the Limberlost Girl Scout Camp.

A multi-pronged approach is recommended to address the erosion problem within the ravines along the northern edge of Dewart Lake. First, the landscape up-gradient from the ravines 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 would reduce stormwater runoff from areas up-gradient of the ravines. Use of the Conservation Reserve Program (described below) may be a cost-effective means to achieve this goal. Additionally, the forested lot southeast of the intersection of the County Road 400 East and County Road 1050 North should be explored for agricultural tiles. This area was formerly farmed and drainage tiles may still exist there. These tiles can be removed (provided they do not drain active agricultural land north and west of the wood lot) since the area is no longer used for agricultural production. Removal of tiles would help restore the watershed natural hydrological regime and reduce stormwater runoff reaching the ravines.

Once the areas up-gradient of the ravines are examined, focus should be directed to the areas at the top of the ravines. The Limberlost Girl Scout Camp has detention basins located at the top of several of the ravines. If space is available, other ravines would benefit from having similar detention basins located immediately upstream of the start of the ravine. These basins capture stormwater runoff from the surrounding area and slowly release the runoff water into the ravines, reducing the erosive potential of the water.

Erosion control may be possible within the ravines themselves. Depending upon the slope and soil composition, it may be possible to install a series of check dams in certain ravines. 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. Additional sediment traps, like the one shown in Figure 36, may also be an option in some of the ravines. Like many of the other practices described above, sediment traps slow and store water for release in the future. As water pools within a sediment trap, heavier particles drop out of suspension, reducing the sediment load that reaches the lake.

Finally, with respect to reducing erosion from the ravines, very careful planning will be necessary when developing the land around or up-gradient of the ravines for residential or commercial use. 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 ravines will be essential to limiting erosion within these ravines.

6.1.2 Residential and Commercial Development Erosion Control

Although little residential and commercial development is occurring in the larger Dewart Lake watershed, areas immediately adjacent to Dewart 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. 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. Of particular concern was a lot on Dewart Lake's shoreline where either new development or remodeling was occurring. As seen in Figure 37, silt fencing was not utilized on this 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 Dewart Lake from this site. Because water clarity has been cited as one of the major concerns in the public meeting held as a part of this study, the use of common erosion control practices are strongly recommended regardless of whether they are required by the State.

Figure 37. Development (or re-development) site along Dewart Lake that appears to lack silt fencing to protect the lake from on-site erosion. Additionally, construction debris is piled immediately adjacent to the lake and ash from the fire is undoubtedly reaching the lake adding to the lake's biological oxygen demand.

6.1.3 Individual Property Management

Individual property owners can take several actions to improve Dewart Lake. First, shoreline landowners should seriously consider re-landscaping lakeside properties to protect their lake. Many of the homes on Dewart Lake have maintained turf grass lawns that extend to a concrete seawall at the lake's edge (Figures 38 and 39). Runoff from residential lawns can be very high in phosphorus. In a study on residential areas in Madison, Wisconsin, Bannerman et al. (1993) 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).

Figure 38. View of the water's edge along Dewart Lake. Native shoreline vegetation has been removed and replaced with turf grass and a concrete seawall.

Figure 39. View of the water's edge along Dewart Lake. Filamentous algae, which likely receives high nutrient loads from the adjacent lawn, thrives in front of the seawall.

The ideal way to re-landscape a shoreline is to replant as much of the shoreline as possible with native shoreline species. Rushes (*Juncus* spp.), sedges (*Carex* spp.), pickerel weed (*Pontederia cordata*), arrowhead (*Sagittaria latifolia*) and blue-flag iris (*Iris viginica*) 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 (*Scirpus spp*.) 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 I contains a list of potential species that could be planted at the lake's shoreline and further inland to restore the shoreline.

Restoring Dewart 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. 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 (Figure 40). 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 concrete seawalls with glacial stone to reduce the "rebound" effect.) Finally, well-vegetated shorelines provide excellent habitat for native waterfowl and other aquatic species.

Figure 40. Wire fence along Dewart Lake. Canada geese are rarely discouraged by such fencing long-term. The geese readily learn how to jump these fences. These fences do not obstruct views so any predators are easily visible to the geese.

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, again either directly or via storm drains. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The 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 Dewart Lake 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 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, roads, parking areas, driveways, and rooftops. Resident surveys conducted on other northern Indiana lakes have indicated that many lakeside houses have local drains of some sort on their properties (JFNew, 2000a; JFNew, 2002). These drains contribute to sediment and nutrient loading and thermal pollution of 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.

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.

Finally, individual property owners should take steps to minimize the water quality impacts of their on-site waste water treatment systems (i.e. septic systems). Overloaded or leaking septic systems deliver nutrients and other pollutants such as *E. coli* to nearby waterbodies. This can increase the waterbodies' productivity and threaten human health. To address the problems posed by septic systems, properties owners should conduct regular septic tank maintenance. Frequency of septic tanks cleaning depends on the size of the tank and number of persons utilizing it. Jones and Yahner (1994) suggest dividing the size of the septic tank by the product of 100 and the number of persons in the household to determine the frequency of cleaning. For example, if a household of four that does not use a garbage disposal is served by an 800-gallon septic tank, this household should clean its tank every 2 years. (800/(100*4) = 2) Use of a garbage disposal increases solids loading to a septic tank by about 50% so this needs to be considered when calculated cleaning frequency. It is important to distinguish between "cleaning" which means the removal of solids and effluent from the tank and "pumping" which refers to removal of only the liquid effluent from the tank. Where necessary, systems should be upgraded to ensure they can handle any increases in waste stream that have occurred over the years (i.e. modernization of home, increases in residence time, etc.) Water conservation measures such as using low-flow toilets or taking shorter showers will also decrease loading to septic systems.

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

6.1.4 Campground Management

The management techniques described above for individual residential properties are also applicable to the campgrounds around Dewart Lake. Eliminating or reducing fertilizer use, installing shoreline buffers, and preventing organic waste (yard, pet, and wildlife waste) from reaching the lake are important management steps that should be taken in the campground areas. Utilizing an alternative waste treatment system to treat human wastewater should seriously be considered in these areas. A wastewater wetland is ideal for servicing a campground since, as mentioned above, the wetland is operating at its maximum efficiency during the summer months. This coincides with the peak use of the campgrounds. Installation of wastewater wetlands to service Dewart Lake's campgrounds may actually reduce the waste stream reaching the leach field, ultimately reducing the pollutant load to the lake.

6.1.5 Livestock Fencing

Livestock that have unrestricted access to a lake, stream, or wetland have the potential to degrade the waterbody's water quality and biotic integrity. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream and lake ecosystems indirectly. Trampling and removal of vegetation through grazing of riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in a wetland or riparian zone decreasing the area's ability to infiltrate water runoff. Removal of vegetation in a wetland or riparian zone also limits the area's ability to filter pollutants in runoff. The degradation of a waterbody's water quality and habitat typically results in the impairment of the biota living in the waterbody.

Livestock access to a stream or wetland adjacent to a stream was a concern noted in two spots in the Dewart Lake watershed (Figure 41). One area of concern is a wetland immediately upstream of Dewart Lake along Cable Run, north of County Road 850 North and east of County Road 450 East. Livestock were observed grazing in a low lying wetland area. Although it could not be determined from the observation point on County Road 450 East, the livestock may have direct access to Cable Run. They appear to have direct access to the wetland adjacent to Cable Run. Excluding livestock from the wetland and revegetating the wetland to provide better treatment for runoff water before reaching Cable Run is recommended at this site. The second site is located southeast of the intersection of County Roads 500 East and 950 North. Horses appear to have access to the unnamed intermittent stream traversing this parcel. The stream banks also appear to be damaged by grazing and trampling. This area would benefit from exclusion fencing and stabilization of the stream banks.

Restoring areas impacting by livestock grazing often involves several steps. First, the livestock in these areas should be restricted from the wetland or stream to which they currently have access. If necessary an alternate source of water should be created for the livestock. Second, the wetland or riparian zone where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. Minimally, it involves installing filter strips along banks or wetland edge and replanting any denuded areas. Finally, if possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading, particularly nitrate-nitrogen loading, to the adjacent waterbody. Complete restoration of aquatic areas impacted by livestock will help reduce pollutant loading (particularly nitrate-nitrogen, sediment, and pathogens) to Dewart Lake.

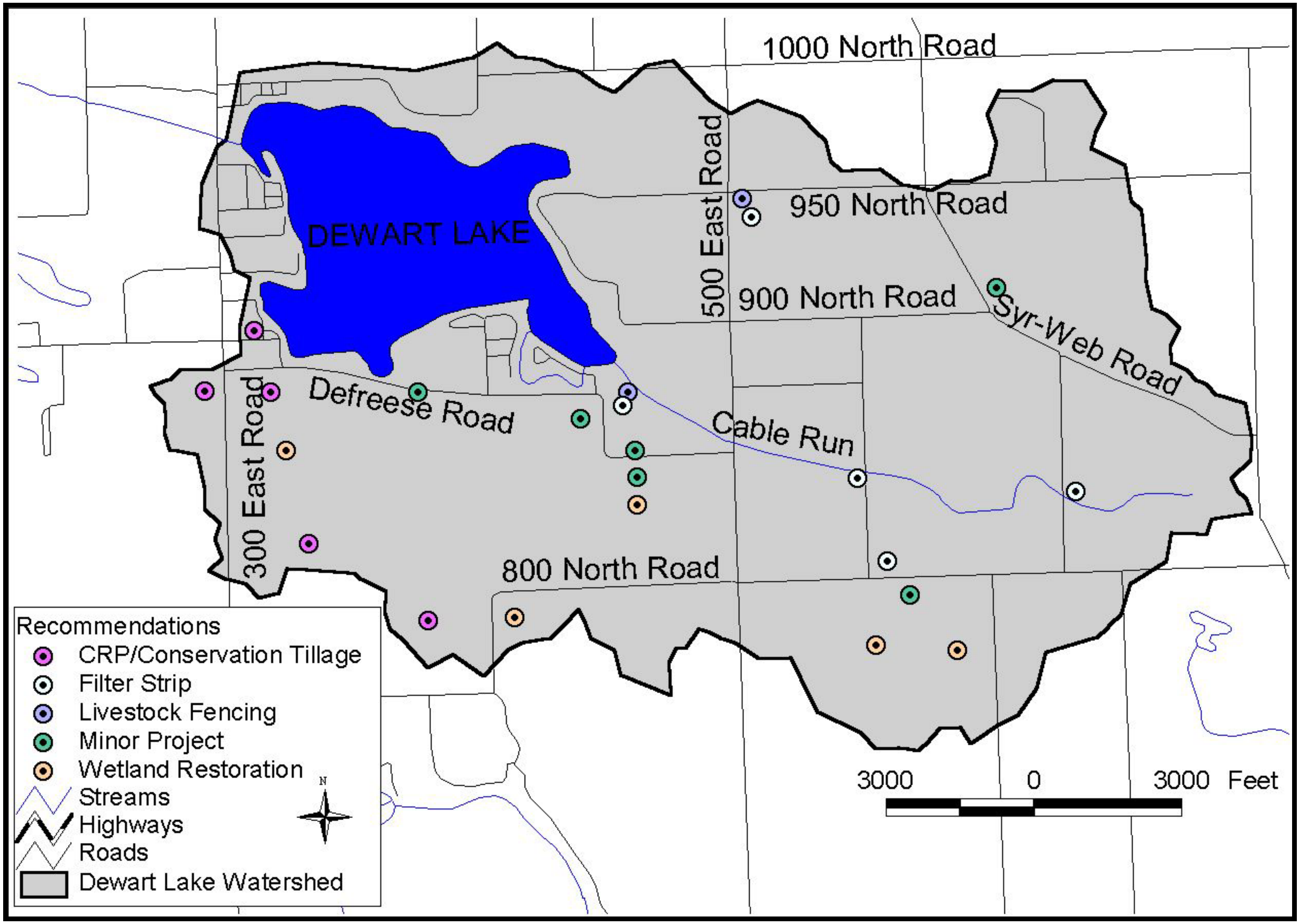

Figure 41. Locations in the Dewart Lake watershed where the installation of water quality improvement projects is recommended. (Appendix J contains UTM coordinates for each location.) Source: See Appendix A. Scale: 1"=3,000'.

6.1.6 Filter Strips

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

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. This is particularly important in the Dewart Lake watershed where the need for filter strips was associated with livestock pastures. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. The reduction in runoff volume decreases the potential for erosion in any receiving stream. It is important to note that filter strips should be used as a component of an overall waste management system when addressing runoff from pastures and feed lots.

Filter strips are most effective when they: 1. are adequately sized to treat the amount of runoff reaching them (Figure 42); 2. include a diverse variety of species; 3. contain species appropriate for filter strips; and 4. are regularly maintained. Filter strip size depends on the purpose of the strip, but should ideally have at least a 30-foot flow path length (the minimum length across which water flows prior to reaching the adjacent waterbody). The variety of species planted in a filter strip depends upon the desired uses of the strip. For instance, if the filter strip will be grazed or if a landowner wishes to attract a diverse bird community, specific seed mixes should be used in the filter strip. The NRCS or an ecological consultant can help landowners adjust filter strip seed mixes to suit specific needs.

Figure 42. An example of a filter strip with excellent width to maximize the reduction of pollutant loads reaching the adjacent ditch. (Photo taken in Cass County, Indiana.)

During the windshield tour of the Dewart Lake watershed, filter strips were observed along portions of Cable Run and its tributaries. However, the need for filter strips or an increase in the width of existing filter strips was noted in the areas impacted by livestock discussed above and along at least two portions of the Cable Run drainage system (Figure 41). Filter strips may be needed in other locations along Cable Run or other minor drainages in the Dewart Lake watershed that are not visible from roadways. Given the benefits filter strips provide, Dewart Lake watershed stakeholders should work with the Kosciusko County SWCD to ensure Cable Run and other minor tributaries in the watershed are protected with wide, functioning filter strips.

6.1.7 Conservation Reserve Program

Some landowners in the Dewart 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.

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 stabilize 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 prairie grasses and plants compared to land supporting row crops. This reduces the erosive potential of rain and decreases the volume of runoff. Multi-layer vegetative communities intercept rainwater at different levels, further reducing the erosive potential of rain and volume of runoff.

Given the ecological benefits that land enrolled in CRP provide, 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 41. 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. Some of the areas shown in Figure 41 may already utilize the 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.

6.1.8 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 Dewart Lake watershed. Tillage transect data collected in 2003 showed that the use of no-till methods on Kosciusko County farmland was near the statewide average (for corn and soybeans). In 2002, Kosciusko County registered an increase in the percentage of corn fields and a decrease in the percentage of soybean fields on which no-till was utilized (Purdue University and IDNR, no date). The 2004 data suggest Kosciusko County producers have increased their use of conservation tillage. Producers utilized mulch tillage methods on 68% and no-till methods on 24% of the acreage planted to corn; producers utilized mulch tillage methods on 28% and no-till methods on 68%of the acreage planted to soybeans. Continued use of conservation tillage, particularly no-till conservation tillage, is recommended in the Dewart 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.

6.1.9 Stream Bank and Channel Stabilization and Restoration

Eroding banks add sediment directly to streams. This sediment can impair stream habitat by filling interstitial crevices in a stream's substrate and smothering spawning gravel. This will, in turn, negatively affect the stream's biota. Sediment from eroding stream banks is also transported downstream to the lakes in the watershed where it degrades the lake habitat and can impair recreational uses of the lake. Sediment deltas at lake mouths often support nuisance levels of rooted aquatic plants. Sediment deltas can also restrict boating in the area. Excess sediment in lakes reduces water clarity, particularly when it is stirred by boating activity. This is a major concern in Dewart Lake.

Although much of Cable Run is not visible from the roadside, one area that would benefit from bank stabilization or restoration was identified during the windshield tour (Figure 41). Landowners living adjacent to Cable Run and other drainages may be aware of additional stream bank areas in need of stabilization In general, bioengineering techniques, such as soil encapsulated lifts or willow staking, which utilize vegetation to stabilize stream banks, are recommended to prevent stream bank erosion. Due to the severity of erosion, the specific area along Cable Run identified during the windshield tour may require crib walls or a similar stabilization technique. Riprap or other hard armoring is not recommended since amoring only transfers the erosive energy downstream. Finding ways to infiltrate and store more water on the landscape before the water reaches the stream is more economical than trying to stabilize sections of the stream.

6.1.10 Wetland Restoration

Visual observation and historical records indicate at least a portion of the Dewart Lake watershed has been altered to increase its drainage capacity. The 1978 Census of Agriculture found that drainage is artificially enhanced on 38% of the land in Kosciusko County (cited in Hudak, 1995). Riser tiles in low spots on the landscape and tile outlets along the waterways in the Dewart Lake watershed confirm the fact that the landscape has been hydrologically altered. Historical aerial photography shows that Dewart 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 Dewart Lake watershed could return many of the functions that were lost when these wetlands were drained. Figure 41 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 41 were selected because they are areas where large scale restoration is possible.

6.1.11 Minor projects

Several minor restoration or management projects were identified during the windshield tour of the Dewart Lake watershed. These minor projects include adding filter strips around tile risers to filter pollutants from runoff water reaching these risers; stabilizing culverts with vegetation, rock, and/or a drop structure; and increasing/enhancing agricultural field edges with additional plantings. Figure 41 shows the location of these minor projects, while Table 23 details the specific need at each site.

Table 23. Minor restoration or management projects in the Dewart Lake watershed. Locations of the projects correspond to Figure 41.

Location	Management Need
South side of Defreese Road, east of Crowl's Landing	Field edge revegetation/stabilization
South side of Defreese Road, south of Blueberry Island	Culvert protection and stabilization
South side of CR 850 North, west of CR 500 East	Filter around tile riser
North side of CR 850 North, west of CR 500 East	Filter around tile riser
South side of CR 800 North, east of CR 550 East	Filter around tile riser
East side of Syr-Web Road, across from CR 900 North	Filter around tile riser
East side of Syr-Web Road, across from CR 900 North	Field edge revegetation

6.2 In-Lake Management

6.2.1 Boat Management

During the first public meeting, several watershed stakeholders expressed a concern over the potential ecological impact to Dewart Lake from motor boats. The stakeholders also communicated a perceived increase in the number of boats using Dewart Lake over the past few years. Although an assessment of the ecological impact of motor boating on Dewart Lake's health was beyond the scope of this study, the scientific literature contains several studies documenting the effects of motor boating on lake health in general. A review of the potential ecological impacts of motor boating on lake health may be useful to understand how Dewart Lake may be affected by this activity.

Water Clarity Concerns

One of the most common impacts associated with motor boating, and one of the primary concerns noted by Dewart Lake stakeholders, is a decrease in water clarity. As motor boats travel through shallow water, the energy from movement of the boat propeller may be sufficient to resuspend sediment from the lake bottom, decreasing the lake's water clarity. Several researchers have documented either an increase in turbidity or a decrease in Secchi disk transparency during and following motor boat activity (Wagner, 1990; Asplund, 1996; Yousef et al., 1980). Crisman (1986) reports a decrease in Secchi disk transparency following holiday weekend use of Lake Maxinkuckee in Culver, Indiana. Asplund (1996) also observed poorer water clarity in his study lakes following weekend boating and that this decrease in water clarity is more pronounced in lakes with generally better water clarity. This finding is particularly significant for Dewart Lake, since Dewart Lake generally exhibits better water clarity than the typical Indiana lake.

The ability of a motor boat to resuspend sediment from the lake bottom depends on several factors. Some of these factors, such as boat length, motor size, and boat speed, are related to the boat itself and the boat's operator. Yousef et al. (1978) found that 10 horsepower (hp) motors were capable of mixing the water column to a depth of 6 feet (1.8 m), while 50 hp motors were capable of mixing the water column to a depth of 15 feet (4.6 m). While larger motor sizes have a greater potential to resuspend sediments than smaller motors, longer boats and higher speeds do not automatically translate to a greater ability to resuspend sediments. Boats that are 'planing' on the water actually have little impact on the lake's bottom. This is because the velocity of water at the lake bottom created by a motor boat depends on the boat's displacement, which is a function of boat length and speed. Beachler and Hill (2003) suggest that boat speeds in the range of 7 to 12 mph may have the greatest potential to resuspend sediment from the lake bottom. (This range is based on typical recreational boat length.)

Certain characteristics of lakes also influence the ability of motor boats to resuspend sediments. Shallow lakes are obviously more prone to water clarity degradation associated with motor boating than deeper lakes. Wagner (1990) suggests little impacts from motor boating are likely in water deeper than 10-15 feet (3.0-4.6 m). Lakes with soft fine sediments are more likely to suffer from sediment resuspension than lakes with coarser substrates. Lakes with extensive rooted plant coverage throughout the littoral zone are less prone to motor boat related resuspension problems than lakes with sparse vegetation since plants help hold the lake's bottom substrate in place.

Given this information, it is clear that some of Dewart Lake's physical characteristics predispose it to water clarity problems associated with motor boating. First, because Dewart Lake is over 300 acres in size, high speed boating is permissible on Dewart Lake. Consequently, the lake is likely to be a popular boating destination, and boats are likely to, at least during some portion of the time, travel at the rate of speed (7 to 12 mph) suggested above to have the greatest potential to resuspend sediment from the lake bottom. Second, while Dewart Lake is deep relative to many Indiana lakes, very little water lies over the lake's deepest areas. The lake's depth area curve (Figure 18) indicates that approximately 44% of the lake's surface area covers water less than 5 feet (1.8 m) deep. Nearly 60% of the lake's surface area covers water less than 15 feet (4.6 m) deep. Thus, a large portion of Dewart Lake is potentially subject to impacts due to motor boating. Fortunately, chara covers large portions of Dewart Lake's bottom sediment and sand is the dominate substrate type. However, these characteristics may not be sufficient to prevent the resuspension of bottom sediment during periods of heavy use.

It is important to note that the decrease in water clarity is not usually permanent. Once motor boating activity ceases, resuspended materials will sink to the lake bottom again. However, this process can take several days. Wagner (1990) found that while turbidity levels steadily decreased following boating activity in his shallow study lakes, the turbidity had not returned to baseline levels even two days after the activity. Crisman (1986) found similar lags on Lake Maxinkuckee. Thus, Dewart Lake residents may need to wait several days before their lake returns to its baseline clarity following heavy weekend motor boating use.

Other Potential Concerns

In addition to a decrease in water clarity, several other potential ecological impacts from motor boating exist. Various researchers have documented increased phosphorus concentrations, damage to rooted plants, changes in rooted plant distribution, and increased shoreline erosion associated with motor boating activity (Asplund, 1996; Asplund, 1997; Schloss, 1990; Yousef et al., 1980). Less commonly studied concerns include potential increases in heavy metal and hydrocarbon pollution, changes in algal populations, and impacts to lake fauna.

Just as the potential impact of motor boating on a lake's water clarity depends in large part to the specific characteristics of the lake, the potential for other ecological impacts associated with motor boating often depend on characteristics of the specific lake (Wagner, 1990). For example, Yousef et al. (1980) found increases in total phosphorus concentrations associated with motor boating activity in all his study lakes. However, only one of Wagner's study lakes showed an increase in phosphorus concentrations associated with motor boating activity. This lake possessed a nutrient rich, fine particle substrate. Similarly, Schloss (1990) reported greater increases in phosphorus concentrations due to motor boat activities in those New Hampshire lakes with high levels of internal phosphorus loading. New Hampshire lakes with lower levels of internal phosphorus loading were less likely to see large increases in phosphorus concentration associated with motor boat activity.

As noted above, Dewart Lake's extensive areas of shallowness and popularity predispose the lake to a decrease in water clarity associated with motor boat activity. Other characteristics that increase Dewart Lake's potential for ecological damage due to motor boat activity include the presence of Eurasian water milfoil and sensitive rooted plants in the lake, the prevalence of concrete seawalls along the lake's shoreline, and the lake's relatively long hydraulic residence time.

The presence of Eurasian water milfoil combined with motor boating activity is a problem since motor boats driven through stands of Eurasian water milfoil have the potential to spread the invasive plant throughout the lake. The species is already a nuisance to recreation in Dewart Lake. The spread of the species will only further impair recreation. Increased growth of Eurasian water milfoil might also result in the decline of some of the lake's more sensitive rooted plant species such as Beck's water marigold. Eurasian water milfoil has the potential to shade out other native plants. This would reduce the diversity of rooted plants in the lake and could, in turn, adversely affect the lake's fish community.

The prevalence of concrete seawalls around Dewart Lake combined with motor boating is a problem since concrete seawalls do little to reduce the energy of waves hitting the walls. Motor boating along with wind action are responsible for the generation of waves on most lakes. These waves can carry a significant amount of energy. Waves striking concrete seawalls reflect off the walls without releasing much of their energy. This energy simply returns to the lake where it can play a role in resuspending bottom sediments and reducing water clarity.

Dewart Lake's relatively long residence time means that any changes in the lake's water quality due to motor boating may have a greater impact on Dewart Lake than they would in a lake with a shorter residence time. In lakes with very short hydraulic residence times (less than 2-3 months), water within the lake is constantly being replaced with new water from the watershed. Thus, any pollutants added to the water column from motor boating are quickly flushed from the lake. In lakes with longer residence times, like Dewart Lake, these pollutants stay within the lake longer before being flushed.

Impact to Dewart Lake's Painted Turtles
The preceding paragraphs have focused on potential impacts to Dewart Lake's ecological health due to motor boating. As noted earlier the scope of this study did not allow for the direct examination of motor boating on Dewart Lake. However, several researchers have studied the turtle population in Dewart over the course the last 20 years and suggest the lake's turtles have been impacted by motor boating. Smith et al. (unpublished) found an increase in the proportion of painted turtles with propeller damage to their shells. Concurrently, they observed a decline in the painted turtle population in Dewart Lake and hypothesize that the increase in human use, specifically an increase in watercraft use, may be responsible for the observed changes in the painted turtle populations.

Carrying Capacity
Boat density on a lake influences the magnitude of effect possible from motor boating activity. Typically, more power watercraft utilizing a lake results in a greater potential for ecological damage to the lake. While there is little or no documentation available on exactly how many motor boats a lake can support without impairing its ecological health, several researchers have tackled the question of how many motor boats a given lake can support at one time without compromising user safety or what is the lake's safety-related carrying capacity. This estimate of a lake's safety-related motor boat carrying capacity may be used as a surrogate for the lake's ecological-related motor boat carrying capacity. It is important to note that a lake's safety-related carrying capacity is not necessarily directly related to its ecological-related carrying capacity. There is a certain amount of subjectivity with respect to a lake's safety-related carrying capacity since some users will feel safer than others at different levels of congestion. However, a lake's safety-related carrying capacity may be the best approximation we have for a lake ecological-related carrying capacity.

Dudiack (2004) suggests a conservative estimate of a lake's motor boat carrying capacity is around 15-20 acres of usable lake per boat, while an estimate that allows a little more congestion is around 10-15 acres of usable lake per boat. (A lake's "usable" acreage usually refers to those areas that are obstruction free and have sufficient depth to support motor boating.) Applying this to Dewart Lake, this suggests Dewart Lake has a safety-related carrying capacity of 15-30 motor boats if 10-20 acres per boat is necessary for safety of the boat operators and other lake users. (This calculation assumes that the area of Dewart Lake that is less than 5 feet (1.8 m) deep is not usable.) Interestingly, the public launch area for Dewart Lake has 30 parking spots. While certainly not every boat being launched from the public boat ramp is a motor boat, there is certainly the potential for concern.

Boat Management
It is clear from the preceding discussion, the management of boating, particularly motor boating, is necessary to ensure Dewart Lake continues to be a healthy, functioning lake capable of providing recreation and aesthetic enjoyment for all users. However, "managing" boat use of any lake often entails limiting use of the lake in some way. This is highly contentious and different user groups will undoubtedly have differing opinions on the best course of management.

Despite this, development of a use management plan, which includes motor boat use, is recommended for Dewart Lake. The management plan needs to take into account Dewart Lake's specific morphological and ecological characteristics noted above. For example, the plan might restrict boat speeds in areas less than 10 feet of depth to idle only. This would help reduce water clarity impacts. The plan should also consider safety issues. Most importantly, the plan must be developed with input of all users (including non-residents). Finally, representatives from the IDNR Division of Fish and Wildlife and Division of Law Enforcement should be intimately involved in the development of any lake use management plan. These divisions are responsible for the management of Dewart Lake's resources and the enforcement of state laws with respect to use of Dewart Lake.

6.2.2 Aquatic Plant Management
Development of an aquatic plant management plan is also a recommended in-lake management step for Dewart 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 Dewart 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. Dewart Lake's high rooted plant diversity and state listed plant species should be protected. The lake supports excellent rooted plant diversity and this undoubtedly plays a role in supported its healthy fishery. Additionally, four state listed species inhabit the lake. Management techniques that are not species specific, such as contact herbicides or large scale harvesting, should be avoided to ensure the protection of these rare species.

2. The Dewart Lake Protective Association should begin the process to set up "ecozones" in the lake. Dewart Lake supports some shallow areas vegetated with bulrush and other tall emergent vegetation that deserve special protection. These areas offer excellent spawning habitat for fish. Additionally, they help stabilize the bottom sediment, reducing the potential for declining water clarity. They also provide oxygen to the water column and play a role in nutrient cycling. Unfortunately, aerial photography and anecdotal information suggest these emergent areas have experienced a decrease in size and density of plant coverage over the past several years. The special protection afforded to ecozones

would help protect these emergent areas from further damage and perhaps help them regain their former condition.

3. Dewart Lake residents should take steps to restore the lake's shoreline vegetation. Currently, much of the developed portion of the lake's shoreline lacks a healthy emergent plant population. 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 **Section 6.1.3 Individual Property Management**.

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

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 Dewart Lake, given its specific ecological condition.

Chemical Control

Herbicides are the most traditional means of controlling aquatic vegetation. Herbicides have been used in the past on Dewart Lake. In 2004, the Indiana Department of Natural Resources, Division of Fish and Wildlife issued permits to two chemical applicators for treatment of six locations along Dewart Lake's shoreline (Jed Pearson, personal communication, and DNR permit files). One commercial applicator treated two areas totaling 1.7 acres (0.7 ha) along the northern shoreline to control Eurasian water milfoil, curly leaf pondweed, chara, filamentous algae, slender naiad, and large leaved pondweed. Because of its value to fish, the Division of Fish and Wildlife restricted treatment in dense areas of large leaved pondweed. The other commercial applicator received a permit to treat six areas totaling over 7 acres (2.8 ha). The treatment areas were scattered along the lake's shoreline with three of the sites bordering the eastern shoreline, two bordering the northern shoreline, and one near the public boat launch. At each of the six sites, the applicator targeted his treatment for Eurasian water milfoil and curly leaf pondweed. Neither applicator intended to treat plants in water deeper than 5 feet (1.5 m), according to their permit applications. Both applicators applied for permits to treat the same areas in 2002 and 2003. (IDNR records beyond that date were not requested, but it is likely that the same areas receive routine treatment.)

In addition to these large scale applications, 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. Such herbicides can kill non-target plants and sometimes even fish species in a lake. Costs of an herbicide treatment vary from lake to lake depending upon the type of plant species present in the lake, the size of the lake, access availability to the lake, the water chemistry of the lake, and other factors. Typically in northern Indiana, costs for treatment range from $275 to $300 per acre or $680 to $750 per hectare (Jim Donahoe, Aquatic Weed Control, personal communication).

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

Chemical treatment should be used with caution on any Dewart 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 while Dewart Lake's possessed relatively low nutrient concentrations compared to many Indiana lakes, the lake's total phosphorus concentration may be high enough to support algal blooms. Spot chemical treatments are recommended only for patches of Eurasian water milfoil.

Mechanical Harvesting

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

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

Hand harvesting may be the most economical means of harvesting on Dewart 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 43). 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.)

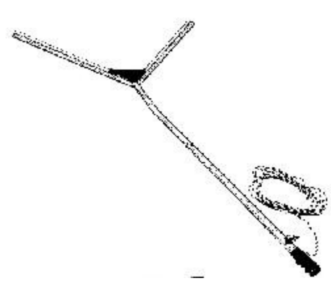

Figure 43. An aquatic weed cutter designed to cut emergent weeds along the edge of ponds. It has a 48" cutting width, uses heavy-duty stainless steel blades, can be sharpened, and comes with an attached 20' rope and blade covers.

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

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

While the populations of Eurasian water milfoil and purple loosestrife on Dewart Lake are relatively small and therefore may not be suitable for biological control efforts, it may be worthwhile for Dewart Lake residents to understand the common biocontrol mechanisms for these two species should the situation on the lake change. 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 Water Milfoil

Euhrychiopsis lecontei has been implicated in a reduction of Eurasian water milfoil 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 water milfoil. A nine-year study of nine southeastern Wisconsin lakes suggested that weevil activity might have contributed to Eurasian water milfoil declines in the lakes (Helsel et al, 1999). The Indiana Department of Natural Resources is currently conducting field trials on three Indiana lakes.

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian water milfoil (Christina Brant, EnviroScience, personal communication). Cost advantages include the weevil's low maintenance and long-term effectiveness versus the annual application of an herbicide. In addition, use of the weevil does not have use restrictions that are required with some chemical herbicides. Use of the weevil has a few drawbacks. The most important one to note is that reductions in Eurasian water milfoil are seen over the course of several years in contrast to the immediate response seen with traditional herbicides. Therefore, lake residents need to be patient. Additionally, the weevils require natural shorelines for over-wintering. Unfortunately, Dewart Lake lacks natural shoreline adjacent to the largest patch of Eurasian water milfoil in the lake.

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 water milfoil 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). Dewart Lake residents should take this into consideration before attempting treatment of the lake's Eurasian water milfoil 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 water milfoil, purple loosestrife is an aggressive non-native species. Once purple loosestrife becomes established in an area, the species will readily spread and take over the habitat, excluding many of the native species which are more valuable to wildlife. Conventional control methods including mowing, herbicide applications, and prescribed burning have been unsuccessful in controlling purple loosestrife.

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

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

At Dewart Lake, a beetle release may be beneficial in the wetland adjacent to the kettle in the lake's southeastern corner. One possible means to fund such an endeavor is to utilize the resources of the local 4-H organization. In Marshall County, 4-H has participated in several beetle releases. Utilizing the 4-H also provides an avenue for local children to be involved with the management of their lake.

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 44). Milfoil, for example, can survive for up to a week in this state; it can then infect a milfoil-free lake when the boat and trailer are launched next. It is important to educate boaters to clean their boats and trailers of all plant fragments each time they retrieve them from a lake.

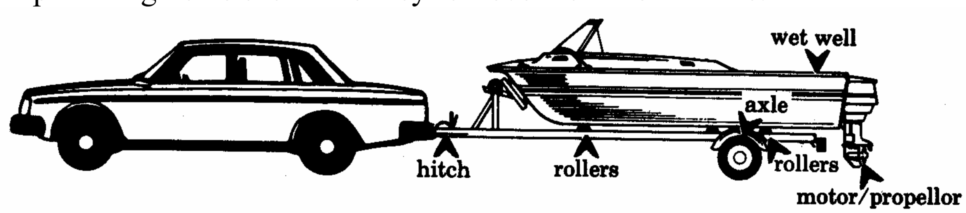

Figure 44. Locations where aquatic macrophytes are often found on boats and trailers.

Educational programs are effective ways to manage and prevent the spread of aquatic nuisance species (ANS) such as Eurasian water milfoil, 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 Dewart Lake. Although Eurasian water milfoil already exists in Dewart Lake, educational programs and lake signage will help prevent the spread of this nuisance species to other lakes. This is particularly important given the popularity of Dewart Lake. Non-resident angling tournament participants and other visitors will use their boats in other lakes in addition to Dewart Lake, potentially spreading Eurasian water milfoil 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.

6.2.3 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. Dewart Lake has participated in this program in the past but does not currently have a citizen volunteer. Continued participation in the Indiana Clean Lakes Volunteer Monitoring Program is highly recommended. This is particularly important on Dewart Lake where information regarding the lake's stratification would be helpful in understanding phosphorus cycling in the lake.

7.0 RECOMMENDATIONS

As noted in the previous section, Dewart Lake currently possesses good water quality. However, it is unlikely that the lake can 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 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 Dewart Lake's specific characteristics, both in-lake and watershed management is recommended to maintain the lake's good water quality. Dewart 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 ravines, individual residential properties, and campground areas 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 high nitrate and bacteria levels observed in Cable Run are also important but should receive a lower priority since flow in Cable Run is often intermittent.

The following list summarizes the recommendations for maintaining and improving Dewart Lake's chemical, biological, and physical condition. The recommendations are separated in two groups based on priority described above. Recommendations in the first group are of higher priority than recommendations in the second group since implementation of these recommendations would provide greatest benefit to Dewart Lake. Implementation of recommendations in the second group is, however, important and should not be ignored. Each of the following recommendations should be implemented and will help maintain Dewart Lake's good water quality.

The list is prioritized based on the current ecological conditions of Dewart 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 K 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.

Primary recommendations

1. Stabilize actively eroding ravines by reducing the amount of water reaching the ravines and slowing the velocity of water that does reach the ravine and in the ravine itself. Consider the installation of sediment traps and check dams in ravines 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 Dewart 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 concrete seawalls with glacial stone seawalls.
   e. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
   f. Properly maintain septic systems. Systems should be pumped regularly and leach fields should be properly cared for.
   g. Examine all drains that lead from roads, driveways, or rooftops to the watershed's lakes and/or streams; consider alternate routes for these drains that would filter pollutants before they reach the water. Stabilize bare drainage ditches with vegetation where possible or rock where flow rates are too high for vegetation.
   h. Obey no-wake zones.
   i. Clean boat propellers after lake use and refrain from dumping bait buckets into the lake to prevent the spread of exotic species.

3. With the help of the Indiana Department of Natural Resources, manage the boating activity on Dewart Lake. The best way to do this may be to develop a recreational use management plan for the lake that considers the needs of the users and the ecological limitations of the lake. This plan should include an aquatic plant management component since aquatic plant management is inextricably linked with recreational use management.

4. Manage the Eurasian water milfoil 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 water milfoil hot spots until these areas can be treated.

5. Monitor and improve erosion control techniques on residential and commercial development sites. Bring areas of concern to appropriate authorities.

6. Construct a wastewater wetland to treat the human waste stream at each of the campgrounds on Dewart Lake. Consider doing the same for residential areas along the shoreline since the area is unlikely to be serviced by a sewer system in the near future.

7. Become an active volunteer in the Indiana Clean Lakes Program volunteer monitoring program. Dewart Lake has had a volunteer in the past; 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.

Secondary Recommendations

8. Work with the Kosciusko County Health Department to determine the cause of the extremely high *E. coli* concentration observed in Cable Run following a storm event. Potential sources of the bacteria include a failing septic system, wildlife, and livestock.

9. Install fencing to protect wetland and stream areas mapped in Figure 41. Install an alternative water source if necessary. Restore areas where grazing cattle have damaged the stream/wetland habitat. This may include stabilizing or reconstructing the banks using bioengineering techniques. Construct filter strips between grazing areas and the adjacent aquatic ecosystems. If possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading particularly, nitrate-nitrogen loading, to the adjacent wetland or stream.

10. Install filter strips and enhance/widen existing filter strips along waterways within the Dewart Lake watershed. Figure 41 maps recommended locations for this management technique.

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

12. Restore wetland habitat within the Dewart Lake watershed where feasible. Figure 41 shows areas that are good candidates for wetland restoration.

13. Implement the minor projects listed in Table 23.

14. Stabilize Cable Run's banks in the location shown in Figure 41 and any other areas identified by adjacent property owners.

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APPENDICES

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

APPENDIX A:

GEOGRAPHIC INFORMATION SYSTEMS (GIS) MAP DATA SOURCES

DEWART LAKE DIAGNOSTIC STUDY KOSCIUSKO COUNTY, INDIANA

Appendix A. Geographic Information Systems (GIS) map data sources.

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

Figure 3. Topographic relief of the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Relief coverage is the U.S. Geological Survey National Elevation Data set.

Figure 4. Subwatersheds within the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Watershed and subwatershed boundaries were delineated based using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI.

Figure 5. The major soil associations covering the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soil associations digitized from Staley, 1989.

Figure 6. Highly erodible and potentially highly erodible soils within the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soils coverage is from the Natural Resources Conservation Service National Ssurgo Soils Database. Highly erodible and potentially soils criteria were set by the NRCS.

Figure 6. Soil limitation for se as septic tank absorption fields throughout the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soils coverage is from the Natural Resources Conservation Service National Ssurgo Soils Database. Soil septic tank limitations were set by the NRCS and are reported in Staley, 1989.

Figure 9. Land use in the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Land

use comes from the USGS Indiana Land Cover Data Set. The data set was corrected based on 2003 aerial photographs.

Figure 10. Wetlands in the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Wetland location source is U.S. Fish and Wildlife Service National Wetland Inventory GIS coverage.

Figure 11. Hydric soils in the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Soils coverage is from the Natural Resources Conservation Service National Ssurgo Soils Database. Hydric soil classifications were previously set by the NRCS.

Figure 12. Stream sampling site in the Dewart Lake watershed.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set.

Figure 24. Dewart Lake plant beds.
Shoreline boundaries are from the U.S. Census Bureau TIGER data set. Plant bed coverage is based on field surveys conducted August 3, 2004 and was drawn by JFNew. JFNew utilized field sketches, field notes regarding the depth of rooted plant growth, the lake's bathymetric map, and aerial photography to estimate the perimeters of plant beds.

Figure 35. Locations in the Dewart Lake watershed where the installation of water quality improvement projects is recommended.
Watershed boundaries generated using ArcView 3.3 Spatial Analyst with a hydrological modeling extension available from ESRI. Computer generated boundaries were field checked for accuracy. Road and stream coverages are from the U.S. Census Bureau TIGER data set. Improvement project locations are based upon field surveys conducted by JFNew. Coverages were drawn by JFNew.

APPENDIX B:

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

DEWART LAKE DIAGNOSTIC STUDY KOSCIUSKO COUNTY, INDIANA

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED
FROM THE DEWART LAKE WATERSHED, KOSCIUSKO COUNTY, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENTS
LEESBURG							
Bird	CHLIDONIAS NIGER	BLACK TERN	SE	**	T34NR06E 25	1949	
Bird	IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	T34NR06E 25 & 36	1950	NEST
Forest	FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	T33NR07E 6 SWQ	1983	
Forest	FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	T33NR07E 06 SWQ	1983	
Reptile	CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	T34NR07E 31 NWQ NEQ	1984	
Reptile	EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	T34NR07E 31 NEQ	1997	
Vascular Plant	BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	T34NR06E DEWART LAKE	1941	
MILFORD							
Vascular Plant	GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	T34NR06E 24 E HALF SWQ	1982	
Wetland	WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	T34NR06E 24 E HALF SWQ	1982	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern
FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, ESA=appearance similar to LE species,**=not listed

APPENDIX C:

ENDANGERED, THREATENED, AND RARE SPECIES LIST, KOSCIUSKO COUNTY, INDIANA

DEWART LAKE DIAGNOSTIC STUDY KOSCIUSKO COUNTY, INDIANA

November 12, 1999

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

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARETHUSA BULBOSA	SWAMP-PINK	SX	**	SX	G4
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX AUREA	GOLDEN-FRUITED SEDGE	SR	**	S2	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX DISPERMA	SOFTLEAF SEDGE	SE	**	S1	G5
CAREX ECHINATA	LITTLE PRICKLY SEDGE	SE	**	S1	G5
CAREX FLAVA	YELLOW SEDGE	ST	**	S2	G5
CAREX PSEUDOCYPERUS	CYPERUS-LIKE SEDGE	SE	**	S1	G5
CORNUS AMOMUM SSP AMOMUM	SILKY DOGWOOD	SE	**	S1	G5T?
CORNUS CANADENSIS	BUNCHBERRY	SE	**	S1	G5
CYPRIPEDIUM CALCEOLUS VAR PARVIFLORUM	SMALL YELLOW LADY'S-SLIPPER	SR	**	S2	G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
ELEOCHARIS GENICULATA	CAPITATE SPIKE-RUSH	ST	**	S2	G5
ERIOPHORUM ANGUSTIFOLIUM	NARROW-LEAVED COTTON-GRASS	SR	**	S2	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	S2	G5
JUGLANS CINEREA	BUTTERNUT	WL	**	S3	G3G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MYRIOPHYLLUM VERTICILLATUM	WHORLED WATER-MILFOIL	ST	**	S2	G5
PANICUM BOREALE	NORTHERN WITCHGRASS	SR	**	S2	G5
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
POTAMOGETON EPIHYDRUS	NUTTALL PONDWEED	SE	**	S1	G5
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON OAKESIANUS	OAKES PONDWEED	SE	**	S1	G4
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
SCIRPUS SUBTERMINALIS	WATER BULRUSH	SR	**	S2	G4G5
SELAGINELLA APODA	MEADOW SPIKE-MOSS	SE	**	S1	G5
SPARGANIUM ANDROCLADUM	BRANCHING BUR-REED	ST	**	S2	G4G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
STENANTHIUM GRAMINEUM	EASTERN FEATHERBELLS	SE	**	S1	G4G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5

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

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
WOLFFIELLA FLORIDANA	SWORD BOGMAT	SX	**	SX	G5
ZANNICHELLIA PALUSTRIS	HORNED PONDWEED	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
MOLLUSCA: BIVALVIA (MUSSELS)					
ALASMIDONTA VIRIDIS	SLIPPERSHELL MUSSEL	**	**	S2	G4G5
EPIOBLASMA OBLIQUATA PEROBLIQUA	WHITE CAT'S PAW PEARLYMUSSEL	SE	LE	S1	G1T1
EPIOBLASMA TORULOSA RANGIANA	NORTHERN RIFFLESHELL	SE	LE	S1	G2T2
LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
LAMPSILIS OVATA	POCKETBOOK	**	**	S2	G5
LIGUMIA RECTA	BLACK SANDSHELL	**	**	S2	G5
PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G2
PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4G5
QUADRULA CYLINDRICA CYLINDRICA	RABBITSFOOT	SE	**	S1	G3T3
TOXOLASMA LIVIDUS	PURPLE LILLIPUT	SSC	**	S2	G2
TOXOLASMA PARVUM	LILLIPUT	**	**	S2	G5
VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G1G2
VILLOSA LIENOSA	LITTLE SPECTACLECASE	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
EURISTRYMON ONTARIO	NORTHERN HAIRSTREAK	WL	**	S2S4	G4
HESPERIA LEONARDUS	LEONARDUS SKIPPER	SR	**	S2	G4
LYCAENA HELLOIDES	PURPLISH COPPER	**	**	S2S4	G5
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
ARTHROPODA: INSECTA: LEPIDOPTERA (MOTHS)					
HEMILEUCA SP 3	MIDWESTERN FEN BUCKMOTH	**	**	S1?	G3G4
LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	S2	GU
FISH					
ACIPENSER FULVESCENS	LAKE STURGEON	SE	**	S1	G3
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
HYBOPSIS AMBLOPS	BIGEYE CHUB	**	**	S2	G5
NOTROPIS HETEROLEPIS	BLACKNOSE SHINER	**	**	S2	G5
PERCINA EVIDES	GILT DARTER	SE	**	S1	G4
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER	SE	**	S2	G5

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

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	SE	**	S2	G5T2T3
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
FALCO PEREGRINUS	PEREGRINE FALCON	SE	E(S/A)	S2B,SZN	G4
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S1S2B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3

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

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

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APPENDIX D:

MACROINVERTEBRATE AND HABITAT DATA SHEETS

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

STREAM: Cable Run **RIVER MILE:** ______ **DATE:** 8/11/2004 **QHEI SCORE** 44

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

SUBSTRATE SCORE 14

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

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

SUBSTRATE ORIGIN (all)

- [ ] LIMESTONE(1)
- [X] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

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 7

TYPE (Check all that apply)

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

AMOUNT (Check only one or Check 2 and AVERAGE)

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

COMMENTS:

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

CHANNEL SCORE 8

SINUOSITY

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

DEVELOPMENT

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

CHANNELIZATION

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

STABILITY

- [X] HIGH(3)
- [ ] MODERATE(2)
- [ ] LOW(1)

MODIFICATION/OTHER

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

COMMENTS:

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

RIPARIAN SCORE 6

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[X]	[ ]	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)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[X]	[X]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

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

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 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)
- [ ] FAST(1)
- [X] MODERATE(1)
- [ ] SLOW(1)
- [ ] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS: No Pools

RIFFLE SCORE 3

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

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

RIFFLE/RUN EMBEDDEDNESS

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

COMMENTS:

6) GRADIENT (FEET/MILE): 0.1

% POOL ______ % RIFFLE ______ % RUN ______ **GRADIENT SCORE** 2

Appendix D. Detailed mIBI results.

Table A. Cable Run multi-habitat macroinvertebrate results, August 11, 2004.

Order	Family	#	EPT	# w/t	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	1		1	4	4	0.79
Colepotera	Dytiscidae	2					1.59
Colepotera	Noteridae	3					2.38
Diptera	Chironomidae	3		3	6	18	2.38
Diptera	Tabanidae	1		1	6	6	0.79
Diptera	Tipulidae	7		7	3	21	5.56
Ephemeroptera	Heptageniidae	24	24	24	4	96	19.05
Gastropoda	Lymnaeidae	10		10	6	60	7.94
Hempitera	Gerridae	3		3	5	15	2.38
Hirundinea	Helobdella	1		1	10	10	0.79
Isopoda	Asellidae	3		3	8	24	2.38
Lepidoptera	Langessa	33					26.19
Odonata	Gomphidae	1		1	1	1	0.79
Trichoptera	Hydropsychidae	34	34	34	4	136	26.98
		126	**58**	**88**		**4.4**	
						HBI	

Table B. Cable Run mIBI metrics, August 11, 2004.

		Metric Score
HBI	4.40	6
Number of Taxa (family)	14	6
Percent Dominant Taxa	27.0	6
EPT Index	2	0
EPT Count	58	4
EPT Count/Total Count	0.46	4
EPT Abundance/Chironomid Abundance	19.33	8
Chironomid Count	3.00	8
mIBI Score		**5.3**

APPENDIX E:

HISTORIC WATER QUALITY DATA COLLECTED IN THE DEWART LAKE WATERSHED

DEWART LAKE DIAGNOSTIC STUDY KOSCIUSKO COUNTY, INDIANA

Appendix E. Results of Clean Lakes Program Assessments in 1988, 1994, and 2000.

Table A. Water Quality Characteristics of Dewart Lake, 8/22/88.

Parameter	**Epilimnetic Sample**	**Hypolimnetic Sample**	**Indiana TSI Points (based on mean values)**
pH	8.4	7.3	-
Alkalinity	101 mg/L	142 mg/L	-
Conductivity	400 μmhos	320 μmhos	-
Secchi Depth Transparency	8.86 ft	-	0
Light Transmission @ 3 ft.	35 %	-	3
1% Light Level	25.5 feet	-	-
Total Phosphorous	0.204 mg/L	0.090 mg/L	3
Soluble Reactive Phosphorous	0.026 mg/L	0.010 mg/L	0
Nitrate-Nitrogen	0.298 mg/L	0.417 mg/L	1
Ammonia-Nitrogen	0.055 mg/L	1.559 mg/L	3
Organic Nitrogen	0.888 mg/L	0.123 mg/L	1
Oxygen Saturation @ 5ft.	91.8 %	-	0
% Water Column Oxic	27.3 %	-	4
Plankton Density	843 #/L	-	0
Blue-Green Dominance	63%	-	10
Chlorophyll *a*	-	-	-
		TSI score	**25**

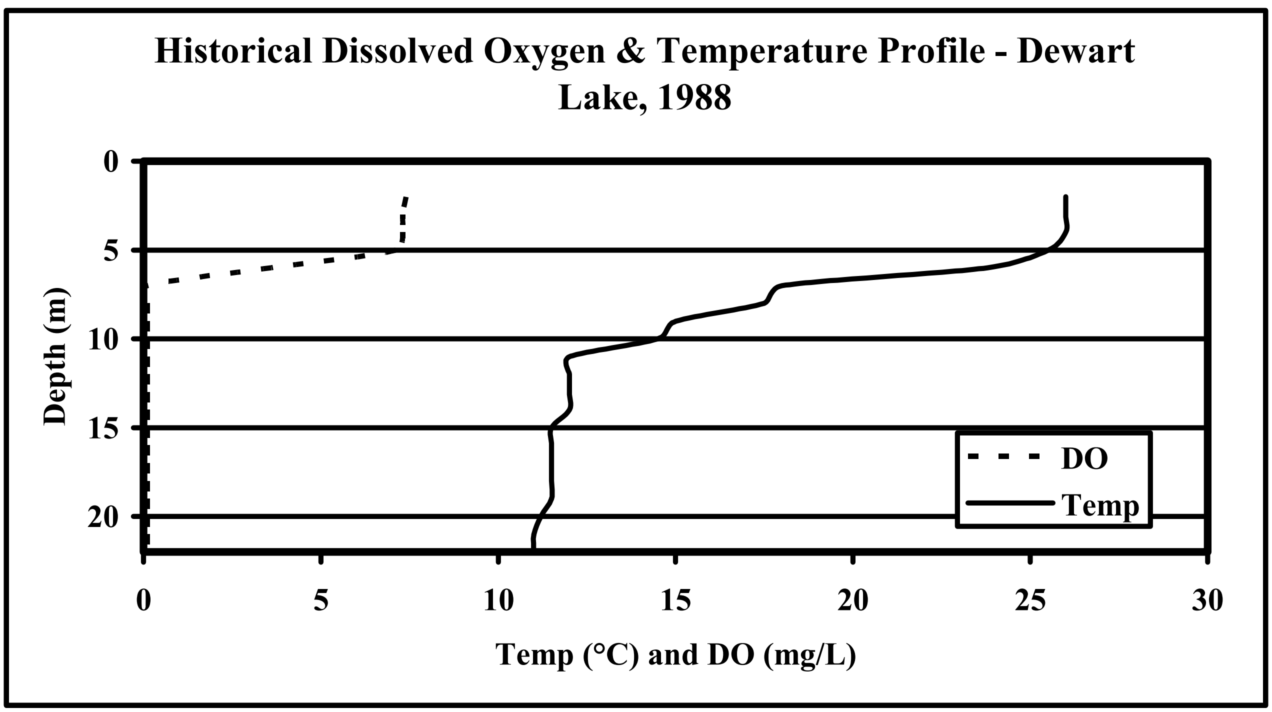

Figure A. Historical dissolved oxygen profile for Dewart Lake, sampled by the Indiana Clean Lakes Program in 1988.

Table B. Water Quality Characteristics of Dewart Lake, 8/1/94.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.7	7.7	-
Alkalinity	125 mg/L	174 mg/L	-
Conductivity	318 µmhos	312 µmhos	-
Secchi Depth Transparency	2.3 meters	-	0
Light Transmission @ 3 ft.	40 %	-	3
1% Light Level	20 feet	-	-
Total Phosphorous	0.017 mg/L	0.094 mg/L	2
Soluble Reactive Phosphorous	0.002 mg/L	0.074 mg/L	1
Nitrate-Nitrogen	0.022 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.765 mg/L	1
Organic Nitrogen	0.23 mg/L	0.23 mg/L	0
Oxygen Saturation @ 5ft.	108 %	-	0
% Water Column Oxic	37 %	-	3
Plankton Density	7213 #/L	-	2
Blue-Green Dominance	70.3%	-	10
Chlorophyll *a*	1.03 µg/L	-	-
		TSI score	**22**

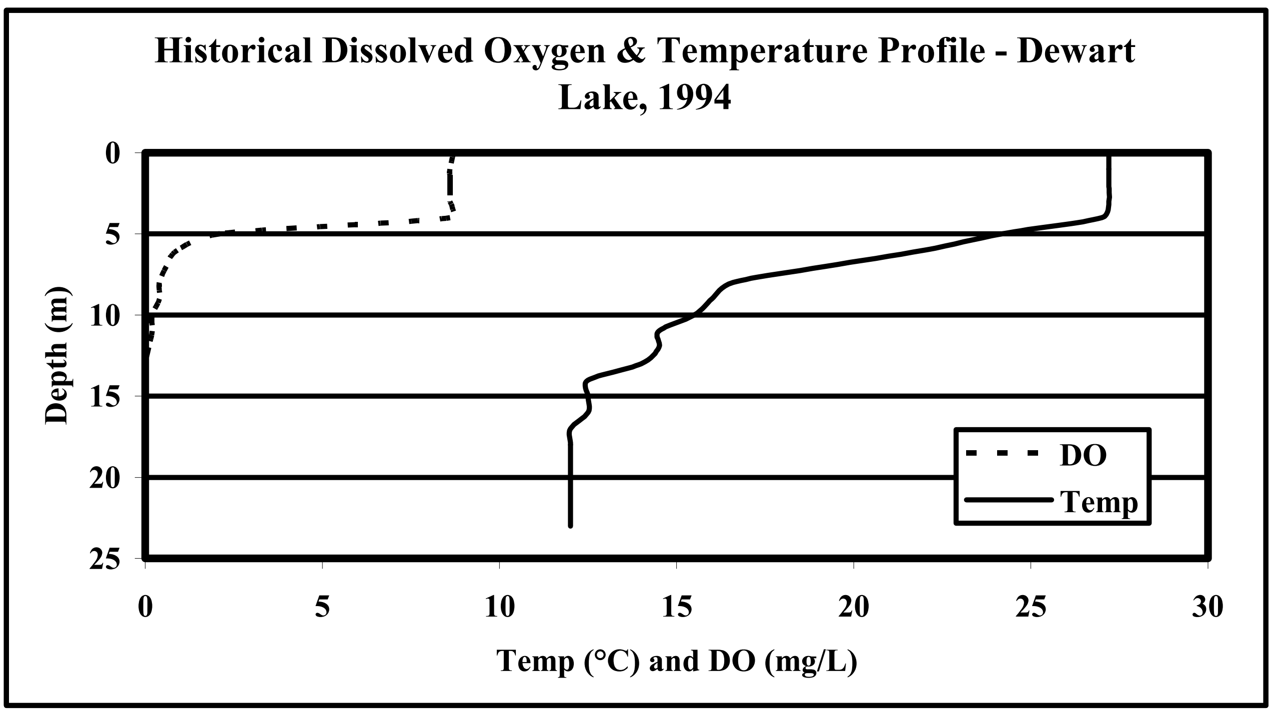

Figure B. Historical dissolved oxygen profile for Dewart Lake, which were sampled by the Clean Lakes Program in 1994.

Table C. Water Quality Characteristics of Dewart Lake, 8/1/00.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Indiana TSI Points (based on mean values)
pH	8.5	7.6	-
Alkalinity	116 mg/L	148 mg/L	-
Conductivity	304.8 μmhos	262.2 μmhos	-
Secchi Depth Transparency	2.2 meters	-	0
Light Transmission @ 3 ft.	38 %	-	3
1% Light Level	20 feet	-	-
Total Phosphorous	0.013 mg/L	0.058 mg/L	1
Soluble Reactive Phosphorous	0.016 mg/L	0.070 mg/L	2
Nitrate-Nitrogen	0.022 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.342 mg/L	0
Organic Nitrogen	0.606 mg/L	0.5 mg/L	1
Oxygen Saturation @ 5ft.	106 %	-	0
% Water Column Oxic	26 %	-	4
Plankton Density	3112 #/L	-	1
Blue-Green Dominance	66.7%	-	10
Chlorophyll *a*	2.79 μg/L	-	-
		TSI score	**22**

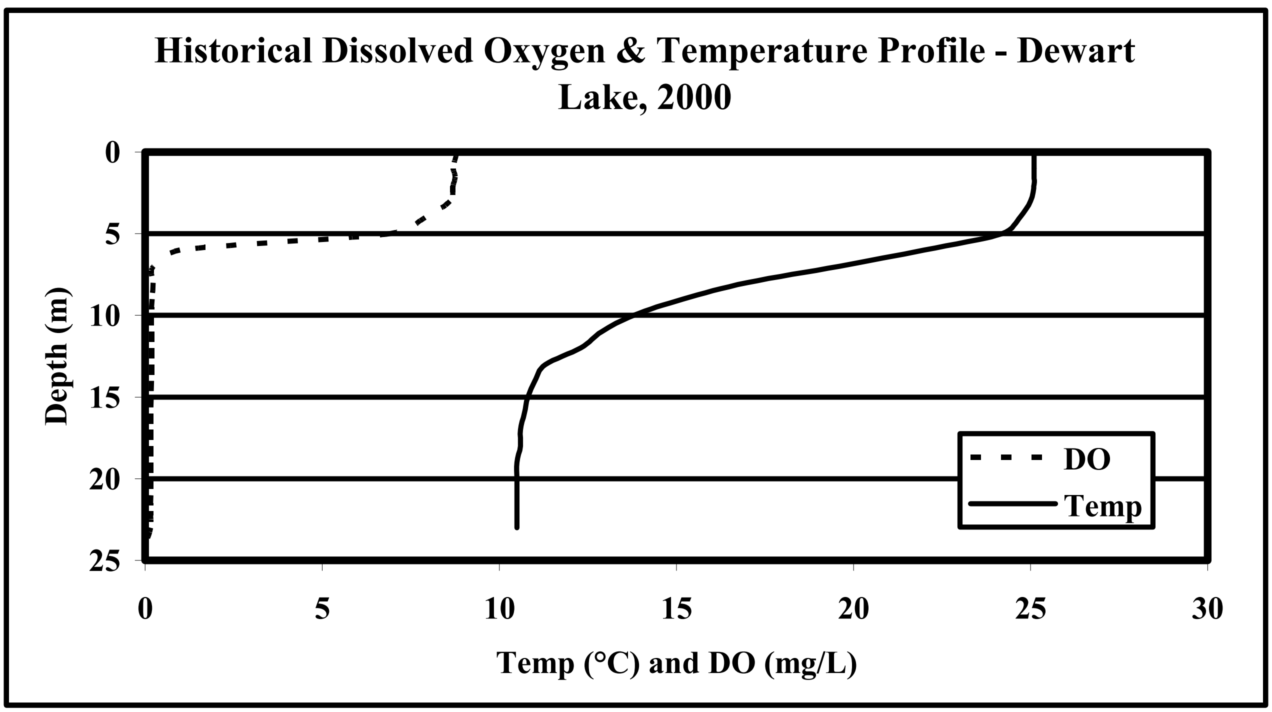

Figure C. Historical dissolved oxygen profile for Dewart Lake, sampled by the Indiana Clean Lakes Program in 2000.

APPENDIX F:

PLANT COMMUNITY SURVEY

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Aquatic Vegetation Reconnaissance Sampling

Waterbody Cover Sheet

Surveying Organization: JFNew

Waterbody Name: Dewart Lake

Lake ID:

County: Kosciusko County

Date: 8/3/04

Habitat Stratum: IL

Ave. Lake Depth (ft): 16.3 ft

Lake Level: NA

GPS Metadata

Crew Leader: M. Giolitto

Datum:	Zone:	Accuracy:
NAD83	16N	2 m.

Recorder: S. Namestnik

Method: Trimble PRO XRS Receiver

Secchi Depth (ft): 9.3 ft

Total # of Plant Beds Surveyed: 9

Total # of Species: 44

Littoral Zone Size (acres): 414 ac

- ❑ Measured
- ✓ Estimated

Littoral Zone Max. Depth (ft): 28 ft

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

Notable Conditions:

Abbreviation	**Plant Species**	**Common Name**
ALGAE		Filamentous algae
BIDBEC	*Bidens beckii*	Beck's water marigold
CERDEM	*Ceratophyllum demersum*	Coontail
CEPOCC	*Cephalanthus occidentalis*	Buttonbush
CHARA	*Chara* species	Chara species
DECVER	*Decodon verticillatus*	Swamp loosestrife
ELOCAN	*Elodea canadensis*	Common waterweed
HETDUB	*Heteranthia dubia*	Water star grass
JUSAME	*Justicia americana*	Water willow
LEEORY	*Leersia oryzoides*	Rice cutgrass
LEMMIO	*Lemna minor*	Lesser duckweed
LEMTRI	*Lemna trisulca*	Forked duckweed
LYTSAL	*Lythrum salicaria*	Purple loosestrife
MYREXA	*Myriophyllum exalbescens*	Northern water milfoil
MYRHET	*Myriophyllum heterophyllum*	Various leaved water milfoil
MYRSPI	*Myriophyllum spicatum*	Eurasian water milfoil
NAJGUA	*Najas guadalupensis*	Southern naiad
NAJMAR	*Najas marina*	Spiny naiad
NUPADV	*Nuphar advena*	Spatterdock
NYMTUB	*Nymphaea odorata tuberosa*	White water lily
PELVIR	*Peltandra virginica*	Arrow arum
PHAARU	*Phalarus arundinacea*	Reed canary grass
PONCOR	*Pontederia cordata*	Pickerel weed
POTAMP	*Potamogeton amplifolius*	Large leaved pondweed
POTCRI	*Potamogeton crispus*	Curly-leaf pondweed
POTFRI	*Potamogeton friesii*	Fries pondweed
POTGRA	*Potamogeton gramineus*	Variable leaved pondweed
POTILL	*Potamogeton illinoensis*	Illinois pondweed
POTNAT	*Potamogeton natans*	Floating leaved pondweed
POTNOD	*Potamogeton nodosus*	Long leaved pondweed
POTPEC	*Potamogeton pectinatus*	Sago pondweed
POTPUS	*Potamogeton pusillus*	Small pondweed
POTRIC	*Potamogeton richardsonii*	Richardson's pondweed
POTROB	*Potamogeton robbinsii*	Robbins pondweed
POTZOS	*Potamogeton zosterformis*	Flat stem pondweed
SALINT	*Salix interior*	Sandbar willow
SALNIG	*Salix nigra*	Black willow
SAGLAT	*Sagittaria latifolia*	Arrowhead
SCIACU	*Scirpus acutus*	Hardstem bulrush
SCIPUN	*Scirpus pungens*	Chairmakers rush
SPAEUR	*Sparganium eurycarpum*	Giant burreed
SPIPOL	*Spirodela polyrhiza*	Giant duckweed
TYP sp.	*Typha* species	Cattail
UTRVUL	*Utricularia vulgaris*	Common bladderwort
WOLCOL	*Wolffia columbiana*	Columbia watermeal

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/03/04**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 01	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 16.9 ac					UTM Northing: 601656.76872
Substrate: 3	Waterbody ID:				UTM Easting: 4581168.82206
Marl?	Total # of Species: 32				Max. Lakeward Extent of Bed
High Organic? 1	**CanopyAbundance at Site**				UTM Northing: 601752.25945
	S: 4	N: 1	F: 4	E: 1	UTM Easting: 451177.12560

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUPADV	3			
NYMTUB	3			
POTAMP	2			
ELOCAN	2			
CERDEM	2			
POTZOS	2		1	
NAJGUA	2			
CHARA	4			
MYRSPI	2			
MYREXA	2		1	
NAJMAR	1			
POTCRI	1			
LEMTRI	1			
SPIPOL	1			
LEMMIO	1			
PELVIR	1			
SAGLAT	1			
LYTSAL	1			
JUSAME	1			
TYP sp.	1			
POTGRA	1		1	
PONCOR	1			

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/03/04**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 01	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 16.9 ac					UTM Northing: 601656.76872
Substrate: 3	Waterbody ID:				UTM Easting: 4581168.82206
Marl?	Total # of Species: 32				Max. Lakeward Extent of Bed
High Organic? 1	**CanopyAbundance at Site**				UTM Northing: 601752.25945
	S: 4	N: 1	F: 4	E: 1	UTM Easting: 451177.12560

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
SALNIG	1			
POTPEC	1		1	
MYRHET	1		1	
POTPUS	1		1	
SCIPUN	1			
LEEORY	1			
SPAEUR	1			
POTNAT	1		1	
POTILL	1		1	
POTFRI	1		1	

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	DATE: 8/03/04

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 02	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 62.7 ac					UTM Northing: 602412.39104
Substrate: 6	Waterbody ID:				UTM Easting: 4581123.15258
Marl?	Total # of Species: 18				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				UTM Northing: 602258.77552
	S: 4	N: 1	F: 1	E: 1	UTM Easting: 450957.08174

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYRSPI	2		1	
CHARA	4			
POTILL	2		1	
POTROB	1		1	
SPIPOL	1			
CERDEM	1			
POTNOD	1		1	
NAJGUA	1			
POTZOS	1			
POTAMP	1			
PELVIR	1			
JUSAME	1			
SCIACU	1			
POTPEC	1		1	
POTFRI	1		1	
POTPUS	1		1	
NYMTUB	1			
MYREXA	4		1	

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew				**DATE: 8/03/04**
SITE INFORMATION				**SITE COORDINATES**
Plant Bed ID: 03	Waterbody Name: Dewart Lake			Center of the Bed
Bed Size: 17.7 ac				UTM Northing: 603404.66432
Substrate: 6	Waterbody ID:			UTM Easting: 4580977.84059
Marl?	Total # of Species: 22			Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**			UTM Northing: 603271.80764
	S: 4	N: 1	F: 2	E: 2	UTM Easting: 4580923.86757

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NUPADV	2			
CERDEM	1			
NYMTUB	2			
LYTSAL	1			
TYP sp.	1			
MYREXA	3		1	
POTZOS	2			
POTCRI	1			
POTNOD	2			
UTRVUL	1			
POTPEC	1			
SAL sp.	1			
PONCOR	1			
BIDBEC	1		1	
MYRHET	1			
NAJGUA	1		1	
PELVIR	1			
POTRIC	1			
POTAMP	2			
HETDUB	1		1	
JUSAME	2			
CHARA	3			

Individual Plant Bed Survey

Comments: This bed covers the cove adjacent to the Girl Scouts' Camp.

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/03/04**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 04	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 34.9 ac					UTM Northing:603417.11963
Substrate: 6	Waterbody ID:				UTM Easting: 4580388.28911
Marl?	Total # of Species: 19				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				UTM Northing: 603317.47712
	S: 4	N: 1	F: 1	E: 1	UTM Easting: 4580230.52181

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYRSPI	3		1	
CHARA	3			
POTILL	2		1	
CERDEM	1			
NAJGUA	1			
JUSAME	1			
PELVIR	1			
POTNOD	1			
POTPEC	1		1	
HETDUB	3		1	
POTCRI	1			
POTAMP	2			
TYP sp.	1			
LYTSAL	1			
NYMTUB	1			
POTFRI	1		1	
PONCOR	1			
ALGAE	1			
POTGRA	1		1	

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					DATE: 8/03/04
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 05	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 10.4 ac					UTM Northing: 603803.23433
Substrate: 2/muck	Waterbody ID:				UTM Easting: 4579815.34471
Marl?	Total # of Species: 24				Max. Lakeward Extent of Bed
High Organic? 1	**CanopyAbundance at Site**				UTM Northing: 603686.98474
	S: 3	N: 2	F: 3	E: 4	UTM Easting: 4579840.25533

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
NYMTUB	2			
NUPADV	3			
TYP sp.	4			
LYTSAL	1			
JUSAME	1			
SAL sp.	1			
MYREXA	3			
CHARA	2			
HETDUB	2			
NAJGUA	1			
POTAMP	1			
POTZOS	1			
MYRHET	1			
BIDBEC	1			
CERDEM	2			
ALGAE	3			
POTCRI	1			
LEMTRI	1			
ELOCAN	1			
LEMMIO	2			
SPIPOL	2			
POTPEC	1			

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/03/04**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 05	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 10.4 ac					UTM Northing: 603803.23433
Substrate: 2/muck	Waterbody ID:				UTM Easting: 4579815.34471
Marl?	Total # of Species: 24				Max. Lakeward Extent of Bed
High Organic? 1	**CanopyAbundance at Site**				UTM Northing: 603686.98474
	S: 3	N: 2	F: 3	E: 4	UTM Easting: 4579840.25533

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
DECVER	1			
WOLCOL	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 suspected
2 = Genus suspected
3 = Unknown

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/03/04**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 06	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 25.3 ac					UTM Northing: 603404.66432
Substrate: 3	Waterbody ID:				UTM Easting: 4579960.65669
Marl?	Total # of Species: 21				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				UTM Northing: 603437.87848
	S: 4	N: 1	F: 1	E: 1	UTM Easting: 4580043.69211

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
POTAMP	2			
HETDUB	2			
NYMTUB	1			
NUPADV	1			
JUSAME	1			
POTCRI	1			
POTGRA	1		1	
MYREXA	3			
PELVIR	1			
ALGAE	2			
SPAEUR	1			
TYP sp.	1			
LEMTRI	1			
CHARA	4			
CERDEM	1			
PHAARU	1			
POTFRI	1		1	
POTNOD	1			
POTPUS	1		1	
POTPEC	1			
NAJGUA	1		1	

Individual Plant Bed Survey

Comments: Secchi disk transparency just over 4 feet in the channel.

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew					**DATE: 8/03/04**
SITE INFORMATION					**SITE COORDINATES**
Plant Bed ID: 07	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 125.9 ac					UTM Northing: 602628.28314
Substrate: 6, muck in coves	Waterbody ID:				UTM Easting: 4580168.24524
Marl?	Total # of Species: 22				Max. Lakeward Extent of Bed
High Organic? In coves	**CanopyAbundance at Site**				UTM Northing: 602777.74689
	S: 4	N: 1	F: 3	E: 2	UTM Easting: 4580683.06485

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
TYP sp.	2			
NYMTUB	2			
NUPADV	2			
POTAMP	2			
CHARA	3			
POTNAT	2		1	
MYREXA	3			
PONCOR	1			
LYTSAL	1			
ALGAE	1			
CEPOCC	1			
POTFRI	1		1	
NAJGUA	1			
POTILL	2		1	
POTPEC	1			
PELVIR	1			
JUSAME	1			
SCIACU	2			
DECVER	1			
SCIPUN	1			
MYRHET	1			
HETDUB	1			

Individual Plant Bed Survey

Comments: Plant bed extends along the southern undeveloped shoreline and includes the island in the middle of the lake.

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew	DATE: 8/03/04

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 08	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 20.6 ac					UTM Northing: 601847.75019
Substrate: 3	Waterbody ID:				UTM Easting: 4579935.74607
Marl?	Total # of Species: 15				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				UTM Northing: 601806.23248
	S: 3	N: 1	F: 2	E: 1	UTM Easting: 4580101.81691

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
MYREXA	2		1	
CHARA	3			
NAJGUA	1		1	
HETDUB	1			
POTPUS	1		1	
POTAMP	2			
JUSAME	1			
POTZOS	1			
POTPEC	1		1	
ELOCAN	1			
CERDEM	1			
NYMTUB	2			
BIDBEC.	1			
POTFRI	1		1	
POTGRA	1		1	

Individual Plant Bed Survey

Comments:

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

Aquatic Vegetation Plant Bed Data Sheet

State of Indiana Department of Natural Resources

ORGANIZATION: JFNew | **DATE: 8/03/04**

SITE INFORMATION					SITE COORDINATES
Plant Bed ID: 09	Waterbody Name: Dewart Lake				Center of the Bed
Bed Size: 29.4 ac					UTM Northing:601926.63384
Substrate: 6	Waterbody ID:				UTM Easting: 4580629.09183
Marl?	Total # of Species: 9				Max. Lakeward Extent of Bed
High Organic?	**CanopyAbundance at Site**				UTM Northing: 601997.21394
	S: 3	N: 1	F: 1	E: 1	UTM Easting: 4580649.85068

SPECIES INFORMATION

Species Code	Abundance	QE	Vchr.	Ref. ID
CHARA	3			
POTAMP	2			
POTNOD	1			
JUSAME	1			
CERDEM	1			
POTGRA	2		1	
POTZOS	1			
NAJGUA	2			
POTFRI	1		1	

Individual Plant Bed Survey

Comments: Bed lies parallel to the developed western shoreline.

REMINDER INFORMATION

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

Marl
1 = Present
0 = absent

High Organic
1 = Present
0 = absent

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

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

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

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

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

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

APPENDIX G:

ANNOTATED BIBLIOGRAPHY OF IDNR FISHERIES SURVEYS OF DEWART LAKE

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Appendix G. Annotated bibliography.

Taylor, M. 1972. Coldwater Fishery Potential. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Indiana Department of Natural Resources, Division of Fish and Wildlife stated on July 24, 1972 that based on water quality, Dewart Lake has little potential to develop as a coldwater fishery. The IDNR recommended that Dewart Lake should not be given any further consideration as a coldwater fishery.

Shipman, S. 1976. Dewart Lake- Fish Management Report. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife conducted a standard fisheries survey of Dewart Lake on July 12-16, 1976. During the 1976 survey, bluegills dominated the Dewart Lake fishery. Lake chubsucker, yellow perch, pumpkinseed, largemouth bass, and redear were also major components of the fishery. The IDNR recommended stocking walleye, a predator, in Dewart Lake.

Pearson, J. 1982. Fishery Survey at Dewart Lake and First-Year Walleye Management. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife conducted a fisheries survey of Dewart Lake on July 12-14, 1982. The survey compared its results to the 1976 fisheries report. The IDNR reported no significant changes between the 1976 and 1982 reports, bluegills still dominated the Dewart Lake fishery. Yellow perch, lake chubsucker, black crappie, largemouth bass, and redear were also major contributors. The IDNR recommended that the walleye management program be continued.

Pearson, J. 1984. First-Year Survival of 3-4 Inch Walleyes in Dewart Lake. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife accomplished that stocking of walleye fingerlings was more effective than similar stocking in Dewart Lake. The IDNR recommended that additional stocking of 3-4 inch walleyes be made in selected northeast Indiana lakes at varying densities to determine the most favorable size and number.

Pearson, J. 1985. Survival of 3-4 Inch Walleye Fingerlings Verses Fry in Dewart Lake. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife compared stocking results between the 5000 walleye fingerlings and the 1.6 million fry released between July 14, 1982 and May 11, 1983. The IDNR concluded that stocking of 3-4 inch walleyes were more effective than high density stocking of either walleye fry or two-inch fingerlings, therefore; Dewart Lake should again be considered for stocking once the production of walleye fingerlings increased.

Walterhouse, M. 1985. Results of Walleye Stockings at Dewart Lake. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife evaluated walleye stocking at Dewart Lake between 1982-1989. The IDNR found that walleye stocking efforts could be successful if advance fingerlings are stocked at 16.2 walleye per acre. The IDNR has no future plans for growing advance fingerlings while hatchery techniques remain costly.

Pearson, J. 1995. Fish Management Report. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

The Indiana Department of Natural Resources, Division of Fish and Wildlife conducted a fisheries survey on July 24-26, 1995. During the 1995 survey, there was a dramatic increase in northern pike, populations of bluegills, bass, perch, and crappies have been fairly stable. The IDNR did not recommend an immediate fish management program. However, the effects of zebra mussels should be monitored.

APPENDIX H:

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

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Appendix H. Fish species collected during Indiana Department of Natural Resources surveys of Dewart Lake.

		Year				
Common Name	**Scientific Name**	**1976**	**1982**	**1983***	**1995**	**2003**
Banded Killifish	*Fundulus diaphanus*				X	
Black Crappie	*Pomoxis nigromaculaus*	X	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X	X
Bluntnose Minnow	*Pimephales notatus*				X	
Bowfin	*Amia calva*	X	X	X	X	X
Brook Silverside	*Labidesthes sicculus*	X	X		X	X
Brown Bullhead	*Ameiurus nebulosus*	X	X	X	X	X
Carp	*Cyprinus carpio*	X	X	X		
Channel Catfish	*Ictalurus punctatus*	X		X		
Golden Shiner	*Notemigonus crysoleucas*	X	X	X	X	X
Grass Pickerel	*Esox americanus*	X	X	X	X	
Green Sunfish	*Lepomis cyanellus*	X		X		
Hybrid Sunfish	*Lepomis sp. x Lepomis sp.*			X		X
Lake Chubsucker	*Erimyzon succeta*	X	X	X	X	
Largemouth Bass	*Micropterus salmoides*	X	X	X	X	X
Logperch	*Percina caprodes*				X	X
Longear Sunfish	*Lepomis megalotis*	X	X			X
Longnose Gar	*Lepisosteus osseus*	X		X	X	X
Mimic Shiner	*Notropis volucellus*					X
Northern Pike	*Esox lucius*		X	X	X	X
Pumpkinseed	*Lepomis gibbosus*	X	X	X	X	
Redear Sunfish	*Lepomis microlophus*	X	X	X	X	X
Rock Bass	*Ambloplites rupestris*	X	X	X	X	
Smallmouth Bass	*Micropterus dolomieu*				X	X
Spotted Gar	*Lepisosteus oculatus*	X	X	X	X	X
Stonecat	*Noturus flavus*					X
Warmouth	*Lepomis gulosus*	X	X	X	X	X
Walleye	*Stizostedion vitreum*			X	X	X
White Sucker	*Catostomus commersoni*	X	X			
Yellow Bullhead	*Ameiurus natalis*	X	X	X	X	X
Yellow Perch	*Perca flavescens*	X	X	X	X	X
Number of Species		**22**	**20**	**22**	**23**	**21**

* only gillnetting was utilized during this survey

APPENDIX I:

POTENTIAL SHORELINE BUFFER SPECIES

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Appendix I. 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

Common Name	Botanical Name	Approximate Location*
Rattlesnake Master	*Eryngium yuccifolium*	Varies/broad range
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 J:

UTM COORDINATES FOR LOCATIONS OF WATER QUALITY IMPROVEMENT PROJECTS

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Management Technique	Location	UTM Coordinates (NAD 83, Zone 16)	
		northing	easting
CRP/Conservation Tillage	East of CR 300 E, north of Defreese Road	601630.2	4579913.3
CRP/Conservation Tillage	Southwest of the intersection of Defreese Road and CR 300 E	601328.8	4579542.3
CRP/Conservation Tillage	Southeast of the intersection of Defreese Road and CR 300 E	601734.5	4579530.7
Wetland Restoration	South of Defreese Road, east of CR 300 E	601827.3	4579171.3
CRP/Conservation Tillage	South of Defreese Road, east of CR 300 E	601966.4	4578591.6
CRP/Conservation Tillage	West of CR 400 E, south of CR 750 N	602708.4	4578116.3
Wetland Restoration	East of CR 400 E, south of CR 750 N	603241.7	4578139.5
Minor Project	Along Defreese Road between CR 300 E and EMS D18 LN	602638.8	4579530.7
Minor Project	Southwest of the bend in Defreese Road, west of CR 500 E	603647.5	4579368.4
Livestock Fencing	East of the bend in Defreese Road along the south side of Cable Run	603937.3	4579530.7
Filter Strip	East of the bend in Defreese Road along the south side of Cable Run	603902.6	4579449.6
Minor Project	North side of Defreese Road, west of CR 500 E	603983.7	4579171.3
Minor Project	South side of Defreese Road, west of CR 500 E	603995.3	4579009.0
Wetland Restoration	South side of Defreese Road, west of CR 500 E	603995.3	4578835.1
Livestock Fencing	Southeast of the intersection of CR 500 E and CR 950 N	604644.5	4580736.4
Filter Strip	Southeast of the intersection of CR 500 E and CR 950 N	604702.5	4580620.5
Minor Project	East side of Syr-Web Road near CR 900 N	606209.7	4580180.0
Filter Strip	North side of Cable Run, east of CR 620 E	606696.6	4578916.2
Filter Strip	South side of Cable Run, west of CR 550 E	605351.8	4578997.4
Filter Strip	Northeast corner of the intersection of Cr 800 N and CR 550 E	605537.3	4578487.3
Minor Project	South side of CR 800 N, east of CR 550 E	605676.4	4578278.6
Wetland Restoration	South of CR 800 N between CR 500 E and CR 600 E	605467.7	4577965.6
Wetland Restoration	South of CR 800 N, east of CR 600 E	605966.2	4577930.8

APPENDIX K:

POTENTIAL FUNDING SOURCES

DEWART LAKE DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

Appendix K. 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 Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a single project or $300,000 for all projects on a lake or stream. 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. Finally, 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. 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 0 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 Dewart Lake watershed. More information about the LARE program can be found at http://www.in.gov/dnr/soilcons/programs/lare.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant
The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested

for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement. To qualify for implementation projects, there must be a watershed management plan for the receiving waterbody. This plan must meet all of the current 319 requirements. This diagnostic study serves as an n excellent foundation for developing a watershed management plan since it satisfies several, but not all, of the 319 requirements for a watershed management plan. More information about the Section 319 program can be obtained from http://www.in.gov/idem/water/planbr/wsm/319main.html.

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

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

Section 205(j) Water Quality Management Planning Grants

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

Other Federal Grant Programs

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

Watershed Protection and Flood Prevention Program

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

Conservation Reserve Program

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

Wetlands Reserve Program

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

Grassland Reserve Program

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

Community Forestry Grant Program

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

Forest Land Enhancement Program (FLEP)

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

Wildlife Habitat Incentive Program

The Wildlife 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