ROCK LAKE DIAGNOSTIC STUDY

Kosciusko and Fulton Counties, Indiana

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EXECUTIVE SUMMARY

Rock Lake is a shallow 56-acre (22.6-ha) lake that drains approximately 1,818 acres of (735.7) east-central Fulton and southwestern Kosciusko County, Indiana. Two major inlets drain 83 percent of the entire Rock Lake watershed from the south and east, Lautzenhizer Drain (1,127 acres or 456.1 ha) and Landis or Bucher Drain (389 acres or 157.4 ha). Water discharges over a steel sheetpile spillway at the northwest corner of Rock Lake forming Chippewanuck Creek, which empties into the Tippecanoe River north and east of Rochester. The estimated hydraulic residence time of Rock Lake is approximately 2 months.

The glacial end moraines which form the southern and eastern boundary of the watershed are 80 feet higher then Rock Lake. Melting ice within glacial outwash formed a series of deep marshes in the Chippewanuck drainage including Lost Lake (approximately 20 acres or 8 ha), Mud Lake (approximately 10 acres or 4 ha) and Rock Lake. The surface soils are dominated by Kosciusko sandy loams on the ridges, Houghton and Palms muck in the low lying areas, with Morley and Pewamo silt loam in between. Although 10 percent of the watershed is still considered wetland, there was approximately an 84 percent loss of wetlands in the watershed due to drainage of hydric soils for farming and or development. Potentially highly erodible and highly erodible soils cover nearly 33 percent of the watershed and 92 percent of the ground is listed as severely limited for septic tank absorption fields. Rock Lake's watershed is relatively undeveloped with less then 0.2 percent of the watershed acreage developed. However, the highest development density is on Rock Lake's eastern shoreline with approximately 30 residential structures within 12 acres. Most of the development of the Rock Lake shoreline occurred between 1940 and 1965 as summer cottages. The lake now supports many permanent or semi-permanent residences.

Rock Lake has historically, and continues to have water quality below the Indiana mean. Average Secchi disk transparencies varied between 1.5 feet and 3.2 feet (0.46 m and 1 m) between 1975 and 2009. This relatively low clarity is due to plankton production which thrives on the high total phosphorus concentrations averaging 0.15 mg/L. This high phosphorus concentration also supports an extensive, but species limited, aquatic macrophyte community that currently covers more than one-third of the lakes surface area. The macrophyte community in-turn supports a relatively healthy fishery. Since the lake is shallow, having a maximum depth of 16 feet or less, complete mixing of the lake occurs keeping most of the water column supplied with oxygen and providing the fish the use of the entire lake volume. This mixing of oxygen rich surface waters with oxygen poor bottom waters also keep the nutrients cycling throughout the lake. Carp are also contributing to the nutrient cycling by a constant disturbance of the lake bottom. Eurasian watermilfoil, an invasive non-native aquatic macrophyte, was at nuisance levels until recently controlled with aquatic herbicides. The shallow nature and high productivity of Rock Lake means that the lake can be dominated by algae or aquatic macrophytes.

Improving the water quality and clarity of Rock Lake will require the combined efforts of lake shore property owners as well as a few of the major landholders in the watershed. Landowner best management practices including maintenance of septic and agricultural drainage systems are identified with the goal of reducing phosphorus inputs to the lake by 77 percent. This phosphorus is concentrating in the lake and is fueling the macrophyte and algae growth. If the macrophytes are reduced by chemical means, the algae may become more prolific in

successive years. If water clarity is improved, the macrophyte community may become more dense and extensive. The Rock Lake Conservation and Improvement Club should promote homeowner Best Management Practices discussed within this report including use of no-phosphorus fertilizers, keeping animal waste out of the lake, and annual maintenance of septic systems to control nutrients reaching the lake from their properties. The Club should also work with upstream landowners on Landis Ditch or contact the Kosciusko County Soil and Water Conservation District (SWCD) for assistance.

ACKNOWLEDGMENTS

The Rock Lake Diagnostic Study was made possible with funding from the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife, Lake and River Enhancement Program (LARE), and the Rock Lake Improvement Association. The Rock Lake Diagnostic Study was completed by JFNew and their subcontractor, Indiana University School of Public and Environmental Affairs. Thanks go to the dedicated members of the Rock Lake Conservation and Improvement Club for their initiative and assistance in getting this study completed and the landowners who provided permission to walk their land along the drainages. Special thanks to residents who participated in this project including: Mary Whitesell, Larry Montgomery, and Larry Hunter. The authors of this report included William Jones at Indiana University, John Richardson, Betsy Ewoldt, Heather Cecrle, and Tom Estrem at JFNew.

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ROCK LAKE DIAGNOSTIC STUDY
KOSCIUSKO AND FULTON COUNTY, INDIANA

1.0 INTRODUCTION

The purpose of this diagnostic study was to describe the conditions and trends in Rock Lake and its watershed, identify potential problems and make prioritized recommendations to improve water quality. This 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.

Rock Lake is a 56-acre (22.6-ha) lake that lies in the southwest corner of Kosciusko County and along the east central edge of Fulton County, Indiana (Figure 1). Specifically, the lake is located in Section 16 of Township 30 North, Range 5 East (Seward Township) in Kosciusko County and Section 21 of Township 30 North, Range 5 East (Henry Township) in Fulton County. The Rock Lake watershed (a portion of the 14-digit Hydrologic Unit Code 05120106040100) stretches out to the south and east of the lake encompassing approximately 1,818 acres (735.7 ha or 2.84 square miles; Figure 2). Water discharges through the lake's steel sheetpile spillway in the northwest corner and forms Chippewanuck Creek, which empties into the Tippecanoe River north of Rochester. The Tippecanoe River drains to the Wabash River in Lafayette, Indiana, which eventually discharges into the Ohio River in southwestern Indiana. From there, water flows to the Mississippi River and then on to the Gulf of Mexico.

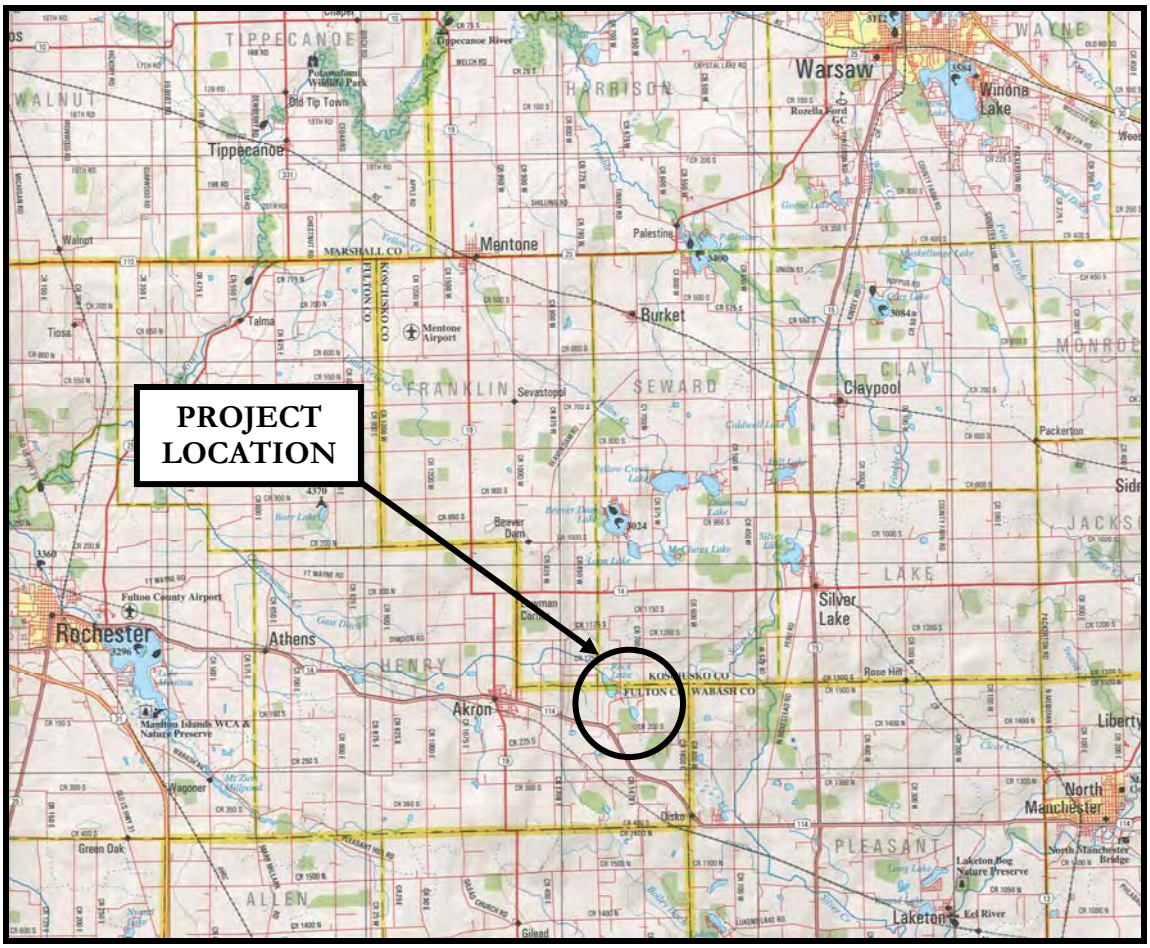

Figure 1. General location of the Rock Lake watershed. Source: DeLorme, 1998.

2.0 WATERSHED CHARACTERISTICS

2.1 Topography and Physical Setting

Rock Lake is a headwaters lake in the Mississippi River Basin. The lake lies south of the north-south continental divide. Similar to the east-west Continental Divide which divides the United States into two watersheds, one that drains to the Atlantic Ocean and one that drains to the Pacific Ocean, the north-south continental divide separates the Mississippi River Basin (land that drains south to the Mississippi River) from the Great Lakes Basin (land that drains north to the Great Lakes). As part of the Mississippi River Basin, water exits Rock Lake near the lake's northwest corner and flows northwest through Fulton County as Chippewanuck Creek. Chippewanuck Creek flows into the Tippecanoe River north of Rochester, which flows west and south, eventually discharging into the Wabash River near Battle Ground, Indiana. The Wabash River flows west and south, eventually discharging into the Ohio River in southwest Indiana.

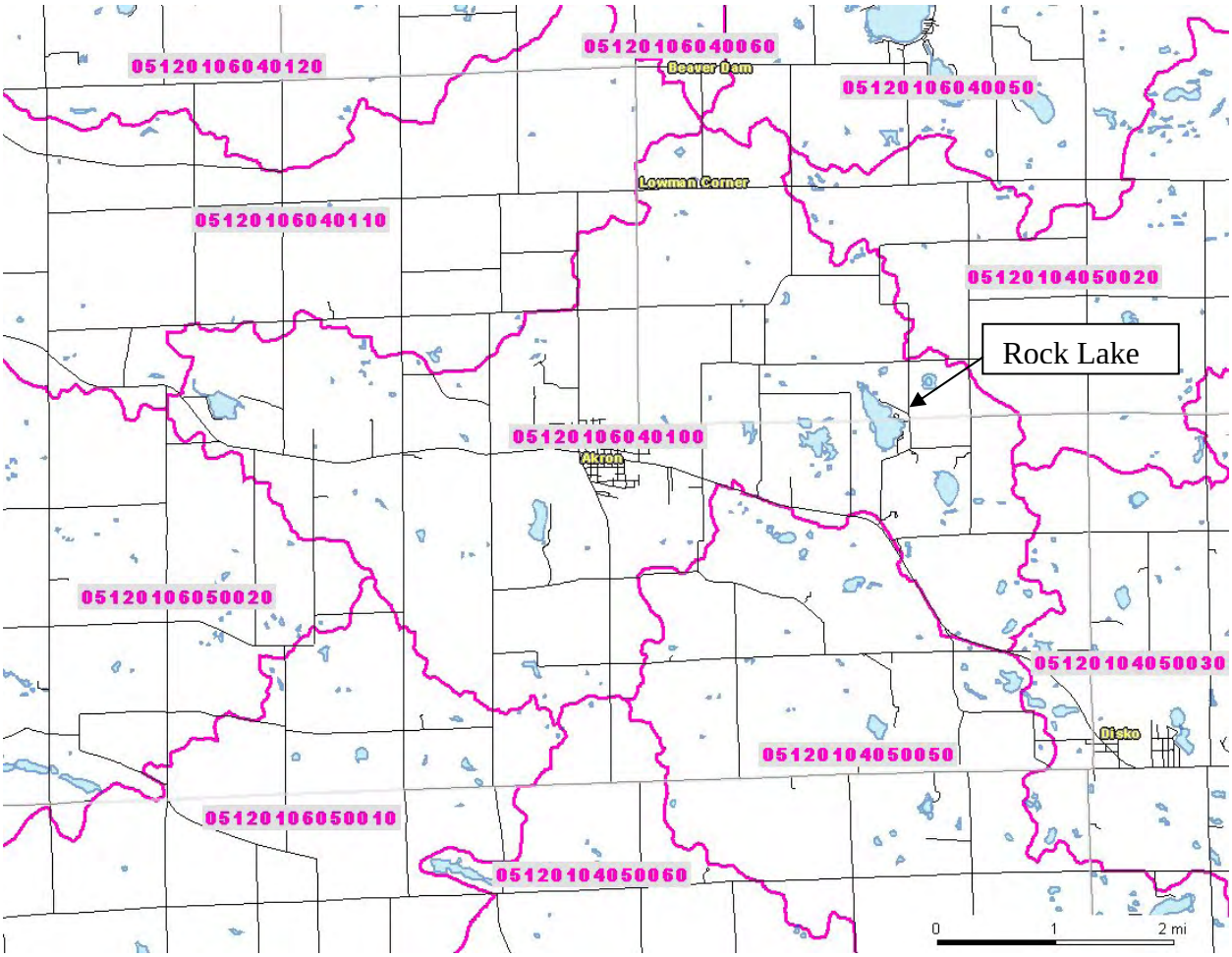

Figure 2a: Rock Lake in relation to its 14-digit Hydrologic Unit in the upper Tippecanoe River basin.

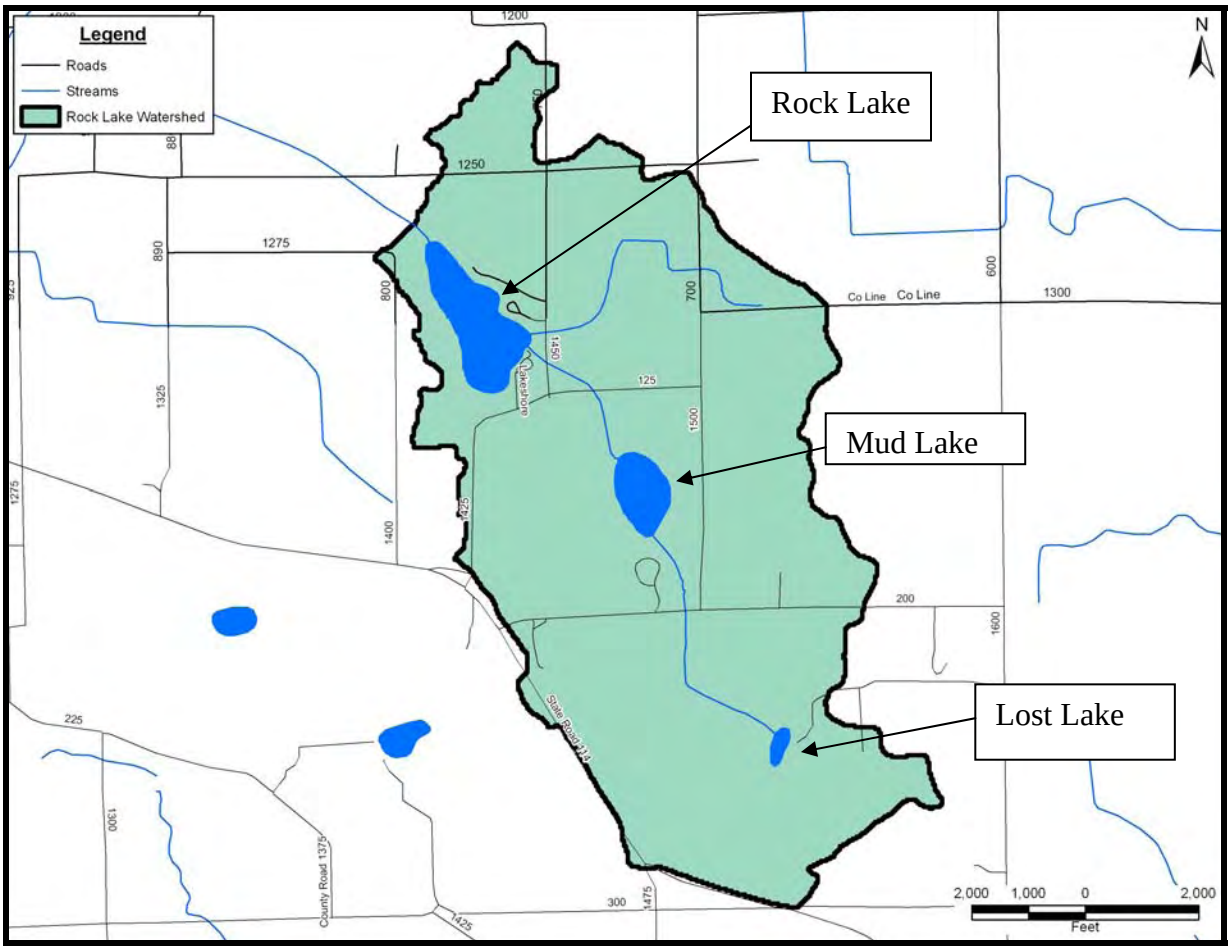

Figure 2b. Rock Lake watershed.

The topography of the Rock Lake watershed reflects the geological history of the watershed. The highest areas of the watershed lie along the watershed's southern and eastern edges, where the Erie Lobe of the last glacial age left end moraines. Along the watershed's eastern boundary, the elevation nears 927 feet (282.5 m) above mean sea level. The ridges along the watershed's southeastern and southern boundaries are nearly as high (910 feet msl), and are equally as steep as the ridge along the eastern watershed boundary. Rock Lake, at an elevation 847 feet (258.2 m) above mean sea level, is the lowest point in the watershed. Figure 3 presents a topographical relief map of the Rock Lake watershed.

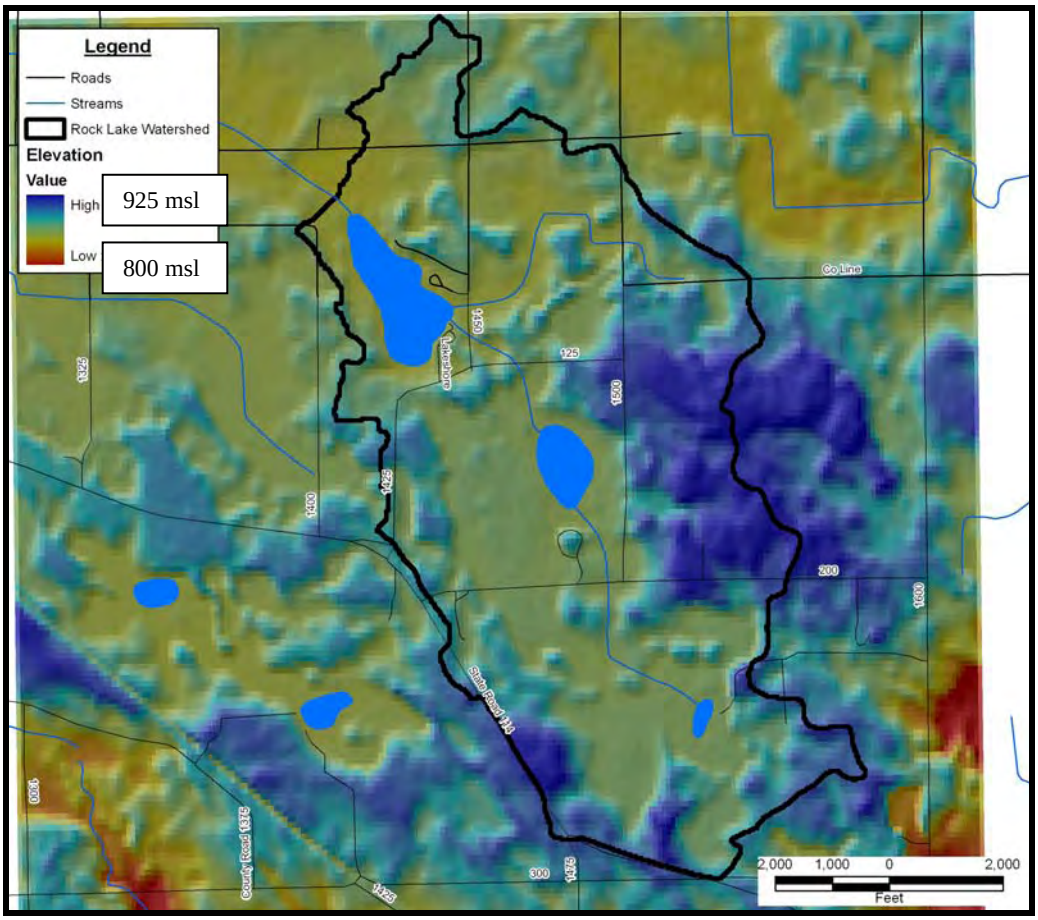

Figure 3. Topographical relief map of the Rock Lake watershed.

Rock Lake has two major subwatershed drainage basins, the 1,127 acre (456.1 ha) Lautzenhizer Drain from the south and the 389 acre (157.4 ha) Landis Drain from the northeast (Figure 4). In addition, a small drainage basin (121 acres or 49.0 ha) drains land directly from the north and approximately 125 (50.6 ha) acres drain directly to the lake from adjacent land on the west and south side of the lake.

Over 83 percent of the surface water entering Rock Lake flows from Lautzenhizer Ditch and Landis Ditch (Table 1). Lautzenhizer Ditch drains the area south of the lake, including Mud and Lost Lakes, and empties into Rock Lake along the lake's eastern shoreline. This drain is a legal drain, which means that the drain may be maintained by the Fulton County Drainage Board. Landis Ditch carries water from the eastern portion of the watershed and empties into Rock Lake immediately north of Lautzenhizer Ditch. Landis Ditch is a legal drain maintained by the Kosciusko County Drainage Board. Figure 4 illustrates the boundaries of each of these subwatersheds of Rock Lake.

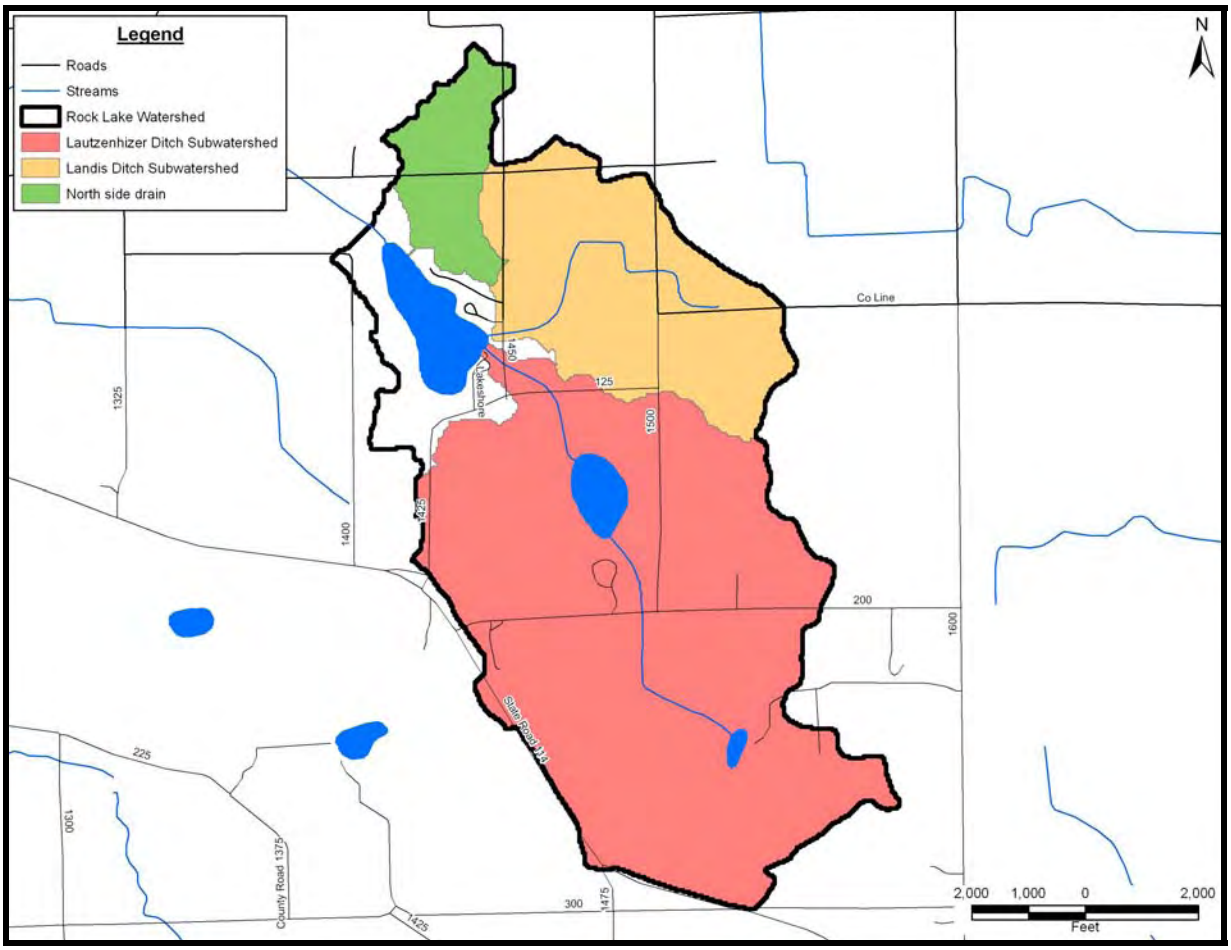

Figure 4. Rock Lake subwatersheds.

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

Subwatershed/Lake	Area (acres)	Area (hectares)	Percent of Watershed
Landis Ditch	389	157.4	21.4%
Lautzenhizer Ditch	1,127	456.1	62.0%
North side drain	121	49.0	6.7%
Area draining directly to Rock Lake	125	50.6	6.9%
Watershed Draining to Lake	1762	713.1	97.0%
Rock Lake	56	22.6	3.0%
Total Watershed	1,818	735.8	100%
Watershed to Lake Area Ratio (rounded)	30:1		

Table 1 also provides the watershed area to lake area ratio for Rock 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. Rock Lake possesses a watershed area to lake area ratio of approximately 30:1. This is a fairly normal watershed area to lake area ratio for glacial lakes (Vant, 1987). Many glacial lakes have watershed area to lake area ratios of less than 50:1 and watershed area to lake area ratios on the order of 10:1 are fairly common (Vant, 1987).

In terms of lake management, Rock Lake's watershed area to lake area ratio means that activities and processes in the landscape that drains to the lake can potentially exert a significant influence on the health of Rock Lake. Consequently, implementing Best Management Practices (BMP's) along the lake's shoreline and in the watershed should rank high when prioritizing management options.

2.2 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.

The climate of the Rock Lake watershed is characterized as having four well-defined seasons of the year. Winter temperatures average 26º F (-3.3º C), with warm summer temperatures averaging 70º F (21.1º C). The growing season typically begins in early April and ends in September. Annual rainfall averages 38.54 inches (98 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 with the exception of the annual rainfall average were from Staley (1989). Average monthly precipitation for the Rock Lake area exceeded that of the 30 year average by 8.26 inches (21cm) in 2008 (Table 2, NOAA, 2008).

Table 2. Monthly rainfall data (in inches) for year 2008 as compared to average monthly rainfall recorded in Rochester, Indiana (NOAA, 2008)**.**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2008	7.33	5.96	2.63	2.88	4.37	5.65	1.57	2.8	3.9	2.67	1.57	5.47	**46.80**
Average	2.03	1.74	2.7	3.81	4.16	4.12	3.81	3.73	3.36	2.91	3.42	2.74	**38.54**

All data were recorded at Rochester, approximately 10 miles (16 Km) west of Rock Lake. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 (NOAA, 2008).

2.3 Geology

The advance and retreat of the glaciers in the last ice age (the Wisconsin Age) removed, shaped and reshaped much of the landscape found in Indiana today. In the northern portion of the state, ground moraines, end moraines, lake plains, outwash plains, and other geologically complex features dominate the landscape. Further, the interaction of three glacial lobes, (Michigan Lobe, Saginaw Lobe, and the Erie Lobe, respectively) left behind a vast array of

deposits and landforms that changed the region's hydrogeology. In comparison to the central portion of the state, surface water, groundwater and soils are more varied and complex. Large raised landforms including the Valparaiso Moraine, the Maxinkuckee Moraine, and the Packerton Moraine, indicate the glacial margins of these ice sheets in the northern portion of the state. Major rivers in northern Indiana cut through course grained outwash and transect these dominant topographical features, suggesting a drainage pattern that was established in an ice proximal and/or subglacial environment. Later, outwash plains formed as the glacial melt waters flowed from retreating glaciers. This further altered the drainage of the landscape as dams between ice, morainal deposits and melt water pooled into lakes. As a result, lake plains and kettle lakes formed as stagnant water settled out and deposited silt and clay (Brown and Jones, 1999).

The movement and stagnation of the Saginaw Lobe of the Wisconsin glacial age shaped much of the Rock Lake watershed, although the influence of the Erie Lobe can be seen on the watershed's landscape as well. The Saginaw glacial lobe moved out of Canada to the south carrying a mixture of Canadian bedrock with it. The Packerton Moraine, an end moraine which forms the southern boundary of the Rock Lake watershed, marks the edge of the Saginaw Lobe's advance into Indiana. The Packerton Moraine extends northeasterly along the eastern edge of the Rock Lake watershed. This ridge separates the Chippewanuck Creek basin from the Yellow Creek basin.

The geology and resulting physiography of the Rock Lake watershed typify the region in which the watershed lies. The Rock Lake watershed lies within Malott's Steuben Morainal Lake Area. Schneider (1966) notes that the landforms common in this diverse physiographic region include till knobs and ice-contact sand and gravel kames, kettle holes and lakes, meltwater channels lined with outwash deposits or organic sediment, valley trains, outwash plains, and small lacustrine plains. Many of these landforms are visible on the Rock Lake watershed landscape.

Surficial geology indicates that Rock Lake lies within glacial till material. Glacial drift covers the Rock Lake watershed to a depth of 300 to 400 feet (91.2 to 122 m; Wayne, 1966). The watershed's surficial geology originates from silty clay loam and clay loam till materials. The northern portion of the watershed located in and around Rock Lake is covered by muck of lacustrine origin. This indicates that this portion of the watershed was likely once home of a larger lake basin. The bedrock underlying the watershed's surficial geology is Devonian shale (Gray, 1989).

2.4 Soils

2.4.1 Soil Associations and Descriptions

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 Kosciusko-Ormas soil association consists primarily of Kosciusko fine sandy loam and Ormas loamy sand.

Two major soil associations, the Kosciusko-Ormas soil association and the Morley-Blount-Pewamo soil association, cover the Rock Lake watershed (Figure 5). A third soil association, the Houghton-Palms soil association, covers a small portion of the northwest corner of the Rock Lake watershed. The following discussion on soil associations in the Rock Lake watershed

relies heavily on the *Soil Survey of Fulton County* (Furr, 1987) and the *Soil Survey of Kosciusko County* (Staley, 1989). Readers should refer to these sources for a more detailed discussion of soil associations covering Fulton and Kosciusko Counties.

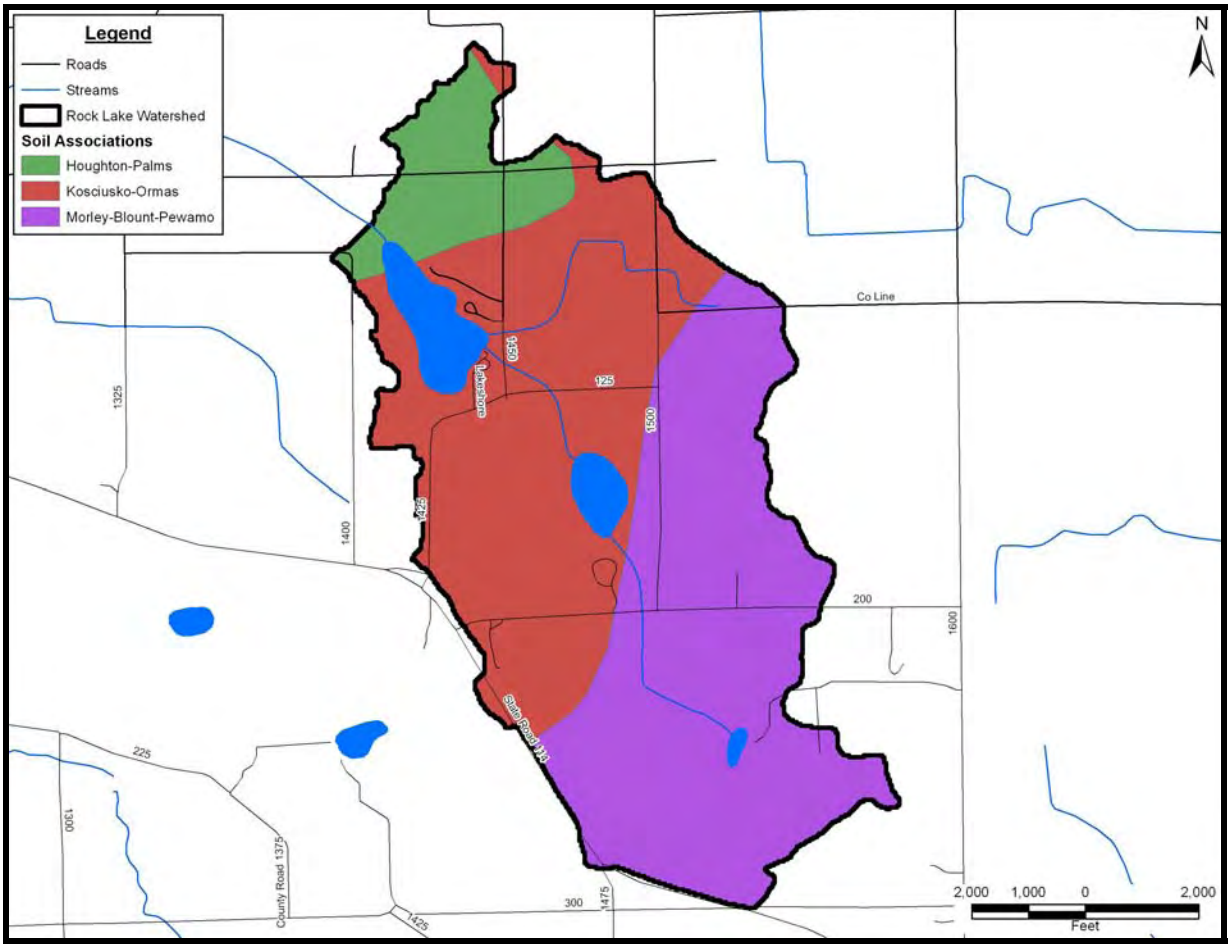

Figure 5. Major Soil Associations in the Rock Lake Watershed.

The Kosciusko-Ormas soil association covers the largest portion of the Rock Lake watershed and is fairly common throughout both counties (15 percent of Fulton County and 19 percent of Kosciusko County). Soils in this soil association developed from loamy and sandy outwash and eolian material. In Fulton County, 40 percent of the soil association consists of Kosciusko and similar soils, while Ormas soils cover 15 percent and minor soils cover 45 percent. In Kosciusko County, 30 percent of the soil association consists of Kosciusko soils, while Ormas soils cover 33 percent and minor soils cover 37 percent. Kosciusko soils are well drained and occur on outwash plains and terraces, and on knolls and ridges on moraines. Ormas soils are also well drained and occur on outwash plains and terraces, and on knolls and ridges in the uplands. Brady sandy loam, Homer fine sandy loam, Gilford fine sandy loam, and Sebewa sandy clay loam are minor components of this association in Fulton and Kosciusko Counties while Boyer loamy sand and Riddles fine sandy loam are also minor components in Kosciusko County. Brady and Homer soils are common on low moderately drained areas in the landscape but Gilford and Sebewa soils are located in depressions and poorly defined drainages, as well as on nearly level areas along the major streams. Boyer soils are found on outwash plains and terraces; Riddles soils are located on low moraines. Soils in this association are well suited to trees and residential development. However, this association is poorly suited to sanitary

facilities and septic tank absorption fields, because of a poor filtering capacity of the underlying material. Contamination of groundwater is a danger.

The Morley-Blount-Pewamo soil association covers the south portion of the Rock Lake watershed, which is located entirely in Fulton County. The Morley-Blount-Pewamo soil association covers only 3 percent of Fulton County. Soils in this soil association developed from glacial till. About 55 percent of the soil association consists of Morley soils, while Blount, Pewamo, and minor soils each cover 15 percent. Morley soils are well drained and moderately well drained, and occur on gently sloping and moderately sloping areas on knolls, ridges, and side slopes. Blount soils are somewhat poorly drained and occur on nearly level areas. Pewamo soils are very poorly drained and occur in slight depressional areas or in poorly defined drainages. Riddles fine sandy loam and Houghton muck, are minor components of this association. Riddles soils are common on knolls and side slopes, while Houghton soils are located in depressional areas and are normally wetlands or shallow ponds in an undrained condition. Soils in this association are suitable for trees and for building site development. However, this association is poorly suited to septic systems because of slow permeability and wetness.

The Houghton-Palms soil association covers a small portion of the northwest corner of the Rock Lake watershed, which is located entirely in Kosciusko County. The Houghton-Palms soil association covers 9 percent of Kosciusko County. Soils in this soil association developed from organic matter under saturated conditions. About 46 percent of the soil association consists of Houghton soils, while Palms soils cover 16 percent and other soils cover 38 percent. Houghton soils are very poorly drained black muck, and occur in depressions on moraines, outwash plains, and till plains. Palms soils are very poorly drained muck that occurs in depressions. Gilford sandy loam, Sebewa loam, Edwards muck, Histosols, Aquolls, and Coloma loamy sand are minor components of this association. Gilford and Sebewa soils are located on slight swells and around the edges of large depressions, while Edwards soils and other undefined Histosols and Aquolls associated with inundation and saturation are located in scattered areas. Coloma soils are located on widely spaced hillocks. This association is used for a variety of purposes. Filled areas contain urban development, drained areas are used for corn and soybean production, and small portions are used for specialty crops such as carrots and mint; areas that have not been drained or filled are generally idle (Staley, 1989). The Houghton-Palms association is poorly suited for residential development and septic systems due to ponding, low strength, and a high potential for frost action.

2.4.2 Highly Erodible Soils

Soils that erode from the landscape are transported to waterways where they degrade water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils can carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals, like some herbicides and pesticides, can kill aquatic life and damage water quality. Highly erodible and potentially highly erodible are classifications used by the Natural Resources Conservation Service (NRCS) to describe the potential of certain soil units to erode from the landscape. The NRCS examines common soil characteristics such as slope and soil texture when classifying soils. The NRCS maintains a list of highly erodible soil units for each county. Table 3 lists the soil units in the Rock Lake watershed that the NRCS considers to be highly erodible and potentially highly erodible.

Table 3. Highly erodible (HES) and potentially highly erodible soil (PHES) units in the Rock Lake watershed.

Soil Unit	Status	Soil Name	Soil Description
KxC3	HES	Kosciusko sandy clay loam	6-12% slopes
KoB	PHES	Kosciusko-Ormas complex	2-6% slopes
KoC	PHES	Kosciusko-Ormas complex	6-12% slopes
MeB	PHES	Metea loamy sand	2-6% slopes
MrB2	PHES	Morley loam	2-6% slopes
MsC3	HES	Morley loam	6-12% slopes
RIB2	PHES	Riddles fine sandy loam	2-6% slopes
RIC2	PHES	Riddles fine sandy loam	6-12% slopes

Highly erodible (HES) and potentially highly erodible soil (PHES) units in the form of Kosciusko sandy loam, Kosciusko sandy clay loam, Metea loamy sand, Morley Loam, and Riddles loam cover almost a third of the watershed (Figure 6). As slope increases, the severity of the limitation increases. Some steeply sloped Kosciusko and Riddles soils are considered unsuitable for agricultural production due to erosion hazard. Residential or commercial development of these same soils can cause severe erosion during construction.

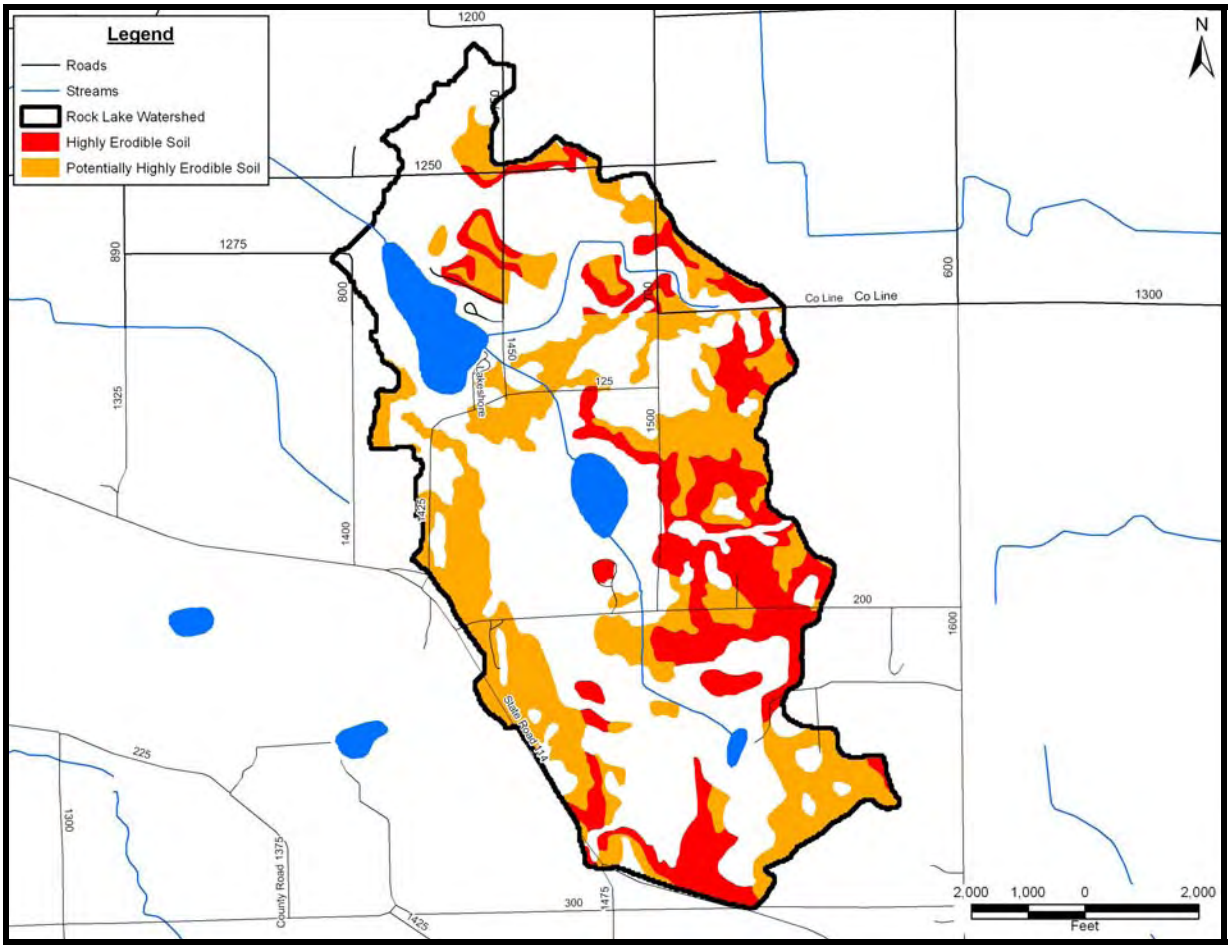

Figure 6. Highly erodible and potentially highly erodible soils within the Rock Lake watershed.

2.4.3 Soils Used for Septic Tank Absorption Fields

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

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

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

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

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

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms

associated with wastewater; and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb bacteria and viruses, but retention is not necessarily permanent. During storm flows, bacteria and viruses may become resuspended in the soil solution and transported throughout the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

Taking into account the various factors described above, the NRCS ranks each soil series in the Rock Lake watershed in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields in moderately or severely limited soils generally requires special design, planning, and/or maintenance to overcome the limitations and ensure proper function. Figure 7 displays the septic tank suitability of soils throughout the Rock Lake watershed, while Table 4 lists the soils located within the watershed and their associated properties. Soils that are severely limited for use as septic systems cover 1,668.7 acres (675.3 ha or 92 percent) of the watershed. Severely limited soils cover the entire watershed east of Rock Lake and are also located along most of the shoreline of the lake. Soils that are moderately limited cover another 3 percent or 52.8 acres (21.4 ha) of the Rock Lake watershed. These soils are found in one small area east of Rock Lake and in the southeast corner of the watershed, east of Lost Lake. Unrated soils, including the area of the lakes, cover the remaining 5 percent of the watershed.

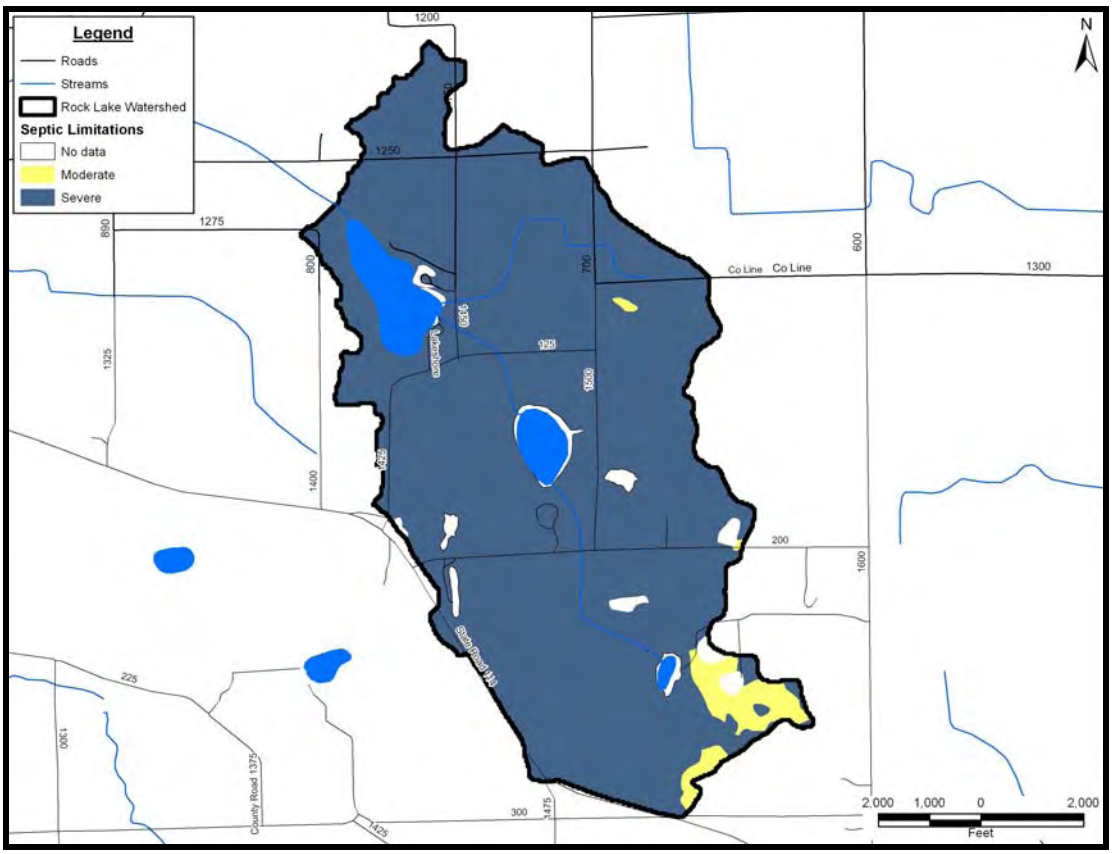

Figure 7. Soil septic tank suitability within the Rock Lake watershed. Note: the majority of homes on the Rock Lake shoreline are located within the area that is severely limited for septic tank absorption fields.

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

Soil Unit	Soil Name	Depth to High Water Table	Restrictive Features
Ad	Adrian muck, drained	+1-0	Severe- high water table
BC	Barry loam	+1-1.0	Severe – high water table
Bp	Brady sandy loam	1-3.0	Severe – high water table
BsA	Branch loamy sand	2-3.5	Severe – poor filter
ClB&ClC	Coloma loamy sand	> 6.0	Severe – poor filter
Ed	Edwards muck	+1-0.5	Severe – high water table
Gf	Gilford sandy loam	+0.5-1	Severe – high water table
Hh	Histosols-Aquolls complex	+1-1.0	Severe - ponding
*Hk & Ho	Homer fine sandy loam	1-3.0	Severe – wet, poor filter
*Hm & Hx	Houghton muck, drained	+1-2.0	Severe – percs slowly, wet
*Ho & Ht	Houghton muck, undrained	+1-1.0	Severe – ponding
KoB&KoC	Kosciusko-Ormas complex	> 6.0	Severe – poor filter
KxC3	Kosciusko sandy clay loam	> 6.0	Severe – poor filter
MeA&MeB	Metea loamy sand	> 6.0	Severe – poor filter
MrB2	Morley loam	3.0-6.0	Severe – percs slowly, wet
MsC3	Morley clay loam	2.0-3.0	Severe – percs slowly, wet
Mx	Muskego muck, drained	+1-1.0	Severe – high water table
Ne	Newton fine sandy loam	+0.5-1.0	Severe – high water table
OmA	Ormas loamy sand	> 6.0	Severe – poor filter
*OrB&OmB	Ormas loamy sand	> 6.0	Severe – poor filter
PlB & PlC	Plainfield sand	> 6.0	Severe – poor filter
RlA	Riddles fine sandy loam	> 6.0	Moderate - percs slowly
RlB2&RlC2	Riddles fine sandy loam	> 6.0	Moderate - percs slowly
Se	Sebewa loam	0-1.0	Severe – high water table
Wa	Wallkill silt loam	+0.5-1.0	Severe – high water table
Wh	Washtenaw silt loam	+0.5-1.0	Severe – high water table

* The first abbreviation is the letter designation used in Fulton County, the second is the designation used in Kosciusko County for the same soil series. Soil Series are designated by two letters, the third letter designates slope: A=0-2%, B=2-6%, and C=6-12% slopes.

2.5 Natural History

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

Forest Associations. As a result, the native floral community of the Rock Lake watershed likely consisted of components of neighboring natural areas and ecoregions in addition to components characteristic of the natural area and ecoregion in which it is mapped.

Homoya et al. (1985) noted that prior to European settlement, the 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. The dry to dry-mesic uplands were likely forested with red oak, white oak, black oak, shagbark hickory, and pignut hickory. More mesic areas probably harbored beech, sugar maple, black maple, and tulip poplar. Omernik and Gallant (1988) describe the region as consisting mostly of cropland agriculture, with remnants of natural forest cover. Mesic forests are dominated by American beech and sugar maple, with a significant component of white oak, black oak, northern red oak, yellow poplar, hickory, white ash, and black walnut. Petty and Jackson (1966) list pussy toes, common cinquefoil, wild licorice, tick clover, blue phlox, waterleaf, bloodroot, Joe-pye-weed, woodland asters, goldenrods, wild geranium, and bellwort as common components of the forest under story in the watershed's region.

2.6 Land Use

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

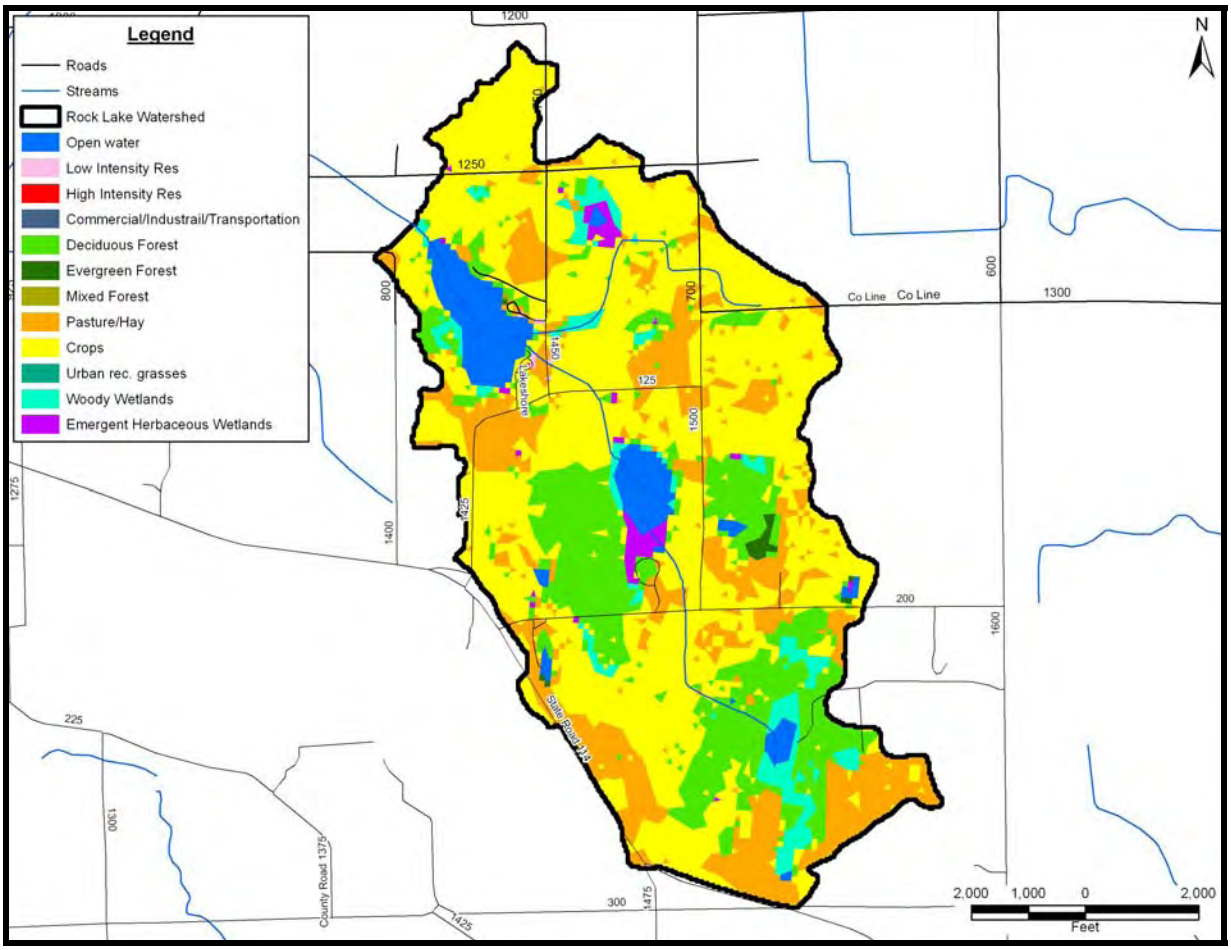

Figure 8. Land use in the Rock Lake watershed. Source: USGS EROS, 1998.

Figure 8 and Table 5 present current land use information for the Rock Lake watershed. Land use data from the U.S. Geological Survey (USGS) form the basis of Figure 8. Like many Indiana watersheds, agricultural land use dominates the Rock Lake watershed, accounting for approximately 71 percent of the watershed. Row crop agriculture makes up the greatest percentage of agricultural land use at 52 percent, while pastures or hay vegetate another 20 percent. Most of the agricultural land in the Rock Lake watershed and throughout Kosciusko and Fulton Counties is used for growing soybeans and corn (USDA, 2002). Fulton County ranks the highest of all 92 state counties for forage (land used for hay, haylage, grass silage, and greenchop) production and sales of donkeys, ponies, mules, burrows, and horses, and also cattle sales.

Land uses other than agriculture account for the remaining 29 percent of the watershed. Natural landscapes, including the lakes, wetlands, and forests, cover approximately 23 percent of the watershed. Most of the natural acreage in the watershed is associated with the forested and wetland areas at the upper (southern) end Lautzenhizer Drain and adjacent to Mud Lake. These natural areas consist of small tracts of wooded or emergent wetlands or deciduous forest, and are scattered along the shoreline. Open water, including Rock Lake, Mud Lake, and Lost Lake accounts for another 5 percent of the watershed. Most of the remaining 0.2 percent of the watershed is occupied by low intensity residential land, with no high intensity residential or commercial land. Much of the residential land lies directly adjacent to Rock Lake.

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

Land Use	Area (acres)	Area (hectares)	% of Watershed
Row Crops	940.4	380.6	51.7
Pasture/Hay	359.2	145.4	19.7
Deciduous Forest	318.0	128.7	17.5
Open Water	98.8	40.0	5.4
Woody Wetlands	74.7	30.2	4.1
Emergent Herbaceous Wetlands	20.1	8.1	1.1
Evergreen Forest	6.0	2.4	0.3
Low Intensity Residential	3.0	1.2	0.2
High Intensity Commercial	0	0	0
High Intensity Residential	0	0	0
Mixed Forest	0	0	0
Entire Watershed	**1819.3**	**736.3**	**100**

Source: USGS EROS, 1998.

2.7 Wetland and Flood hazard Areas

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

The United States Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) Map (Figure 9) shows that wetlands and open water cover approximately 16 percent of the Rock Lake watershed. Table 6 presents the acreage of wetlands by type according to the National Wetland Inventory. Rock Lake and Mud Lake account for 4.4 percent of this wetland/open water acreage. Forested, shrub-scrub, and herbaceous wetlands cover approximately 10.6 percent of the watershed. The largest contiguous tracts of wetland habitat lie to the south of Rock Lake and are associated with Mud Lake and Lost Lake. The remaining percentage of wetland and open water are shallow ponds and submergent wetlands (1 percent).

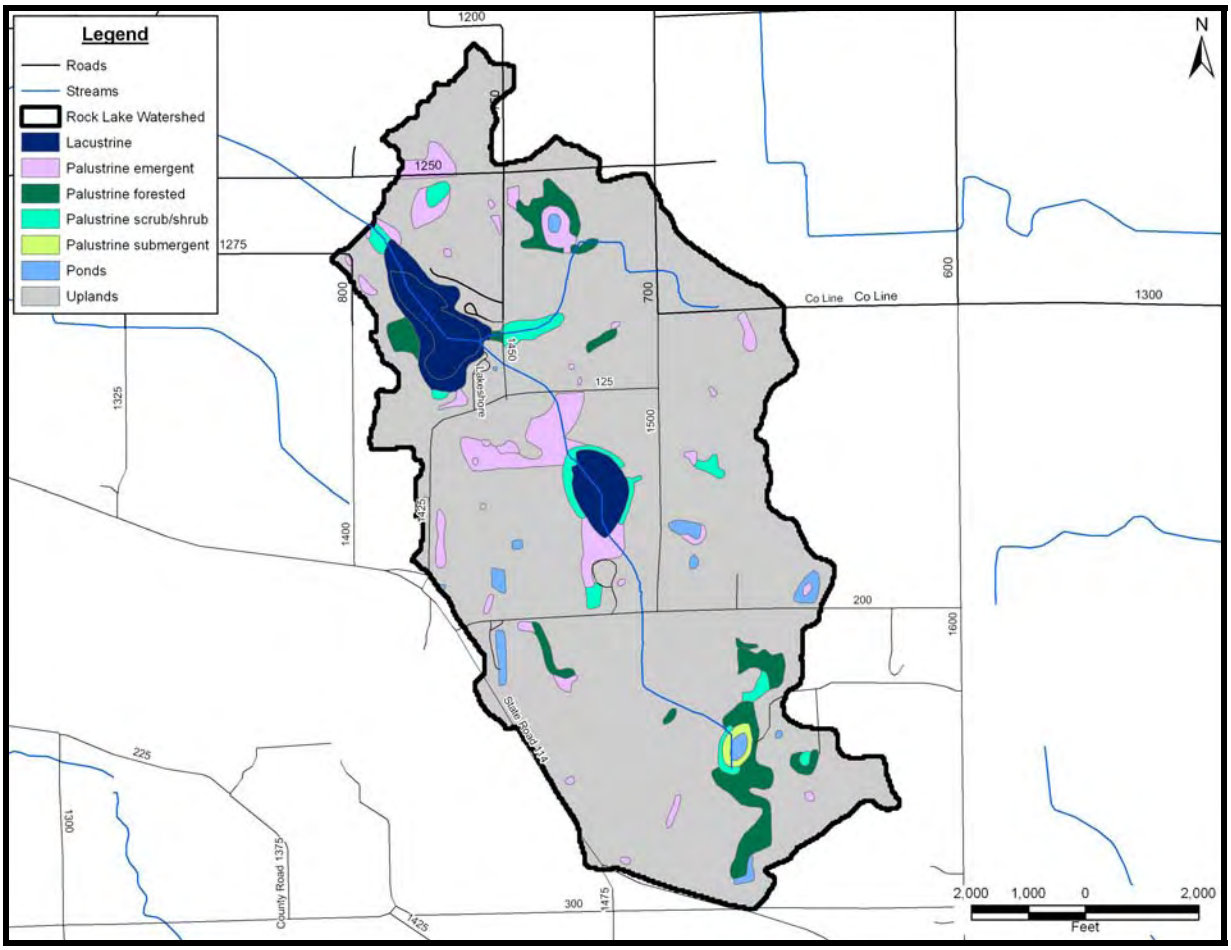

Figure 9. National wetland inventory wetlands in the Rock Lake watershed.

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

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed
Lacustrine	79.5	32.2	4.4
Palustrine emergent	89.0	36.0	4.9
Palustrine forested	69.4	28.1	3.8
Palustrine scrub/shrub	34.3	13.9	1.9
Palustrine submergent	4.7	1.9	0.3
Ponds	19.3	7.8	1.1
Total	**296.1**	**119.8**	**16.3**

Source: National Wetlands Inventory.

Farming within the Rock Lake watershed has reduced wetland acreage. Hydric soil, which formed under wetland conditions, dominates the entire valley of Lautzenhizer Ditch and Landis Ditch. Overall, hydric soils cover approximately 744.7 acres (301.4 ha or 41 percent) of the Rock Lake watershed. When compared to the acreage of wetland mapped by the USFWS NWI map (296.1 acres or 119.8 ha), 16.3 percent of historical wetland acreage remains in the Rock Lake watershed (Figure 10).

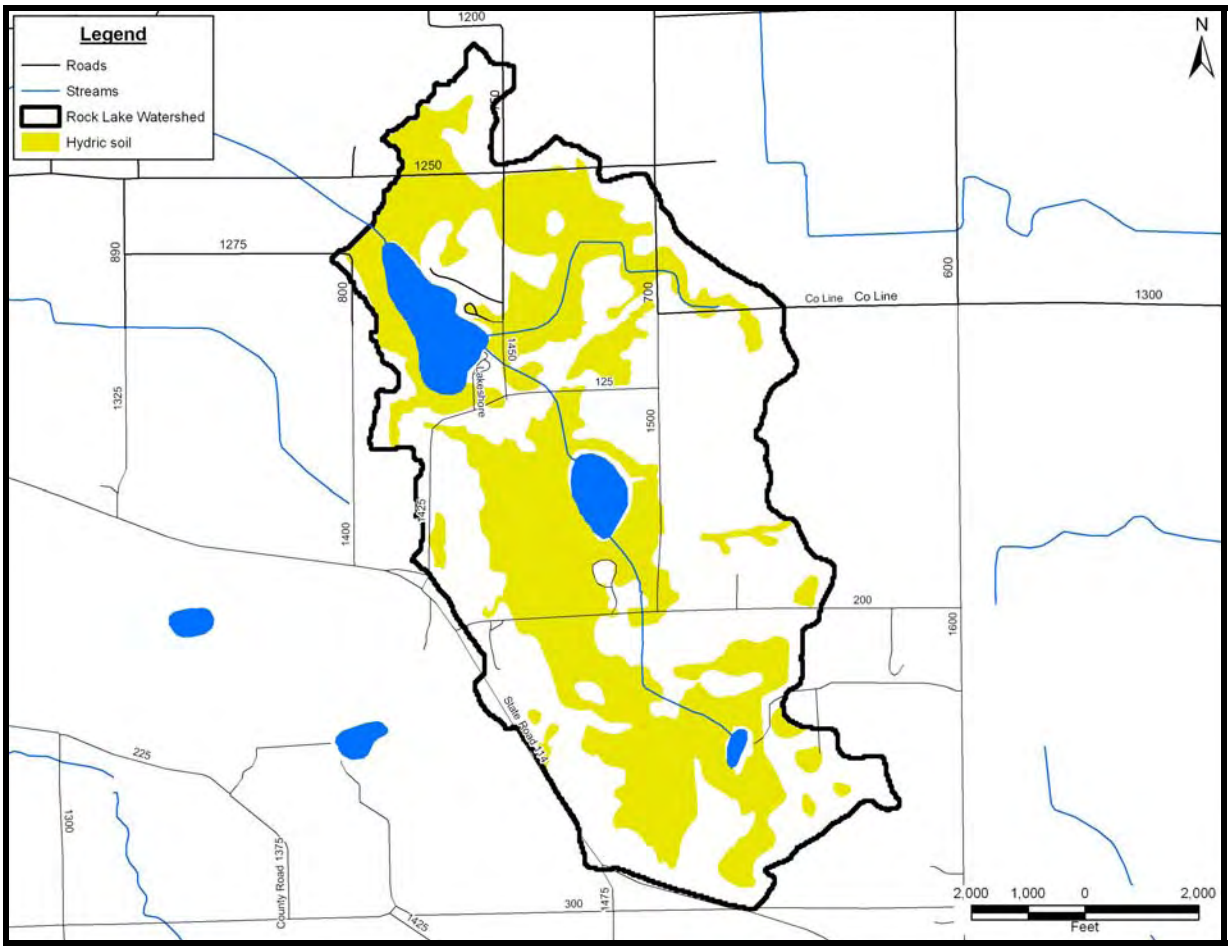

Figure 10a. Hydric soils in the Rock Lake watershed.

The Federal Emergency Management Agency (FEMA) has mapped flood hazard areas throughout the United States. The Rock Lake Flood hazard zone map (Figure 10b), although incomplete, demonstrates that much of the developed shoreline falls within the flood hazard area. These flood hazard areas generally overlaps with the hydric soil areas. The conditions of riparian zones along the stream are described in Section 3.21 of this report.

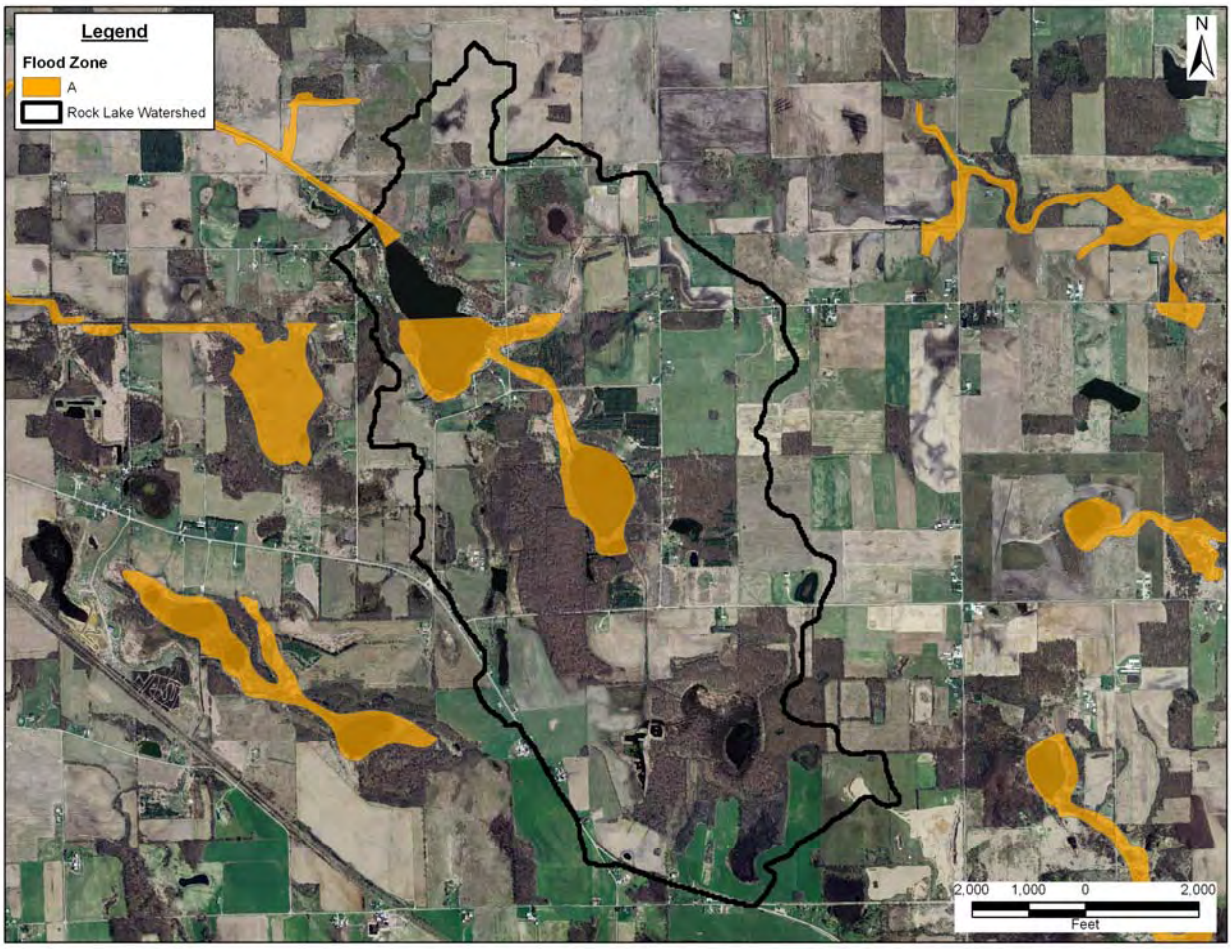

Figure 10b: FEMA Flood Hazard Areas (note missing data on the north end of Rock Lake)
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2.8 Natural Communities and Endangered, Threatened, and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species (ETR); high quality natural communities; and natural areas in Indiana. 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.

The RTE database lists the occurrence of 19 mussel species, 18 insects, 10 fish, 4 amphibians, 5 reptiles, 21 birds, 7 mammals, and 57 plant species between Fulton and Kosciusko County Indiana (Appendix B). Additionally, 13 high Quality Natural Community types are listed as occurring between the two counties.

A request was made to the IDNR Division of Nature Preserves specifically for ETR species and high quality natural communities and Natural Areas known to occur in the Rock Lake watershed (Appendix B). No Natural Areas or high quality natural communities were identified in the watershed. Additionally, no federally listed ETR species are known to exist in the Rock Lake watershed. However, one state listed *rare* plant, the Green-keeled cotton-grass (*Eriophorum viridicarinatum*), is known to occur within the Rock Lake watershed .

2.9 Historic Fisheries Summary

Rock Lake has been surveyed by the Indiana Department of Natural Resources (IDNR) two times; initially in 1977 and most recently in 1997. Rock Lake can be described as a panfish/largemouth bass fishery. The shallow weedy environment of Rock Lake also provides suitable habitat for spotted gar, an important predator species. Since Rock Lake has not had a fish survey conducted during the past 11 years the current fish community structure is unknown except for what anglers report. With only two previous surveys available on the Rock Lake fish community, determining changes or trends in the Rock Lake fishery is not feasible. General assumptions on the state of the fishery are summarized in the following paragraphs.

Proportional stock density (PSD) is an easily calculated statistic used by fisheries biologists when determining if a species population is balanced. Anderson (1980) developed PSD and its use is generally applicable to water bodies less than 500 acres. PSD relates the number of individuals in a population stock size to the number of those individuals that are of quality size or larger. Stock size is generally defined as the minimum size a species becomes available to anglers, while quality size is generally defined as the minimum size anglers consider the species harvestable. Generally, PSDs indicative of balance in a target species population are based on sustainable harvest of sizes preferred by anglers (Kohler and Hubert, 1999). Therefore, balance depends on the density of fish of various sizes in the population; both adequate numbers of catchable size fish and sufficient numbers of smaller fish to provide replacement (Kohler and Hubert, 1999).

Ranges of PSD values indicating balanced populations have been developed for a number of different fish species. For example, largemouth bass populations with PSD values between 40 and 70 and bluegill populations with PSD values between 20 and 40 are characteristic of balanced populations (Anderson, 1980). If a species PSD value is low it would suggest the population has a disproportionate number of small individuals and conversely if a species PSD is high it would suggest the population has a disproportionate number of large individuals. It is important to note that desired PSD values can vary depending on the management goal of a fishery. For example, a largemouth bass oriented fishery would support a low PSD value in the bluegill population and a high PSD value in the largemouth bass population. The low bluegill PSD value would provide an abundance of edible size prey demanded by the large largemouth bass population. It is important to note PSD values are usually calculated for a single collection method, such as electro-fishing, however, due to the absence of data provided on the number of individuals collected by method in historic fishery management reports, an overall PSD was calculated for each given survey year. It is important to recognize that PSD is not an all inclusive statistic which always correlates with the overall state of a population; rather, PSD should be used in series with other population statistics such as recruitment, mortality, growth and condition, and density, just to name a few. The PSD value should be viewed as a general assessment of the population structure.

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

A large number of dead gizzard shad and some spotted gar were reported after ice out on Rock Lake in 1977 which initiated the first survey. The purpose of the survey was to evaluate the extent of the winterkill and assess the fishery as a whole. Eighteen species of fish and 1 hybrid were collected in the initial survey of Rock Lake (Pearson 1977). Bluegill was the most abundant fish species collected by number (40.7 percent), followed by golden shiner (11.3 percent), white crappie (10.3 percent), and largemouth bass (8.2 percent; Figure 11). The main sport species targeted at Rock Lake, bluegill, black and white crappie, largemouth bass, and yellow perch, accounted for 73 percent of the sample by number and 40 percent by weight. Bluegill in Rock Lake had a calculated PSD value of 55 suggesting the population had a good number of harvestable size individuals (a balanced bluegill population has a suggested PSD value between 20 and 40). Growth of bluegill was slightly above average and condition (length to weight relationship) was average. Largemouth bass had a calculated PSD value of 24, suggesting the population was dominated by smaller individuals (a balanced largemouth bass population has a suggested PSD value of between 40 and 70). Only two individuals were collected that were > 14 inches (35.6 cm). The growth and condition of largemouth bass was average. White crappie and black crappie accounted for 18.1 percent of fish collected by number and both had PSD value that fell in the desired range of balanced populations (30-50) 34 and 52, respectively. Growth and condition of both black and white crappie was average. Yellow perch accounted for 5.7 percent of the sample by number and had a PSD value of 36 suggesting the population was balanced (desired PSD range 30-50). It was determined by IDNR that the winterkill did not have much of an effect on the fish community in Rock Lake. No further management recommendations were suggested.

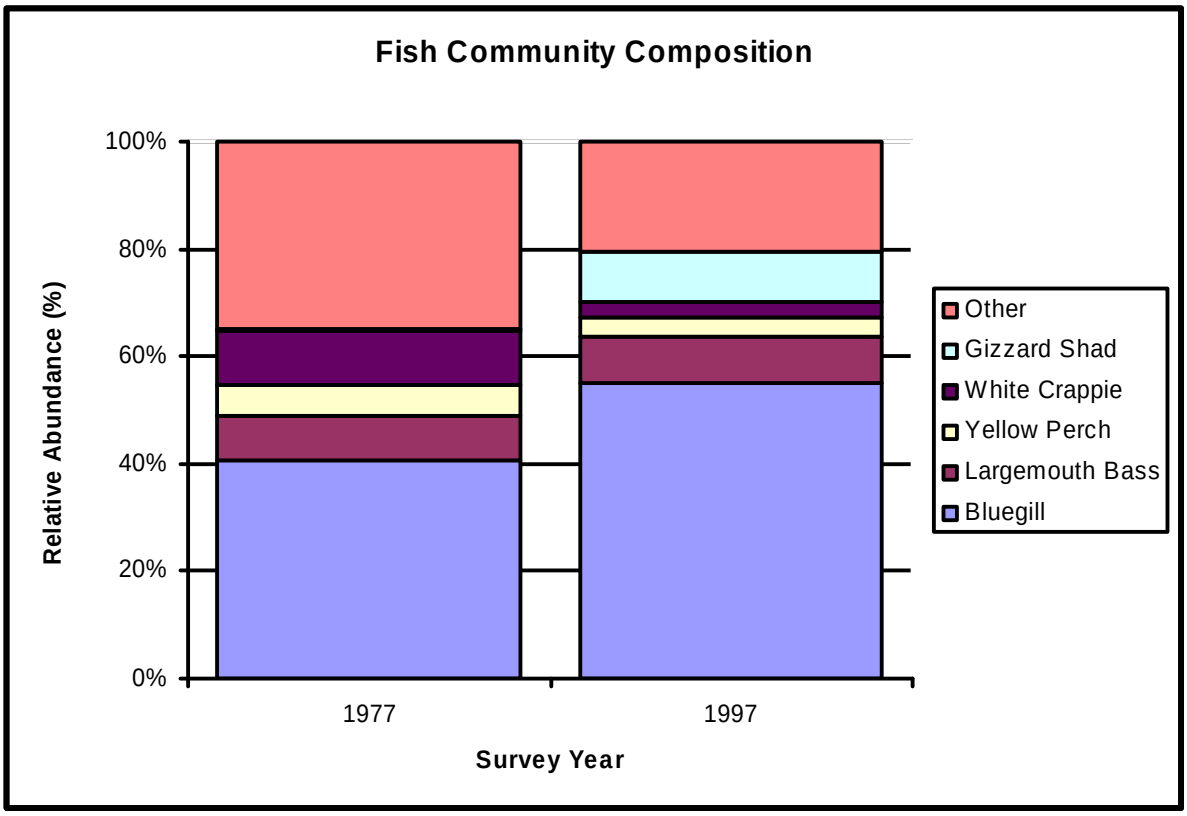

Figure 11: Fish community composition in Rock Lake over time (Pearson 1977; Braun 1998).

The most recent survey of Rock Lake (1997) collected 18 species of fish (Braun 1998). Bluegill was the most abundant fish species collected by number (55 percent), followed by gizzard shad (9.3 percent), largemouth bass (8.8 percent), and golden shiner (4.2 percent; Figure 11). The fish community sampled in 1997 was slightly different than that sampled in 1977. Most notably, gizzard shad which accounted for 0.1 percent of the sample by number in 1977 increased to the second most abundant species in 1997 accounting for 9.3 percent of the sample. Additionally, black and white crappie populations were collected in lower abundance in 1997. Collectively, black and white crappie accounted for 3.5 percent of the fish sampled in 1997 by number compared to 18.1 percent in 1977. Black crappie had a size range of 9.2-10.3 inches (23.4-26.2 cm) and white crappie had a size range of 9.1-12.2 inches (23.1-31 cm) in 1997. Crappies are cyclic species meaning their population will exhibit very strong and very weak year classes. The difference in abundance and the overall size of individuals within the population between the 1977 and 1997 surveys is most likely a result of this population cycle. The 1997 sample would suggest the crappie population was at a low point in its cycle due to the absence of small individuals. Bluegill, as in 1977, were the most abundant species collected, however bluegill relative abundance increased from 40.7 percent in 1977 to 55 percent in 1997. Bluegill PSD was also higher in the 1997 survey than the 1977 survey (62 and 55 respectively). Growth of bluegill was average to above average in 1997. The largemouth bass population sampled in 1997 was very similar to that sampled in 1977. Abundance of largemouth bass and size of individuals in the population was almost the same as sampled in 1977. PSD for largemouth bass in 1997 could not be calculated due to a lack of information. Yellow perch abundance decreased from 5.7 percent in 1977 to 3.6 percent in 1997; however, the calculated PSD for yellow perch increased from 36 in 1977 to 71 in 1997. Notably, spotted gar relative abundance increased from 2.2 percent in 1977 to 3.9 percent in 1997. Spotted gar can be an important component of a fishery because they forage on smaller sunfish species and other small fish. Predation on smaller fishes is important to the species they prey upon because it helps to decrease the amount of intra-specific competition (competition within a species) and inter-specific competition (competition between different species). For example, a bluegill population if overpopulated can develop slow growth rates or a forage species such as gizzard shad if not controlled, can overwhelm a fishery and account for a large percentage of the carrying capacity of a lake thereby impacting the success of other species such as bluegill. IDNR considered the Rock Lake fishery satisfactory and determined the biggest threat to the fishery was the abundance of Eurasian watermilfoil.

During a late May 2009 tour of the lake, numerous carp were noted in the shallows where they typically spawn. Carp are bottom feeders and as such they tend to stir up the bottom while feeding. In this manner the carp contribute to recycling of nutrients (phosphorus) and the subsequent growth of algae.

The bluegill population in Rock Lake was acceptable at least until the 1997 sample year. Growth rates were average to above average and the calculated PSD value was desirable in both survey years. Rock Lake appears to have offered anglers satisfactory bluegill fishing. A more recent interview noted that while bluegills are tending toward smaller individuals, the largemouth bass population has increased in average size caught. This suggests that the bluegill population has outgrown its resources and the population may be stunted, while the bass are thriving on abundant prey. Anglers should practice selective harvesting of panfish (bluegill, black crappie and white crappie) by decreasing their harvest of large adults and increasing their harvest of younger, smaller panfish. This would be beneficial to the population for a couple of reasons: 1) the release of large adults would help develop a large, healthy stock of breeding individuals capable of producing many offspring each year; and 2) the increased harvest of smaller individuals would decrease the amount of intra-specific competition for space

and food resources between young panfish, resulting in a healthy recruitment of individuals into the larger sized breeding population. The goal should be to develop a distribution of sizes within the population that would allow for the harvest of quality size fish while ensuring the replacement of those individuals the following year. The state of Indiana implemented a minimum size for largemouth bass of 14 inches (35.6 cm) in 1998. Rock Lake's largemouth bass population samples from 1977 and 1997 indicated that a majority of the bass were smaller individuals. The recent interview suggests this has changed, with bigger largemouth bass being caught more frequently. This suggests that the 14 inch minimum size limit has worked for bass.

2.10 Historic Water Quality Data

The comprehensive evaluation of lakes and streams require collecting data on a number of different, and sometimes hard-to-understand, water quality parameters. Definitions of water quality parameters discussed in this section the next can be found in Appendix A. Indiana uses standards published by IDEM Table 7.

Table 7: Indiana Standard Water quality parameters (http://www.in.gov/idem/6242.htm)

Ammonia (NH3)	Range between 0.0 and 0.21 mg/L depending upon temperature and pH	Indiana Administrative Code (IAC)
Atrazine	Max: 3.0 ppb	U.S. EPA Drinking Water Standard
Dissolved Oxygen (DO)	Min: 4.0 mg/L Max: 12.0 mg/L	Indiana Administrative Code (IAC)
	Min: 6.0 mg/L in coldwater fishery streams	Indiana Administrative Code (IAC)
	Min: 7.0 mg/L in spawning areas of coldwater fishery streams	Indiana Administrative Code (IAC)
E. coli	Max: 235 CFU/ 100mL in a single sample	Indiana Administrative Code (IAC)
	Max: Geometric Mean of 125 CFU/ 100mL from 5 equally spaced samples over a 30-day period	Indiana Administrative Code (IAC)
Nitrate	Max: 10 mg/L in waters designated as a drinking water source	Indiana Administrative Code (IAC)
Nitrite	Max: 1 mg/L in waters designated as a drinking water source	Indiana Administrative Code (IAC)
Nitrate-N + Nitrate-N	Max: 10 mg/L in waters designated as a drinking water source	Indiana Administrative Code (IAC)
Temperature	Dependant on time of year and whether stream is designated as a cold water	Indiana Administrative Code (IAC)

	fisheries	
Nitrate-nitrogen (NO3)	Max: 0.633 mg/L	U.S. EPA recommendation *
	Max: 1.0 mg/L	Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams and Modified Warm Water Habitat (MWH) headwater streams
	1.5 mg/L	Dividing line between mesotrophic and eutrophic streams (Dodd et al. 1998)
	10.0 mg/L	IDEM draft TMDL target
Ortho-Phosphate also known as Soluble reactive phosphorus (SRP)	Max: 0.005 mg/L	Wawasee Area Conservancy Foundation recommendation for lake systems
Suspended Sediment Concentration (SSC)	Max: 25.0 mg/L	U.S. EPA recommendation for excellent fisheries
	Range: 25.0-80.0 mg/L	U.S. EPA recommendation for good to moderate fisheries
Total Kjeldahl Nitrogen (TKN)	Max: 0.591 mg/L	U.S. EPA recommendation *
Total Phosphorus	Max: 0.076 mg/L	U.S. EPA recommendation
	0.07 mg/L	Dividing line between mesotrophic and eutrophic streams (Dodd et al. 1998)
	Max: 0.08 mg/L	Ohio EPA recommendation to protect aquatic biotic integrity in WWH
	Max: 0.3 mg/L	IDEM draft TMDL target
Total Suspended Solids (TSS)	Max: 80.0 mg/L	Wawasee Area Conservancy Foundation recommendation to protect aquatic life in lake systems
	Max: 30.0 mg/L	IDEM draft TMDL target
	Range: 25.0-80.0 mg/L	Concentrations within this range reduce fish concentrations (Waters, 1995)
	Max: 40.0 mg/L	New Jersey criteria for warm water streams
	Max: 46.0 mg/L	Minnesota TMDL criteria for protection of fish/macroinvertebrate health
Turbidity	Max: 25.0 NTU	Minnesota TMDL criteria for protection of fish/macroinvertebrate health
	Max: 10.4 NTU	U.S. EPA recommendation

Rock Lake has exhibited nutrient rich waters in all sampling events conducted from 1977 to 2008. The water quality rates as poor compared to other Indiana Lakes (Table 7). Historical records from the past forty years show the lake's Secchi disk transparency (a measure of water clarity) has been consistently less then 3 feet (0.9 m) compared to a regional median of 6.9 feet

(2.1 m) (Clean Lakes Program, unpublished data). Total phosphorus concentrations are at the state wide median value, although Total nitrogen concentrations are consistently higher then median values. Primary productivity of the lake (algae and plant growth) has been high as well. Chlorophyll *a* concentrations (an indicator of algae production) measured 35 mg/L or higher during all previous assessments.

The Indiana Department of Natural Resources, Division of Fish and Wildlife, the Indiana State Pollution Control Board, the Indiana Clean Lakes Program (CLP), and Grace College have conducted various water quality tests on Rock Lake. Table 8 presents some selected water quality parameters for these assessments of Rock Lake.

Table 8. Summary of historic data for Rock Lake.

Date	Secchi (ft)	% Oxic	Epi pH	TP (mg/L)	Plankton (#/L)	Chl *a* (μg/L)	ITSI Score	Source
8/5/76	2.5	100.0%	--	0.070*	--	--	61[δ]	ISPCB, 1986
6/20/77	3.0	100.0%	9.00	--	--	--	--	Pearson, 1977
8/26/91	1.6	75.0%	--	0.133	91,728	--	30	CLP, 1991
8/21/95	1.6	75.0%	8.80	0.092	107,846	35.0	41	CLP, 1995
6/23/97	3.2	100.0%	7.70	--	--	--	--	Braun, 1998
8/10/98	2.0	75.0%	8.10	0.318	20,814	53.2	29	CLP, 1998
5/16/05	2.0	--	--	--	--	--	--	Aquatic Control, 2006
8/8/05	2.5	--	--	--	--	--	--	Aquatic Control, 2006
5/25/06	1.5	--	--	--	--	--	--	Aquatic Control, 2007
8/1/06	1.5	--	--	--	--	--	--	Aquatic Control, 2007
6/26/07	2.2	--	8.50	0.023[+]	--	--	--	Lesko 2007
7/18/07	1.8	--	4.45	0.117[+]	--	--	--	Lesko 2007
8/6/07	1.8	--	8.60	0.127[+]	--	--	--	Lesko 2007

*Water column average; all other values are means of epilimnion and hypolimnion values.
[+]Epilimnetic or surface water sample only; all other values are means of epilimnion and hypolimnion values.
[δ]Eutrophication Index (EI) score. The EI differs slightly but is still comparable to the TSI used today.

Based on the data presented in Table 8, water quality in Rock Lake has remained stable or declined slightly over the past 30 years. Water clarity is relatively poor for the region. Since 1976, Secchi disk transparency (a measure of water clarity) has ranged from 2.5 (0.8 m) in August 1976 to a low of 1.8 feet (0.5 m) in July and August 2007. During this time frame, water clarity fluctuated reaching a high of 3.2 feet (1.0 m) in June 1997 and a low of 1.5 feet (0.5 m) in May and August 2006. Figure 12 displays the variation in water clarity over time within Rock Lake. The data suggests a decline in water clarity; however, this is likely due in part to variation in the amount of data collected per year. Only two transparency measurements occurred in Rock Lake prior to 1990; however, seven transparency measurements occurred during the 2005 to 2007 sampling period. The more recent data may indicate poorer water clarity in Rock Lake; however, the disparity in the number of measurements makes determination of changes in water clarity indeterminable at this time.

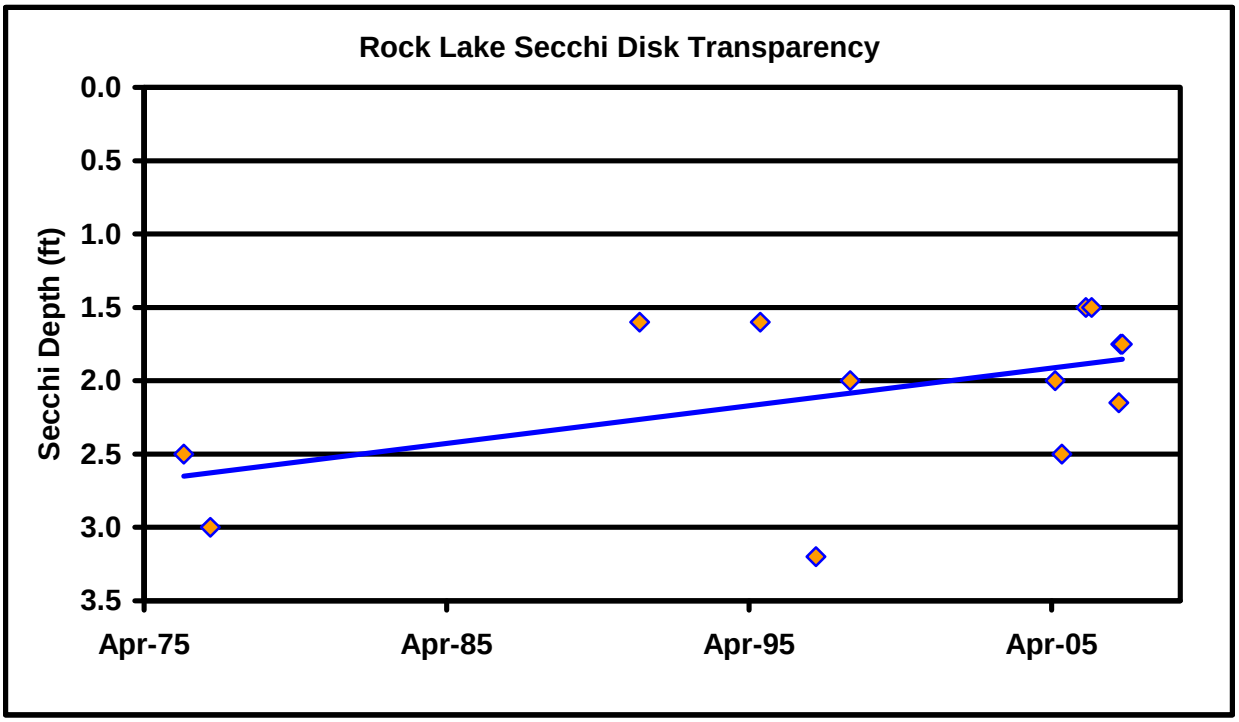

Figure 12. Historic Secchi disk transparency data for Rock Lake.

Other data collected within Rock Lake support the idea that water clarity is relatively poor within the lake. Additionally, the 1 percent light level (point at which only 1 percent of the surface ambient light is available underwater) measurements suggest little change in water clarity over time. Overall, 1 percent light levels vary from 3.8 to 4 feet (1.1 to 1.2 m, respectively) in 1998 and 1995, respectively. This means that light is available to a depth of 3.8 to 4 feet (1.1 to 1.2 m), which is shallower than median measurements for other Indiana lakes.

Despite the relatively poor water clarity, total phosphorus concentrations have generally remained moderate within Rock Lake (Figure 13). Total phosphorus concentrations ranged from 0.070 mg/L in August 1976 (ISPCB, 1986) to 0.318 mg/L in August 1998 (CLP) before declining to 0.023 to 0.117 mg/L in June and August 2007, respectively. Differences in sample collection methodology may play a role in changes in total phosphorus concentration over time. The oldest measurement of 0.070 mg/L taken August 1976 is a water sample column. This means that water was collected at regular intervals throughout the water column, then combined prior to sample analysis occurring. The 1991, 1995, and 1998 samples represent average concentrations of samples collected 3.1 feet (1 m) from the water surface and 3.1 feet (1 m) from the lake bottom. These represent normal conditions present within the surface water (epilimnion) and bottom water (hypolimnion). Conversely, the most recent samples include surface water samples only. This means that any phosphorus release that may be occurring in the lake bottom would not be shown in these samples. This different collection methodology likely results in a lower than normal concentration rather than a true decline in concentration; therefore, these data do not indicate an improvement in water quality.

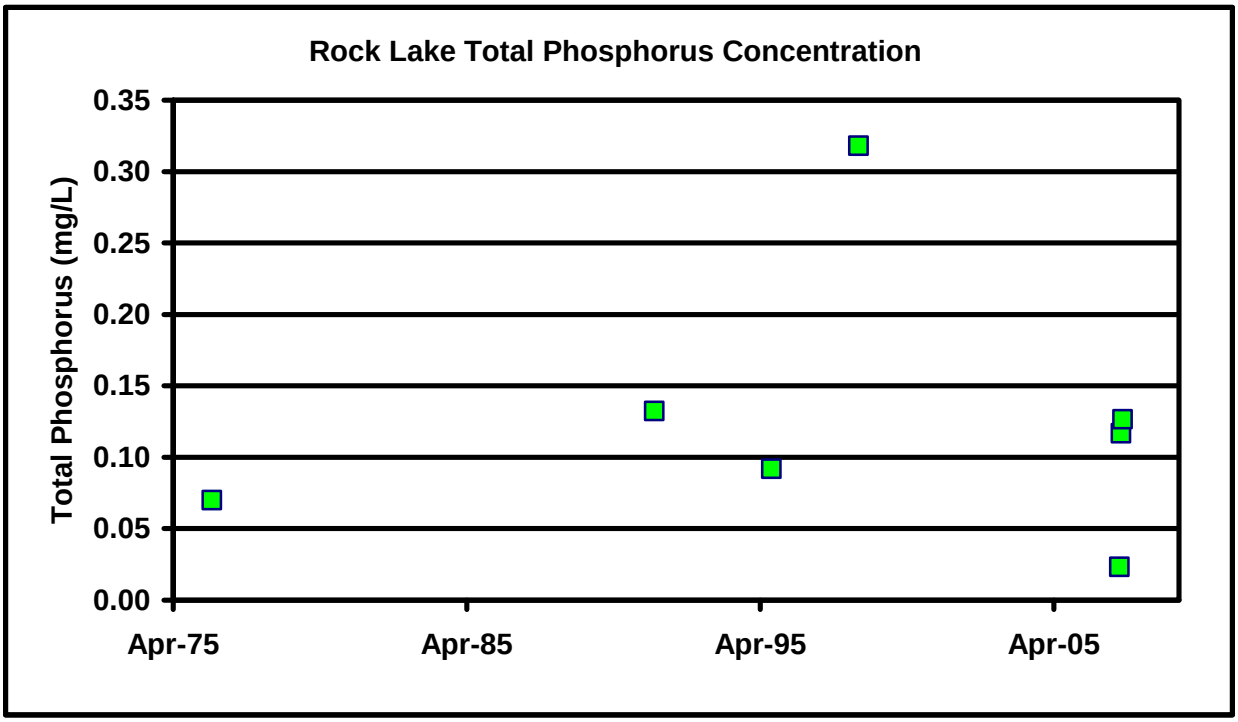

Figure 13. Historic total phosphorus concentrations measured in Rock Lake.
Source: CLP, 1991, 1995, 1998; Lesko, 2007.

When long-term data is compared with median concentrations, trends become more apparent (Figure 14). With the exception the 1998 total phosphorus measurement, all total phosphorus concentrations measured in Rock Lake remain below the median concentration for Indiana lakes (0.17 mg/L). Soluble reactive phosphorus concentrations follow a similar pattern with concentrations as low as 0.005 mg/L measured in 1991 and increasing to 0.217 mg/L in August 1998. During this most recent assessment, soluble phosphorus concentrations measured nearly double the median soluble phosphorus concentration found in most Indiana lakes (0.12 mg/L). Soluble reactive phosphorus is the portion of phosphorus that is available to plankton and aquatic plants for uptake and usage in production. Therefore, increases in soluble phosphorus concentrations in Rock Lake are a concern. Nitrogen concentrations display a marked increase during the most recent assessment as well. Historically, ammonia-nitrogen, nitrate-nitrogen, and organic nitrogen concentrations were relatively normal, typically measuring within the median range of Indiana lakes. However, during the most recent assessment, organic nitrogen and ammonia-nitrogen concentrations increased to measure nearly double the median concentration found in Indiana lakes. These data suggest that water quality in Rock Lake during the 1998 assessment was poorer than water quality measured in Rock Lake historically. During all other assessments, Rock Lake's nutrient data suggest that the lake possesses moderate water quality.

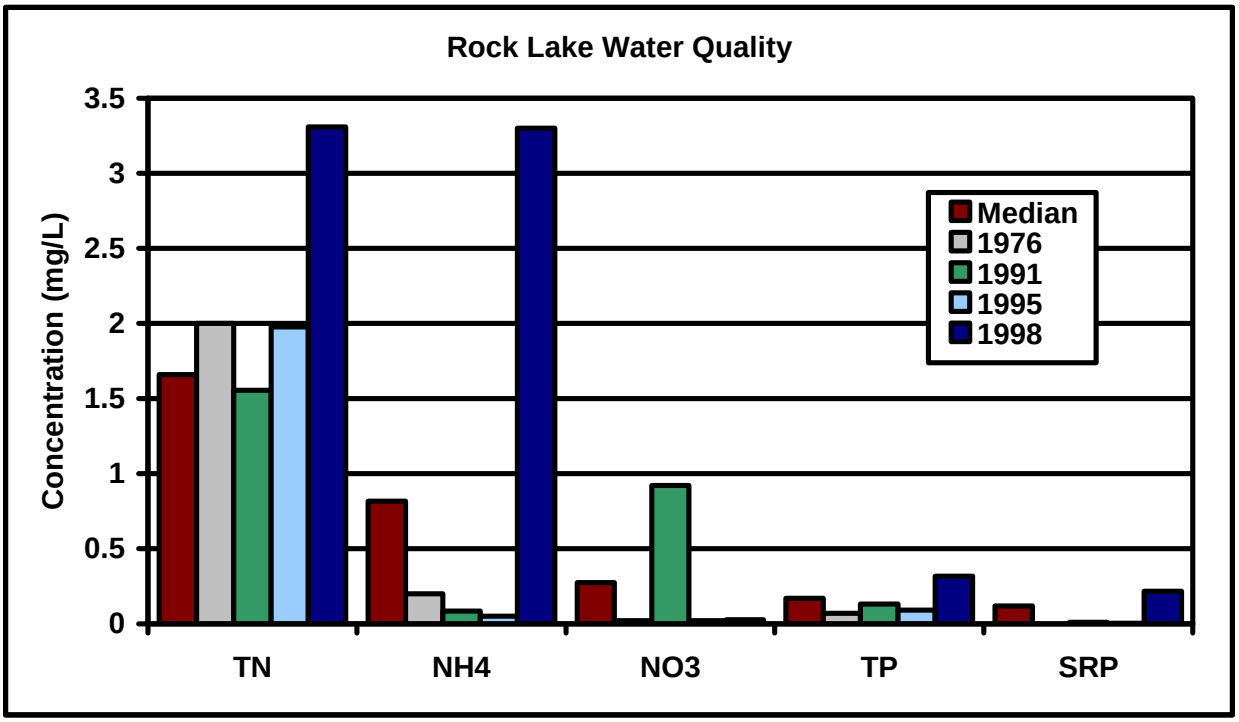

Figure 14. Variation in nutrient concentration in Rock Lake, 1976 to 1998.
Source: CLP, 1991, 1995, 1998; ISPCB, 1986.

The lake's algae (plankton) density reflects the relatively moderate nutrient levels typically present in Rock Lake. Nutrients (nitrogen and phosphorus) promote the growth of algae and/or rooted plant populations. Thus, lakes with high nutrient levels are expected to support dense algae and/or rooted plants. Plankton densities range from moderate during the most recent assessment (20,814/L in 1998) to high (107,846/L in 1995) and do not reflect the nutrient concentrations present within the lake. The lowest plankton density coincides with the highest total and soluble phosphorus concentrations measured in the lake; while this relationship holds true for the other plankton densities with the highest plankton density occurring in concert with the lowest phosphorus concentrations. This inverse relationship is opposite what would be expected for Indiana lakes-typically, high phosphorus concentrations are associated with high plankton densities and low plankton densities are associated with low phosphorus concentrations. This seemingly backwards relationship may be due to Rock Lake being a shallow lake. More details on how the shallow nature and low volume of the lake affects the nutrient concentrations and biota present within the lake will follow in subsequent sections.

Moderate chlorophyll *a* concentrations reflect the plankton densities found in the lake. Both of the chlorophyll *a* concentrations (Table 8) exceed the median concentration of 12.9 μg/L measured in Indiana lakes. Concentrations of chlorophyll *a* in 1998 measure more than four times the median concentration found in Indiana lakes corresponding to the high nutrient concentrations measured that same year. Historically, Rock Lake's overall Indiana Trophic State Index (ITSI) scores ranged from a high of 71 (hyper-eutrophic) to a low of 29 (mesotrophic). The wide variance in the ITSI measurement most likely reflects the variable chlorophyll *a* concentration. Please see the discussion of lake water quality parameters and trophic state indices later in the discussion section.

Figure 15 displays the temperature profiles recorded during IDNR fisheries surveys and Indiana CLP assessments. With the exception of the 1976 profile, the temperature profiles show that Rock Lake was at least weakly stratified at the time of the assessments. The weakly developed hypolimnion (bottom water) present during the surveys is very typical of shallow Indiana lakes. The metalimnion, or area of rapidly changing water temperature, extended from 4 feet (1.5 m) to approximately 10 feet (3.1 m) at the time this data was collected. Water within the epilimnion and hypolimnion are typically separated during the summer in stratified lakes and do not mix. However, in lakes that are weakly stratified, wind or wave action can disrupt the stratification allowing the lake to mix throughout. This type of situation is apparent during 1976 sampling event. During this assessment, the temperature changed relatively little from the surface of Rock Lake to its deepest measurement. Overall, this profile suggests uniform temperature throughout the lake. This occurs in a lake that is undergoing mixing.

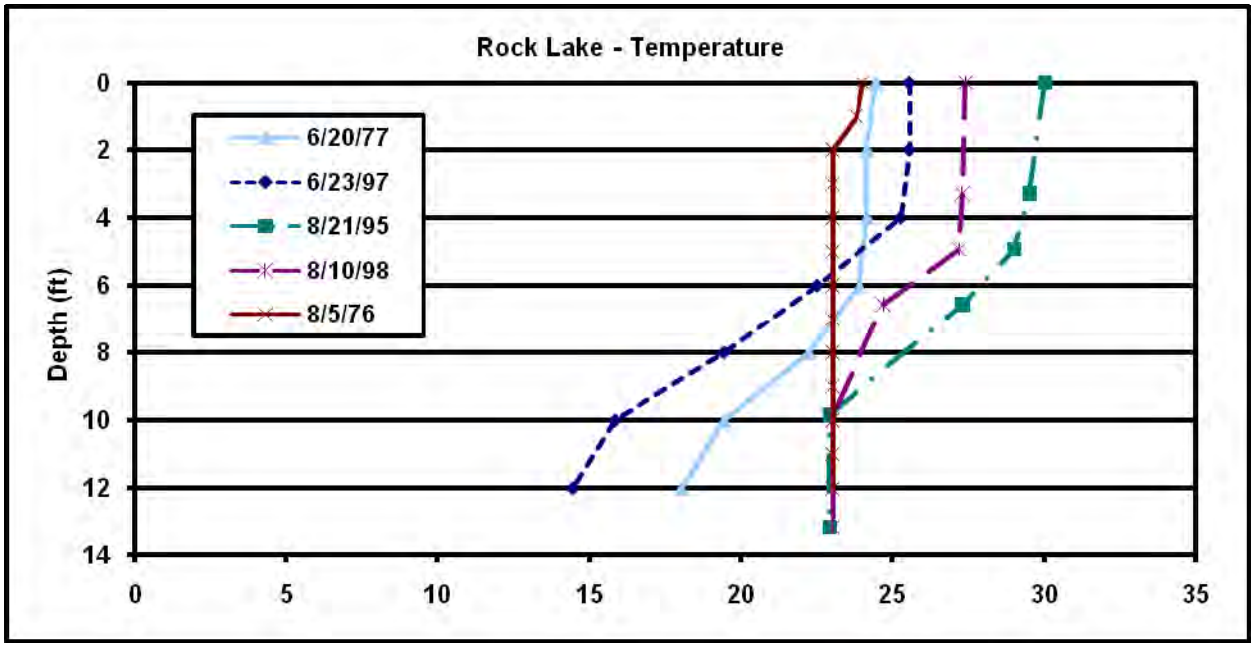

Figure 15. Historical temperature profiles for Rock Lake.
Source: Braun, 1998; CLP, 1995, 1998; ISPCB, 1986; Pearson, 1977.

Dissolved oxygen data indicate that the lake possessed dissolved oxygen greater than 1 mg/L in 75 to 100 percent of the water column (Figure 16). This relatively high dissolved oxygen concentration present throughout the water column is likely due in part to the shallow nature of the lake. Additionally, as the temperature and oxygen profiles suggest, Rock Lake is likely undergoing at least period mixing. This means that wind or wave action, motor boating, and other activities destabilize the weak stratification present within Rock Lake resulting in the two separate layers (epilimnion and hypolimnion) periodically merging into one layer. When this happens, oxygen rich water from the epilimnion is mixed with oxygen poor water from the hypolimnion forming a relatively equal distribution of oxygen. This is especially apparent during the 1997 sampling event when similar oxygen concentrations were recorded throughout the water column. This mixing of the surface and bottom waters is termed ***meromixis.*** Based on these data, it is likely that Rock Lake undergoes meromixis throughout the summer when most lakes are stratified. Fortunately, most of the lake's volume has oxygen levels sufficient to support fish.

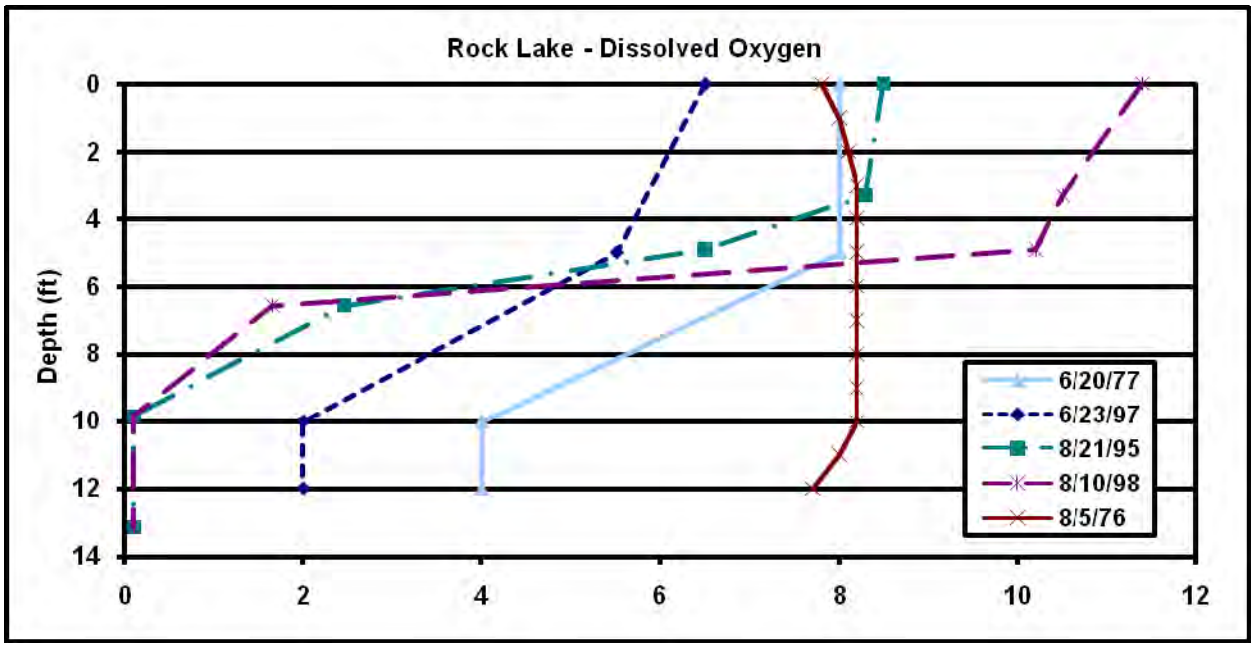

Figure 16. Historical dissolved oxygen profiles for Rock Lake.
Source: Braun, 1998; CLP 1995, 1998; ISPCB, 1986; Pearson, 1977.

3.0 CURRENT SAMPLING METHODS AND RESULTS

3.1 Lake Assessment

The water sampling and analytical methods used for Rock Lake were consistent with those used in IDEM's Indiana Clean Lakes Program and IDNR's Lake and River Enhancement Program. We collected water samples from Rock Lake on June 24, 2008 from the surface waters (***epilimnion***) and from the bottom waters (***hypolimnion***) at a location over the deepest water. Chlorophyll was determined only for the epilimnetic sample. Other parameters such as Secchi disk transparency, light transmission, and oxygen saturation are single measurements made in the epilimnion. In addition, 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 percent light level to the water surface.

Conductivity, temperature, and dissolved oxygen were measured *in situ* at the lake sampling site with an YSI Model 85 meter. In addition, lake water samples were collected for the following parameters:

- pH
- alkalinity
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- nitrate-nitrogen (NO_3^-)
- ammonia-nitrogen (NH_4^+)
- total Kjeldahl nitrogen (TKN)
- turbidity
- plankton
- chlorophyll *a*

The lake and stream water samples were placed in appropriate bottles (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. The *E. coli* bacteria samples were taken to Sherry Laboratories in Warsaw, 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, 21th Edition (APHA, 2005). Plankton counts were made using a standard Sedgewick-Rafter counting cell. Fifteen fields per cell were counted. Plankton identifications were made according to: Wehr and Sheath (2003), Prescott (1982), Ward and Whipple (1959) and Whitford and Schumacher (1984).

3.1.1 Lake Morphology

Rock Lake is roughly triangular in shape with the deepest area in the southern third of the lake (Figure 17). The lake's deepest point lies south of the triangular point near the southeastern edge of the 56-acre (22.7-ha) lake. Here, the lake extends to a maximum depth of 16 feet (4.9 m; Table 9). Although the DNR map shows a maximum depth of 16 feet (4.9 m), more recent DNR fisheries surveys suggest that the maximum depth of Rock Lake more likely measures 12 to 13 feet (3.7 to 3.9 m; Braun, 1998). Using the 1954 bathymetric map, we prepared depth-area and depth-volume curves for Rock Lake (Figures 17 and 18).

Figure 17. Rock Lake bathymetric map. Source: IDNR, 1954.

Table 9. Morphological characteristics of Rock Lake.

Characteristic	Value
Surface Area	56 acres (22.7 ha)
Volume	352 acre-feet (433,972 m^3)
Maximum Depth	16 feet* (4.9 m)
Mean Depth	6.5 feet (2.0 m)
Shallowness Ratio	0.59
Shoalness Ratio	1.0
Shoreline Length	7,967 feet (2,428 m)
Shoreline Development Ratio	9.1

*Depth based on most recent DNR bathymetric survey. More recent data suggest that the maximum depth more likely measures 12 feet (3.7 m).

Rock Lake is classified as a shallow lake. According to its depth-area curve (Figure 18), nearly 60 percent (33 acres or 13.4 ha) of the lake is covered by water less than 5 feet (1.5 m) deep, while the entire lake is covered by water less than 20 feet (6.1 m) deep. This translates into a very high shallowness ratio of 0.59 (ratio of area less than 5 feet (1.5 m) deep to total lake area) and a high shoalness ratio of 1.0 (ratio of area less than 20 feet (6.1 m) deep to total lake area) (Table 9), as defined by Wagner (1990). The lake's area gradually increases with depth to a water depth of about 10 feet (3.1m) before the rate of change increases. This rate (slope of lake bottom) continues to a depth of 16 feet (4.9 m). This results in a very small portion of the lake being deeper than 12 feet (3.7 m).

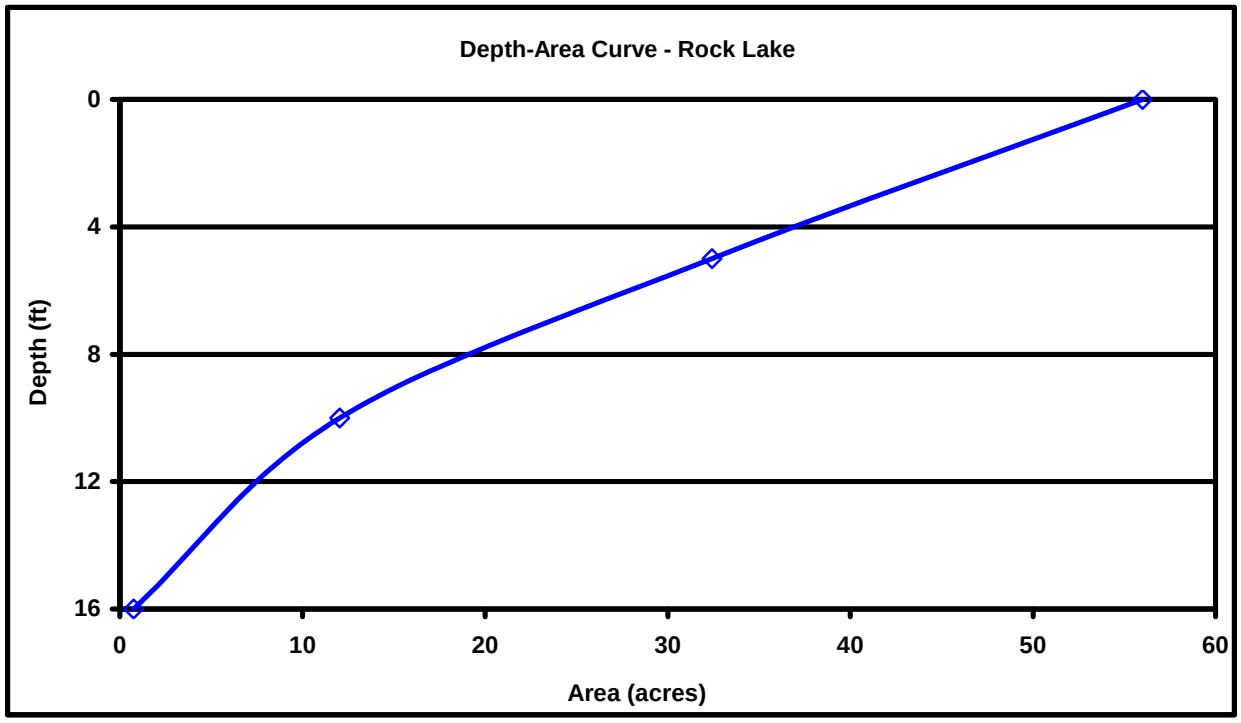

Figure 18. Depth-area curve for Rock Lake.

Limnologists suggest that, in theory, shallow lakes exist in one of two forms: clear, with a dominance of rooted plants or turbid, with a dominance of algae (Scheffer, 1998; Cooke et al., 2001; Mott unpublished data). Positive feedback mechanisms work to maintain whichever form a lake currently exhibits, creating a relatively stable environment. For example, there is some

evidence that vegetation controls turbidity through a variety of mechanisms (Scheffer, 1998). Vegetation helps stabilize bottom sediments from wind and wave action. It provides a refuge for zooplankton, the primary predator of phytoplankton. Some rooted plant species can secrete allelopathic compounds limiting algae growth. Similarly, rooted plants compete with algae for available nutrients and may affect the availability of nitrogen by creating conditions that facilitate denitrification. While none of these mechanisms may be sufficient to control turbidity, Scheffer (1998) suggests the combination of them can exert enough control to maintain a clear, vegetated lake. Conversely, turbidity, once it reaches a certain level, can impair the ability of rooted plants to grow, reinforcing the tendency for a turbid, unvegetated lake to remain unvegetated. As a shallow lake, these principles apply to Rock Lake and will be explored as they relate to water quality, plant community, and fisheries in further detail in subsequent sections.

Due to its shallow nature, Rock Lake has a relatively small volume holding approximately 352 acre-feet (433,972 m^3) of water. As illustrated in the depth-volume curve (Figure 19), most of the lake's volume is contained in the shallower areas of the lake. More than 60 percent of the lake's volume is contained in water that is less than 5 feet (1.5 m) deep. The lake's volume gradually increases with depth to a water depth of about 10 feet (3.1 m) before the rate of change increases. Below 10 feet (3.1 m), the steep curve indicates a greater change in depth per unit volume.

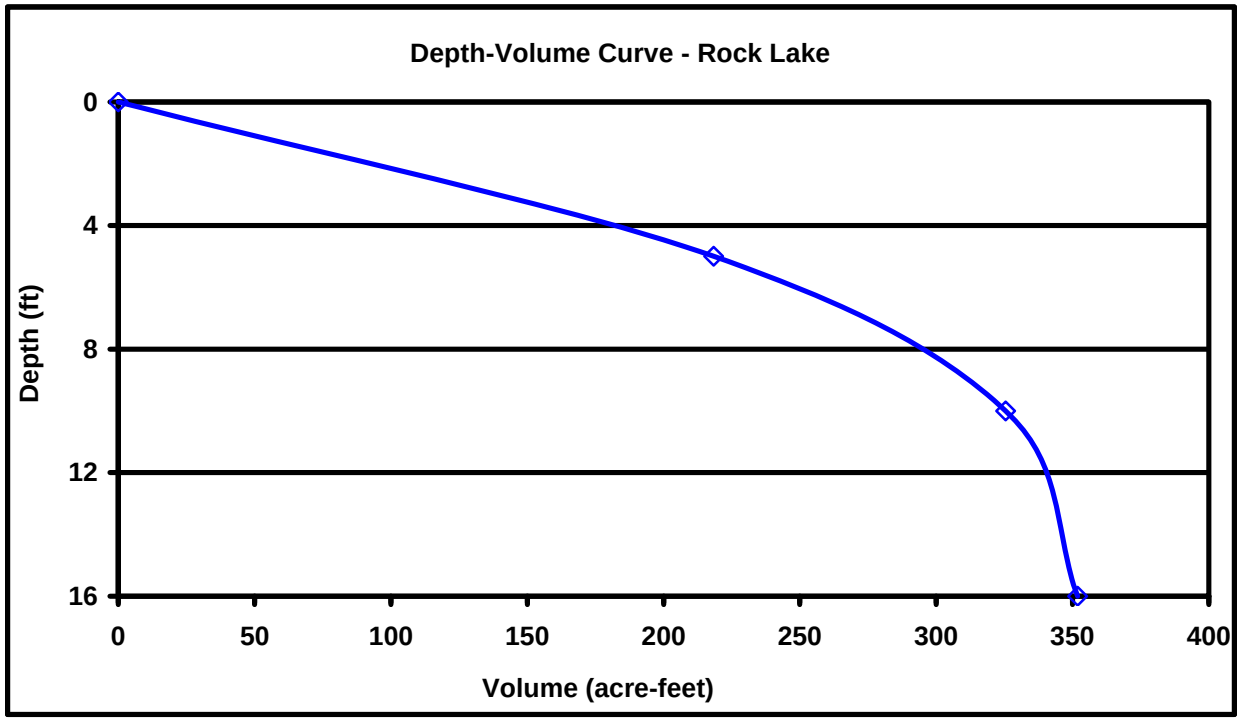

Figure 19. Depth-volume curve for Rock Lake.

A lake's morphology can play a role in shaping the lake's biotic communities. For example, Rock Lake's wide, shallow shelf around much of the perimeter of the lake coupled with its average clarity suggests the lake is capable of supporting a rooted plant community which covers a majority of the lake bottom. Based on the lake's average clarity (2.1 feet or 0.6 m), Rock Lake's littoral zone (or the zone capable of supporting aquatic rooted plants) extends from the shoreline to a depth of approximately 6.3 feet (1.9 m), which is calculated by multiplying the recent transparency by a factor of three. Referring to Rock Lake's depth-area curve (Figure 18),

the lake's littoral zone measures approximately 28 acres (11.3 ha) or 50 percent of the lake. The lake's 1 percent light level (or the depth at which only 1 percent of available surface light penetrates) can also be used to estimate the littoral zone extent. Rock Lake's 1 percent light level reaches a depth of 4 to 6 feet (1.2 to 1.8 m), covering 20 to 28 acres (8.1 to 11.3 ha) or 36 to 50 percent of the lakes surface area. Aquatic Control (2007) documented macrophytes at a maximum depth of 4 feet (1.2 m) in their 2006 Tier II assessment. The littoral zone is a significant percentage of the lakes surface area and thus has a significant influence over biotic communities and nutrient cycling. Biotic communities include macrophytes (plants) as well as fish, which utilize the plants for cover from predators, spawning habitat, and foraging cover. The growth and decay of the plants each year alternately uses and then releases nutrients from the sediments and water column.

A lake's morphology can also 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 Rock Lake (56 acres or 22.6 ha) would have a circumference of 5,537 feet (1,688 m). Dividing Rock Lake's shoreline length (7,967 feet or 2,428 m) by 5,537 feet yields a ratio of 1.4:1. This ratio is relatively low. Although Rock Lake is relatively triangular in shape, it lacks extensive shoreline channeling observed on other popular Indiana lakes. 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.

3.1.2 Lake Water Quality

The following lake water quality data was obtained from sampling efforts at one point over the deepest area of Rock Lake on June 8, 2008 (Table 10). Data such as this should always be viewed in comparison with other samples in the same lake to develop an understanding of seasonal and decade long changes in the lakes chemical and physical properties. Nutrient concentrations, temperature, dissolved oxygen, and plankton fluctuate daily and seasonally. Therefore; if there is more data available on a lake, then the better the understanding of the lakes general health and subsequent management decisions.

Table 10. Water Quality Characteristics of Rock Lake, June 24, 2008.

Parameter	Surface Water Sample	Deep Water Sample	Indiana TSI Points (based on mean values)
pH	8.3	7.9	-
Alkalinity	184 mg/L	187 mg/L	-
Conductivity	379 μmhos	380 μmhos	-
Secchi Depth Transparency	2 ft (0.6m)	-	6
Light Transmission @ 3 ft.	1.6 %	-	4
1% Light Level	3.3 ft (1m)	-	-
Total Phosphorous	0.125 mg/L	0.148 mg/L	3
Soluble Reactive Phosphorous	0.003 mg/L	0.003 mg/L	0
Nitrate-Nitrogen	0.020 mg/L	0.016 mg/L	0
Ammonia-Nitrogen	0.032 mg/L	0.269 mg/L	0
Organic Nitrogen	2.616 mg/L	2.481 mg/L	4
Oxygen Saturation @ 5ft.	74.9 %	-	0
% Water Column Oxic	98.6%	-	0
Plankton Density	75,889 NU/L	-	10
Blue-Green Dominance	19.8 %	-	0
Chlorophyll *a*	57.83 μg/L	-	-
*Method Detection Limit		**TSI score**	**27**

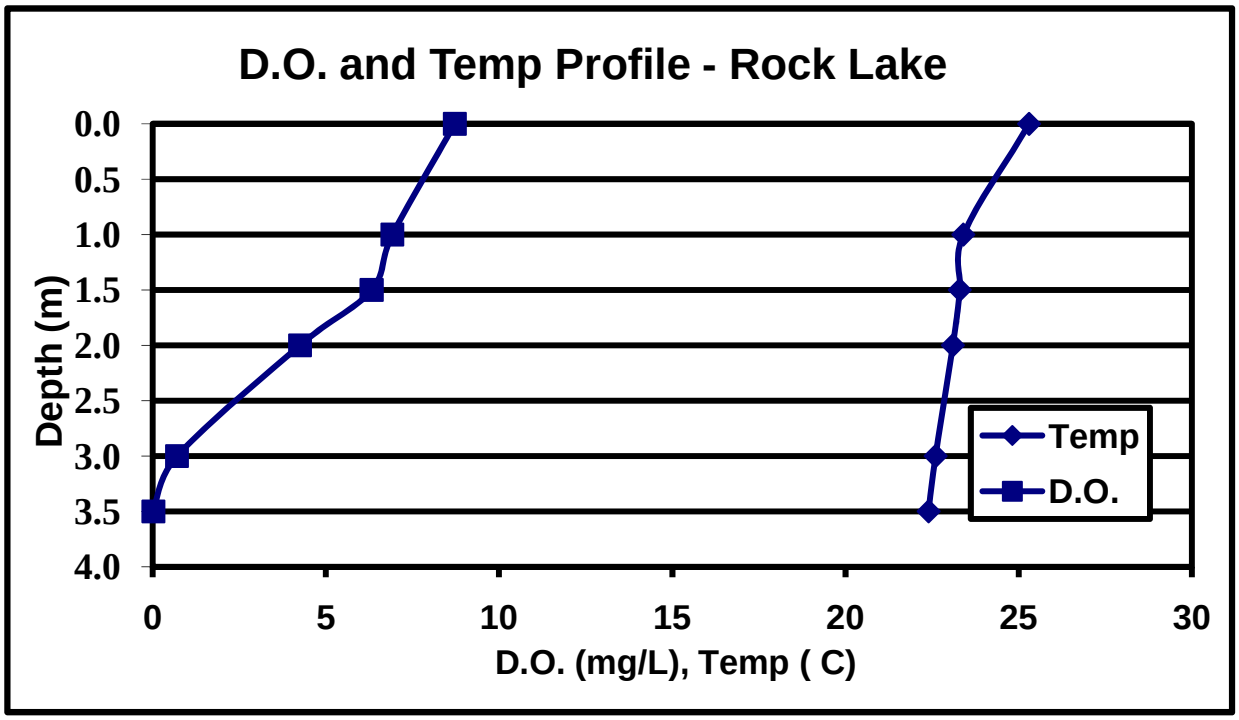

Figure 20. Temperature and dissolved oxygen profiles for Rock Lake on June 24, 2008.

Temperature and oxygen profiles for Rock Lake show that the lake was not stratified at the time of sampling (Figure 20). The lake is too shallow for pronounced thermal stratification. During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the well-mixed *epilimnion* (surface waters) by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the *metalimnion*. At the time of our sampling, the surface water temperature was elevated, likely due to solar gain during a hot summer day. There is little temperature difference at depths below 3.3 feet (1 m) and thus, no thermal stratification. The uniform temperature profile indicates that wind mixes the waters of Rock Lake down to the bottom.

Rock Lake had 74.9% oxygen saturation at a depth of 5 feet (1.5 m). Dissolved oxygen concentrations of less than 100 percent are usually an indicator of one or a combination of: a) poor mixing of surface water, b) low phytoplankton productivity, or c) intensive bacterial respiration. The lake reached anoxic ([D.O.] < 1.0 mg/L) conditions around the depth of approximately 10 feet (3 m). Due to the high algal productivity (see below), there is likely a significant amount of decaying algae and other organic matter in the deeper water and in the sediments. Bacteria that consume this organic matter consume dissolved oxygen in the water and release ammonia as a decomposition by-product. Water below 10 feet (3m) had no oxygen content to support fish and other aquatic organisms.

The 1 percent light level, which limnologists use to determine the lower limit where photosynthesis can occur, extended to 3.25 ft (~1 m) at the time of sampling. Based on the depth-area curve in Figure 18, approximately 28.6 percent of lake bottom (approximately 15 acres or 6 ha) is shallower than 3.25 feet. This represents the <u>area</u> of the lake bottom with sufficient light to support rooted plants. This area is called the *littoral zone*. Furthermore, based on the depth-volume curve (Figure 19), we see that a <u>volume</u> of approximately 150 acre-feet of Rock Lake (43 percent of total lake volume) lies above the 3.25-foot 1 percent light level. This area, referred to as the *photic zone*, represents the amount of water with sufficient light to support algal growth.

Phosphorus and nitrogen are the primary plant nutrients in lakes. Phosphorus concentrations that exceed 0.03 mg/L concentration are considered high enough to support eutrophic conditions. Total phosphorus (TP) concentrations are relatively high and similar in both the surface and bottom waters of Rock Lake (0.125 mg/L and 0.148 mg/L respectively) due to the complete mixing of top and bottom waters. Higher phosphorus concentrations near the bottom of the lake are usually associated with nutrient release from the sediments under anoxic conditions. Settling of particulates and plankton also provide a source of phosphorus to the lake bottom. Since soluble reactive phosphorus (SRP) is at relatively normal levels of 0.003 in both the epilimnion and the hypolimnion, the high TP readings are likely due to the phosphorus found within the algae.

Nitrate nitrogen was low in the surface and bottom waters, measuring 0.020 and 0.016 mg/L, respectively. Ammonia oxidizes rapidly to nitrate in the presence of adequate oxygen and nitrifying bacteria, which partially explains the increased concentrations in the surface water in comparison to the deep water. Nitrate, on the other hand, is reduced to ammonia when oxygen is low. The high ammonia concentration (0.269 mg/L) in the deep water indicates the presence of a high rate of bacterial decomposition and a high amount of biochemical oxygen demand (BOD) that produces ammonia and consumes dissolved oxygen.

Values for pH are within the normal range for Indiana lakes, pH 8.3 for the surface water and pH 7.9 for the deep water. pH values for most fresh waters fall between pH 6-9 (Kalff, 2002). The

high alkalinity concentrations (184 mg/L to 187 mg/L) measured indicate that Rock Lake is a well-buffered system.

Plankton enumerated from the sample collected from Rock Lake are shown in Table 11. *Desmodesmus*, a green algae, was the most dominant genera found, and accounted for more than one-third of the plankton density. In addition to this particular green algae, other green algae species contributed to the overall plankton dominance by greens of approximately 60 percent. Green algae are more palatable as food for zooplankton grazers and usually do not form nuisance blooms. Blue-green algae are usually associated with degraded water quality. Blue-green algae are less desirable in lakes because they may form extremely dense nuisance blooms, may cause taste and odor problems, and are unpalatable as food for many zooplankton grazers. Blue Green algae made up 40 percent of the algae population in Rock Lake on June 24, 2008. Overall, we identified 42 different genera of algae in our Rock Lake sample and found a high plankton density of more than 75,000 Natural Units of plankton per liter.

Table 11. The plankton sample representing the species assemblage on June 24, 2008.

SPECIES	ABUNDANCE (NU/L)
Blue-Green Algae (Cyanophyta)	
Chroococcus	6526
Aphanizomenon	5624
Aphanocapsa	1250
Spirulina	868
Anabaena	382
Coelosphaerium	347
Merismopedia	35
Green Algae (Chlorophyta)	
Desmodesmus	29681
Ulothrix	9547
Scenedesmus	1458
Pediastrum	798
Misc Green	729
Coelastrum	590
Ankistrodesmus	521
Staurastrum	521
Pandorina	347
Mougiotia	347
Selenastrum	208
Cosmarium	174
Zygnema	174
Tetraedron	174
Crucigenia	174
Cladophera	139
Gloeocystic (Coccoid green)	139
Actinastrum	104
Gomphosphaeria	69
Elakatothrix	35
Tetrapedia	35

SPECIES	ABUNDANCE (NU/L)
Sorastrum	35
Misc. Desmid	35
Treubarra	35
Diatoms (Bacillariophyta)	
Synedra	1284
Asterionella	139
Stephanodiscus	139
Misc Diatom	139
Taballaria	69
Navicula	69
Other Algae	
Ceratium	6040
Protozoa	3263
Dinobryon	2708
Peridinium	417
Euglina	104
Rotifers	
Keratella	312
Trichocerca	104
Zooplankton	
Daphnia	1
Nauplius	1
Calanoid Copepod	1

3.1.3 Phosphorus Budget

We have used a phosphorus model to estimate the dynamics of this important nutrient in Rock Lake. With its role as the limiting nutrient, phosphorus should be the target of management activities to lower the biological productivity of these lakes.

The limited scope of this LARE study did not allow us to determine phosphorus inputs and outputs outright. Therefore, we have used a standard phosphorus model 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, and from this, they calculated phosphorus export coefficients for various land uses. We used mid-range estimates of these phosphorus export coefficient values for all watershed land uses (Table 12). Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. The export coefficient for a particular land use was multiplied by the area of land in that land use category to derive an estimate of annual phosphorus export (as kg/year) for each land use.

Table 12. 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)

We estimated direct phosphorus input via precipitation to the lakes by multiplying mean annual precipitation in Kosciusko County (37 in./yr; Clark, 1980) times the surface area of the lake times a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). Because the 49 homes surrounding Rock Lake are on septic systems, there is phosphorus input from septic systems. Having no other data, we assumed that all homes on the lake were occupied year-round. This may overestimate the phosphorus contribution from septic systems but this is a small percentage of annual phosphorus loading to the lake anyway. The results, shown in Table 13, yielded an estimated 507 kg of phosphorus loading to Rock Lake from watershed runoff, septic systems, and from precipitation annually. The greatest estimated source of phosphorus loading to the lake is from row crop agriculture: over 67 percent of total loading and 75 percent of watershed loading.

Table 13. Phosphorus Loading Model for Rock Lake

LAKE:	Rock		**DATE:**	4/01/2009
COUNTY:	Kosciusko			
STATE:	Indiana			
INPUT DATA		**Unit**		
Area, Lake	56	acres		
Volume, Lake	352	ac-ft		
Mean Depth	6.3	ft		
Hydraulic Residence Time	0.16	yr		
Flushing Rate	6.25	1/yr		
Mean Annual Precipitation	0.93	m		
[P] in precipitation	0.03	mg/l		
[P] in epilimnion	0.125	mg/l		
[P] in hypolimnion	0.148	mg/l		
Volume of epilimnion	244	ac-ft		
Volume of hypolimnion	108	ac-ft		
Land Use (in watershed)	**Area**		**P-export Coefficient**	
Deciduous Forest	128.68	hectare	0.2	kg/ha-yr
Emergent Herbaceous Wetlands	8.16	hectare	0.1	kg/ha-yr
Evergreen Forest	2.44	hectare	0.15	kg/ha-yr
Woody Wetlands	30.24	hectare	0.1	kg/ha-yr
Open Water	40.00	hectare	0.5	kg/ha-yr
High Intensity Residential	0.06	hectare	1.5	kg/ha-yr
Low Intensity Residential	0.8	hectare	0.8	kg/ha-yr
Mixed Forest	0.1	hectare	0.175	kg/ha-yr
Pasture/Hay	145.4	hectare	0.5	kg/ha-yr
Row Crops	380.6	hectare	1	kg/ha-yr
Septic Systems	--------	-------	0.50	kg/ha-yr
Other Data				
Soil Retention coefficient	0.75	-------		
# Permanent Homes	49	homes		
Use of Permanent Homes	1.0	year		
Avg. Persons Per Home	3	persons		
OUTPUT				
P load from watershed	482.1	kg/yr		
P load from precipitation	6.33	kg/yr		
P load from septic systems	18.38	kg/yr		
Total External P load	506.81	kg/yr		
Areal P loading	2.236	g/m2-yr		
Predicted P from Vollenweider	0.102	mg/l		
Back Calculated L total	2.902	g/m2-yr		
Estimation of L internal	0.666	g/m2-yr		
% of External Loading	77.1	%		
% of Internal Loading	22.9	%		

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

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

During our June 24, 2008 sampling of Rock Lake, the mean volume weighted phosphorus concentration in the lake was 0.132 mg/L. Now it is useful to ask the question, "How much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.132 mg/L in Rock Lake?" By plugging this mean concentration along with the mean depth and flushing rate into Vollenweider's phosphorus loading model and solving for L, we get an estimated areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 2.90 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.132 mg/L in Rock Lake, a total of 2.90 grams of phosphorus must be delivered to each square meter of lake surface area per year. However, our phosphorus loading model (Reckhow et al. 1980) estimated that 2.24 g/m^2-yr of phosphorus is delivered to the lake annually from watershed sources (runoff, septic tanks and precipitation). Where did this extra phosphorus (2.90 g/m^2-yr – 2.24 g/m^2-yr = 0.66 g/m^2-yr) come from. There are several possible explanations:

1. The phosphorus loading model underestimated the watershed phosphorus delivery to the lake.
2. Phosphorus is released to the lake from the sediments.
3. Phosphorus is pumped into the lake by growing aquatic macrophytes and these macrophytes release phosphorus into the lake when they die back in the fall.

Determining which of the above sources of more importance to the phosphorus dynamics in Rock Lake is difficult. Small, shallow lakes like Rock Lake have significantly less dilutional capacity than do deeper lakes of the same surface area. Results from a previous set of samples collected from Rock Lake in 1998 showed considerably higher concentrations of phosphorus in the hypolimnion sample than in the epilimnion sample, unlike this present year (Table 14). The 1998 data show that there was significant phosphorus release from Rock Lake's Sediments at that time. The 2008 data are likely an anomaly, due to the mixed surface and bottom waters present during the June 2008 sample.

Table 14. Historic sediment phosphorus release from Rock Lake.

Year	Epilimnion (mg/L)	Hypolimnion (mg/L)	Sediment Phosphorus Release Factor
1998	0.011	0.423	38.5
2008	0.010	0.010	1

[1]***Hypo TP concentration/Epi TP concentration. For example, in 1998 hypolimnetic SRP concentration was 38.5 times that in the epilimnion. A large difference is strong evidence of substantial internal loading of phosphorus.***

Another source of internal phosphorus to Rock Lake could be the fall dieback of rooted macrophytes. These plants obtain the majority of their nutrients from the sediments. In essence, they 'pump' nutrients out of the sediments into their tissues. When the rooted plants die back in the fall, the nutrients contained within their tissues are released back into the water.

In Monroe Reservoir, the annual fall senescence of Eurasian watermilfoil alone accounted for up to 24 percent of phosphorus and 2 percent of the nitrogen from all nonpoint sources (Landers and Frey 1980). This release resulted in a massive fall algal bloom in the reservoir. If we consider all the rooted plant species in Rock Lake, it is conceivable that they could contribute a significant amount of phosphorus to the lake at the time of fall die-back.

Our experience on other lakes has shown that the runoff coefficient model of Reckhow et al. (1980) provides a fairly accurate estimate of watershed loadings. The significance of areal phosphorus loading rates is better illustrated in Figure 21 in which areal phosphorus loading to Rock Lake is plotted against the product of Rock Lake's 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). The areal phosphorus loading rate for Rock Lake lies slightly above the acceptable line.

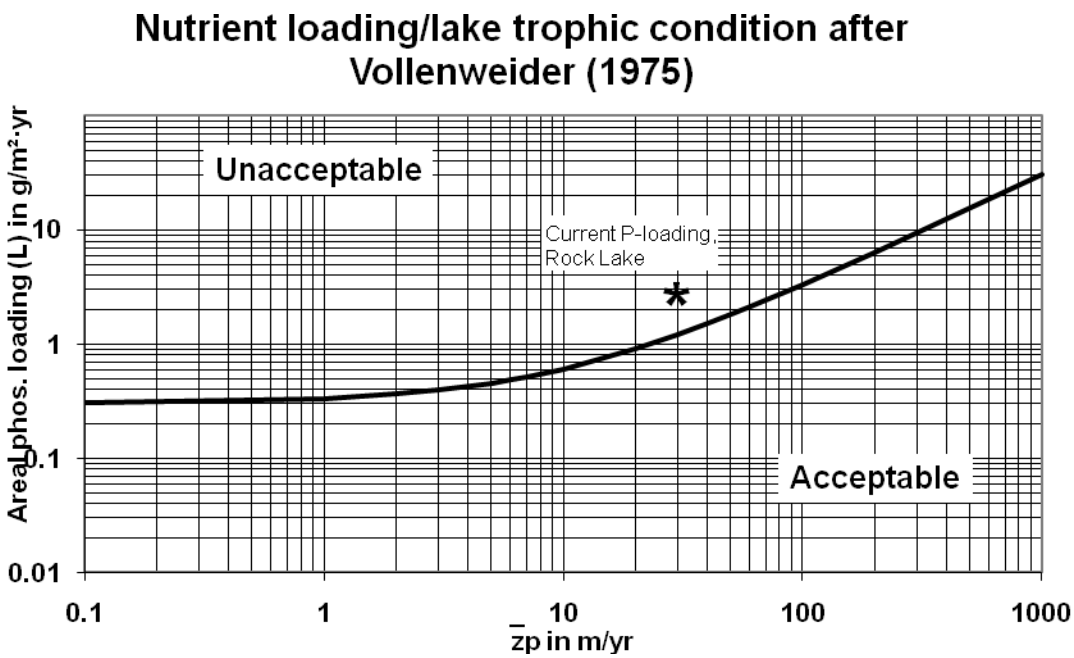

Figure 21. Estimated external phosphorus loadings from Reckhow and Simpson's runoff coefficients to Rock Lake compared to acceptable loadings determined from Vollenweider's model. The dark line represents the upper limit for acceptable loading.

This figure can also be used to evaluate management needs. For example, areal phosphorus loading to Rock Lake would have to be reduced from 2.902 g/m^2-yr to 0.660 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 2.24 g/m^2-yr to the lake, which is equivalent to a total phosphorus mass loading reduction of 508 kg P/yr or 77 percent of current estimated total phosphorus loading to the lake (Table 15). The lake management goal should include finding a way to reduce external phosphorus loading to Rock Lake by 508 kg per year.

Table 15. Phosphorus Reduction Required to Achieve Acceptable Phosphorus Loading Rate and a Mean Lake Concentration of 0.03 mg/L

Lake	Current External Total Areal P Loading (g/m^2-yr)	Acceptable Areal P Loading (g/m^2-yr)	Reduction Needed (kg P/yr and %)
Rock	2.902	0.66	508 kg (77%)

3.1.4 Water Budget

A water budget for Rock Lake was calculated to determine how long water remains in the lake once it arrives (residence time). This information is important to lake managers because knowing the residence time, allows more efficient use of herbicides and other management techniques. In order to calculate the residence time we need to know the amount of water entering (inputs) and leaving (exported) the lake.

The Inputs of water to Rock Lake are limited to:
1. direct precipitation to the lake
2. discharge from Landis Ditch and Lautzenhiser Ditch
3. sheet runoff from land immediately adjacent to the lake
4. groundwater

Water leaves the lake system from:
1. discharge from the lake's outlet channel (Chippawanuck Creek or Bucher Ditch)
2. evaporation
3. groundwater

There are no gages in the watershed to measure water inputs and the limited scope of this study did not allow us to quantitatively determine annual water inputs or outputs. Therefore we must estimate the water budget for lakes from other records.

- Direct precipitation to the lake can be calculated from mean annual precipitation falling directly on the lake's surface.
- Runoff from Rock Lake's watershed can be estimated by applying runoff coefficients. A runoff coefficient refers to the percentage of precipitation that occurs as surface runoff, as opposed to that which soaks into the ground. Runoff coefficients may be estimated by comparing discharge from a nearby gaged watershed of similar land and topographic features, to the total amount of precipitation falling on that watershed. The nearest gaged watershed is a U.S.G.S. gaging station on the Eel River at North Manchester, Indiana (USGS 2008). The 77-year (1931–2007) mean annual daily discharge for this watershed is 386.3 cubic feet per second (cfs). However, discharge from the Eel River has been higher in recent decades (Figure 22) so we used the mean annual daily discharge (444.7 cfs) over the past 20 years of record in our water budget. With mean annual precipitation of 37 inches (Clark, 1980), this means that on average, about 39 percent of the rainfall falling on this watershed runs off on the land surface.
- There exist no groundwater records for the lake so we must assume that groundwater inputs equal outputs.
- We can estimate evaporation losses by applying evaporation rate data to the lakes. Evaporation rates are determined at six sites around Indiana by the National Oceanic and Atmospheric Administration (NOAA). The nearest site to the study lakes is located in Wanatah (Porter County), Indiana. Annual evaporation from a 'standard pan' at the Wanatah site averaged 41.8 inches per year between 2003-2005 (NOAA 2005). Because evaporation from the standard pan overestimates evaporation from a lake by

about 30 percent, we correct the evaporation rate by this percentage, which yields an estimated evaporation rate from the lake surface of 29.3 inches per year. Multiplying this rate times the surface area of Rock Lake yields an estimated volume of evaporative water loss from the lake.

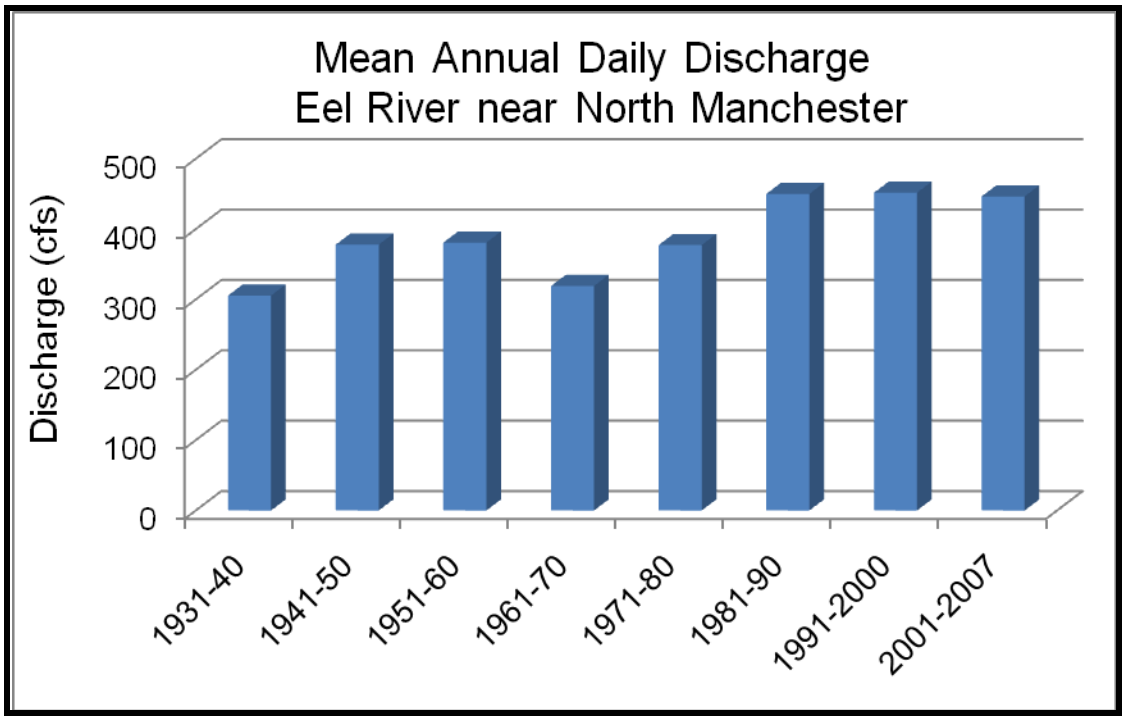

Figure 22. Mean annual daily discharge from the Eel River at North Manachester for the past eight decades indicate that discharge has been higher since 1981.

The water budget for Rock Lake, based on the assumptions discussed above, is shown in Table 16. When the volume of water flowing out of Rock Lake is divided by the lake's volume, we get a *hydraulic residence time* of 0.16 years (58 days). This means that on average, water entering the lake stays in the lake for only 58 days before it flows out. This hydraulic residence time is shorter than other 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 and Simpson, 1980). Most glacial lakes have a watershed area to lake surface area ratio of around 10:1 (Vant, 1987). Rock Lake, with a watershed area to lake surface area ratio of 31:1, has a much larger watershed than the average cited in Vant, and because of its shallow mean depth of only 6.3 feet, the small volume contributes to its shorter hydraulic residence time.

Table 16. Water Budget Calculations for Rock Lake.

Watershed	Rock Lake - Kosciusko Co.
Watershed size (ac)	1819.7
Mean watershed runoff (ac-ft/yr)	2195
Lake volume (ac-ft)	352
Closest gaged stream	Eel River @ N. Manchester
Stream watershed (mi^2)	417
Stream watershed (acres)	266880
Mean annual daily Q (cfs)	444.7
Mean annual total Q (ac-ft/yr)	321948
Mean ppt (in/yr)	37
Mean watershed ppt (ac-ft/yr)	822880
Watershed C	0.39
Pan evaporation (in/yr)	41.80
Pan evaporation coefficient	0.70
Lake surface area (acres)	56
Estimated lake evaporation (ac-ft)	137
Direct precipitation to lake (ac-ft)	173
	= input data
	= output data
Water Budget Summary	
Direct precipitation to lake (ac-ft)	173
Runoff from watershed (ac-ft)	2195
Evaporation (ac-ft)	137
TOTAL LAKE OUTPUT (ac-ft)	2231
Hydraulic residence time (yr)	0.16

3.1.5 Shoreline Development

Approximately 55 percent of Rock Lake's shoreline has been altered from its natural state (Figure 23). Along these portions of Rock Lake's shoreline emergent and floating rooted vegetation has been partially or completely removed from adjacent to the shoreline. This leaves exposed soils or mowed, residential lawns exposed to wave action. Natural shoreline remains along approximately 45 percent of Rock Lake's shoreline where bands of plants like those described by McGinty (1966) are present with trees, emergent vegetation, floating vegetation, and submerged vegetation located in distinct zones along the lakeshore. In these areas, the submerged, floating, emergent, and shoreline canopy layers all remain intact. The shoreline surface becomes especially important in and adjacent to shallow portions of Rock Lake. Wave turbulence caused by armored shorelines can resuspend bottom sediments thereby increasing the transfer of nutrients from the sediment-water interface to the water column. Continuous disturbance in shallow areas can also encourage the growth of disturbance-oriented plants. In contrast, shorelines vegetated with emergent or rooted floating vegetation will absorb more of the wave energy. The waves will dissipate along the shoreline each time a wave meets the

shoreline surface. Stone seawalls, which are common at Rock Lake, are a good compromise between concrete and vegetation that decrease shallow water turbulence and lakeward wave energy reflection while still providing shoreline stabilization.

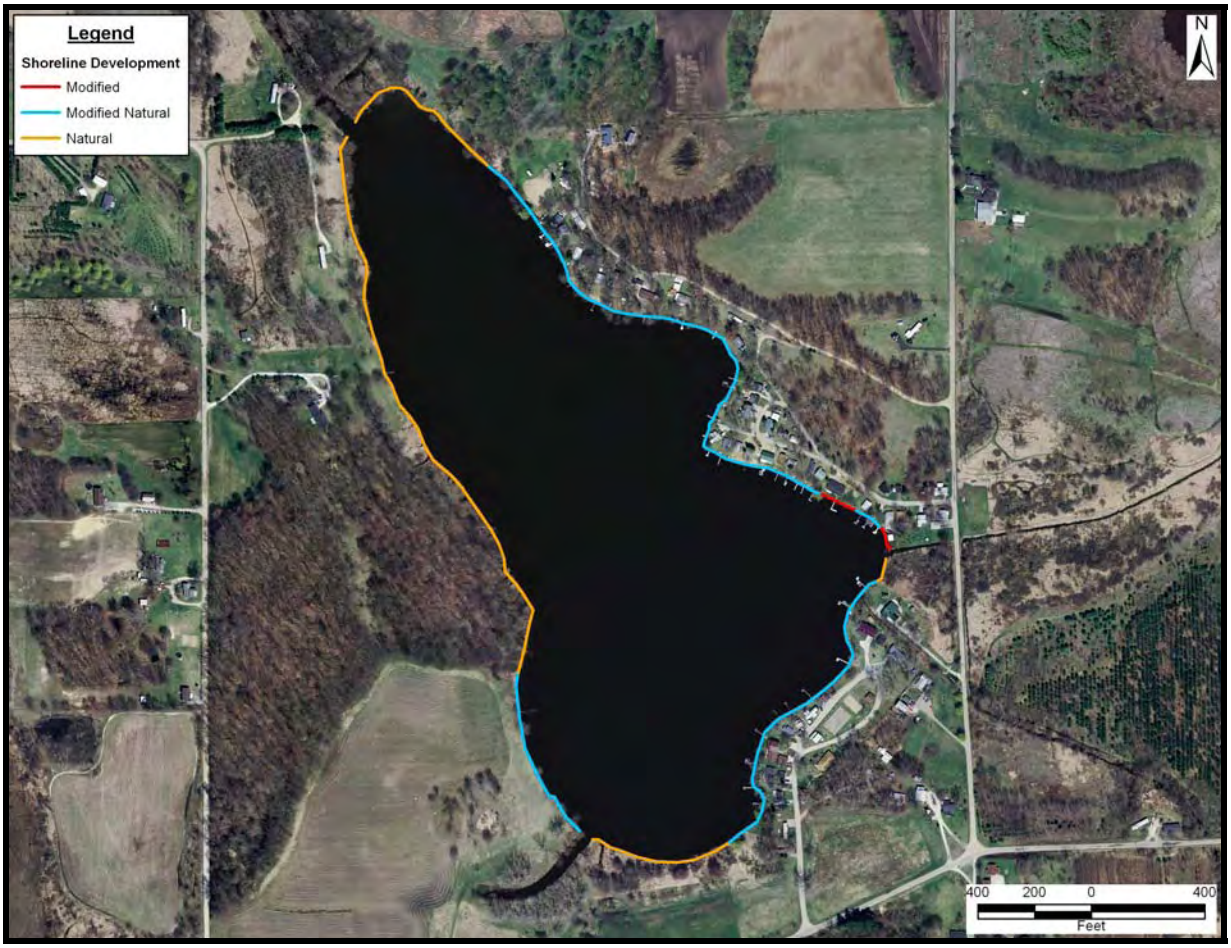

Figure 23. Shoreline Development observed at Rock Lake on August 4, 2008. Note: There is little or erosion of the shorelines on Rock Lake.

3.1.6 Macrophyte Inventory

Introduction

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

The composition and structure of a lake's rooted plant community also help determine the lake's fish community composition and structure. Submerged aquatic vegetation provides cover from predators and is a source of forage for many different species of fish (Valley et al., 2004). However, extensive and dense stands of exotic aquatic vegetation can have a negative impact on the fish community. For example, a lake's bluegill population can become stunted because dense vegetation reduces their foraging ability, resulting in slower growth. Additionally, dense stands reduce predation by largemouth bass and other piscivorous fish on bluegill which results in increased intraspecific competition among both prey and predator species (Olsen et al., 1998). Vegetation removal can have variable results on improving fish growth rates (Cross et al., 1992, Olsen et al., 1998). Conversely, lakes with depauperate plant communities may have difficulty supporting some top predators that require emergent vegetation for spawning. In these and other ways, the lake's rooted plant community illuminates possible reasons for a lake's fish community composition and structure.

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

Aquatic Control (2007) conducted three annual surveys of Rock Lake from 2005-2007. Their detailed surveys documented Eurasian watermilfoil (EWM) the first year, then treated it with herbicide. Subsequent surveys did not locate EWM and so treatment was halted (Aquatic Control, 2007). JFNew conducted a general macrophyte (rooted plant) survey on Rock Lake as part of the overall lake and watershed diagnostic study on August 4, 2008. Before detailing the results of the macrophyte survey, it may be useful to outline the conditions under which lakes may support macrophyte growth. Additionally, an understanding of the roles that macrophytes play in a healthy, functioning lake ecosystem is necessary for lake users to manage the lake's macrophyte community. The following paragraphs provide some of this information.

Conditions for Growth

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

As a general rule of thumb, rooted plant growth is restricted to the portion of the lake where water depth is less than or equal to 2 to 3 times the lake's Secchi disk depth. This holds true in Rock Lake. The Secchi disk depth measured during the 2008 plant survey was 2.5 feet (0.76 m). This measurement was slightly better than the Secchi disk depth measured for the lake during the 2007 sampling (1.5 feet or 0.46 m Aquatic Control, 2007). Rock Lake's maximum rooted plant growth was documented by Aquatic Control (2007) at a depth of 4 feet (1.2 m) and by JFNew to a depth of 10 feet (3.0 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. Light is limiting the depth at which plants are growing in Rock Lake.

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 like Rock Lake, have an increased potential for plant growth compared to lakes with gravelly, rocky substrates. Lakes that have significant wave action or motor boat activity that disturb the bottom sediments have decreased ability to support plants. Disturbance of bottom sediment, especially in shallow lakes like Rock Lake, may decrease water clarity, which in turn limits light penetration. Wave action or boating activity may also create significant direct disturbance by eroding the substrate from around the plants roots, or cutting of the plants. EWM whole plants or even fragments of plants released in this manner will establish new populations in other sections of the lake. Herbicide treatment may also affect the species composition and density of plant beds in a lake. For example, treating a plant bed which contains EWM may result in the resurgence of a variety of native species or other weedy invasive species such as curly leaved pondweed.

Boating activity may affect macrophyte growth in conflicting ways. Rooted plant growth may be limited if boating activity regularly disturbs bottom sediments. Alternatively, boating activity in rooted plant stands of species that can reproduce vegetatively, such as Eurasian watermilfoil or coontail, may increase macrophyte density rather than decrease it. Herbicide treatment can also affect the presence and distribution of aquatic macrophytes within a lake. As species or areas are selectively treated, the density and diversity of plants present within those locations can, and typically do change. For example, continuing to treat a specific plant bed which contains Eurasian watermilfoil can result in the disappearance of Eurasian watermilfoil and the resurgence of a variety of native species. It should be noted, however, that non-native plants can regrow in these locations just as easily as native plants.

Ecosystem Roles

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

Emergent and submergent 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 percent covered with aquatic plants for successful survival, while northern pike achieve success in areas where rooted plants cover 80 percent 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 Oliver, Olin, and Martin lakes as habitat during the macrophyte survey. Aquatic plants such as pondweed, coontail, duckweed, watermilfoil, and arrowhead, also provide a food source to waterfowl. Duckweed in particular has been noted for its high protein content and consequently has served as feed for livestock. Turtles and snakes utilize emergent vegetation as basking sites. Amphibians rely on the emergent vegetation zones as primary habitat.

Macrophyte Inventory Methods

JFNew surveyed Rock Lake on August 4, 2008 according to the Indiana Department of Natural Resources Tier II sampling protocols (Table 17). The entire littoral zone was surveyed during this assessment. The lake's littoral zone was estimated to be approximately three times the lake's Secchi disk transparency depth measured just prior to the sampling event. This estimate approximates the 1 percent light level, or the level at which light penetration into the water column is sufficient to support plant growth. Tier II protocols and requires that the sampling points be stratified over the entire depth of the lake's littoral zone. Total points sampled per stratum were determined as follows:

1. Appendix D of the IDNR protocol was consulted to determine the number of points to be sampled. This determination was based on the lake size (surface area) and trophic status.
2. Table 3 of the IDNR protocol was referenced as an indicator of the number of sample points per stratum. Table 17 in this report lists the sampling strategy for Rock Lake.

Stratum refers to depth at which plants were observed. Dominance presented in subsequent tables was calculated by the IDNR protocol. The rake score frequency per species scale presented in subsequent tables provides a measure of the frequency of a species. The percentage of plants found within a frequency measure indicates the frequency of plants found over all the sampling points.

Table 17. Tier II sampling strategy for Rock Lake using the 2007 Tier II protocol.

Lake	Size	Trophic Status	Number of Points	Stratification of Points
Rock Lake	56 acres	Eutrophic	40	30 pts 0-5 feet stratum; 10 pts 5-10 feet stratum;

Macrophyte Inventory Results

Transparency was observed at 2.5 feet (0.76 m) at the time of the survey. Based on the survey protocol, plants were sampled to a depth of 10 feet (3.0 m). Forty sites were randomly selected within the littoral zone based on the stratification indicated in the protocol.

Table 18 and 19 present the results of the sample effort. Plants were present to a maximum depth of 10 feet. Sago pondweed dominated the plant community throughout the littoral zone and in the 0-5 foot (0-1.5 m) and 5-10 foot (1.5-3.0 m) stratum. Sago pondweed was identified at 37.5 percent of sites surveyed throughout Rock Lake. It was also the most frequently identified plant species in the 0-5 foot stratum where it was observed at 40 percent of sites. Coontail and chara were also identified in the 0-5 foot stratum with frequencies of 15 percent and 5 percent, respectively. Filamentous algae were identified at 10 percent of the surveyed

sites.. Historically, sago pondweed, coontail, and Eurasian watermilfoil have been the dominant aquatic plant species in Rock Lake. In 2004, Eurasian watermilfoil was identified at 27.5 percent of the sites surveyed throughout the lake. That same year, 7.5 acres of Eurasian watermilfoil was treated with 2,4-D. In 2005, Eurasian watermilfoil was identified at 3.4 percent of the sites surveyed and 9 acres were treated in the lake with 2,4-D.

Table 18. Aquatic plant species observed in Rock Lake during the summer survey completed August 4, 2008. Plants not observed in the August 4 survey were observed on casual visits to the lake at other times during 2009.

Scientific Name	Common Name	Stratum	August 4, 2008
Ceratophyllum demersum	Coontail	Submergent	X
Chara species	Chara species	Submergent	X
Eleocharis sp.	Spikerush	Emergent	
Filamentous algae	Filamentous algae	Algae	X
Iris virginica	Blue-flag iris	Emergent	X
Justicia americana	Water willow	Emergent	
Lemna minor	Common duckweed	Floating	X
Nymphaea odorata	Spatterdock	Floating	X
Nuphar variegatum	Yellow water lily	Floating	X
Phalaris arundinacea	Reed canary grass	Emergent	X
Phragmites australis	Common reed	Emergent	
Sagittaria latifolia	Common arrowhead	Emergent	X
Scirpus acutus	Hard-stem bulrush	Emergent	X
Scirpus pungens	Chairmaker's rush	Emergent	X
Stuckenia pectinatus	Sago pondweed	Submergent	X
Typha latifolia	Broad leaf cattail	Emergent	X

No submergent exotic species were located in Rock Lake during the August 4, 2008 survey. Although Eurasian watermilfoil has been identified in Rock Lake in past surveys (Aquatic Control, 2007), it was not present in Rock Lake during the summer 2008 survey. Unlike the submergent community, the shoreline was quite diverse on the west (undeveloped side) of Rock Lake. A minimum of 12 twelve emergent or rooted floating species were identified during the survey at the lakes edge including two exotic species: common reed and reed canary grass.

Figure 24 shows the locations where points were sampled within Rock Lake. Raw data and survey results are included in Appendix C.

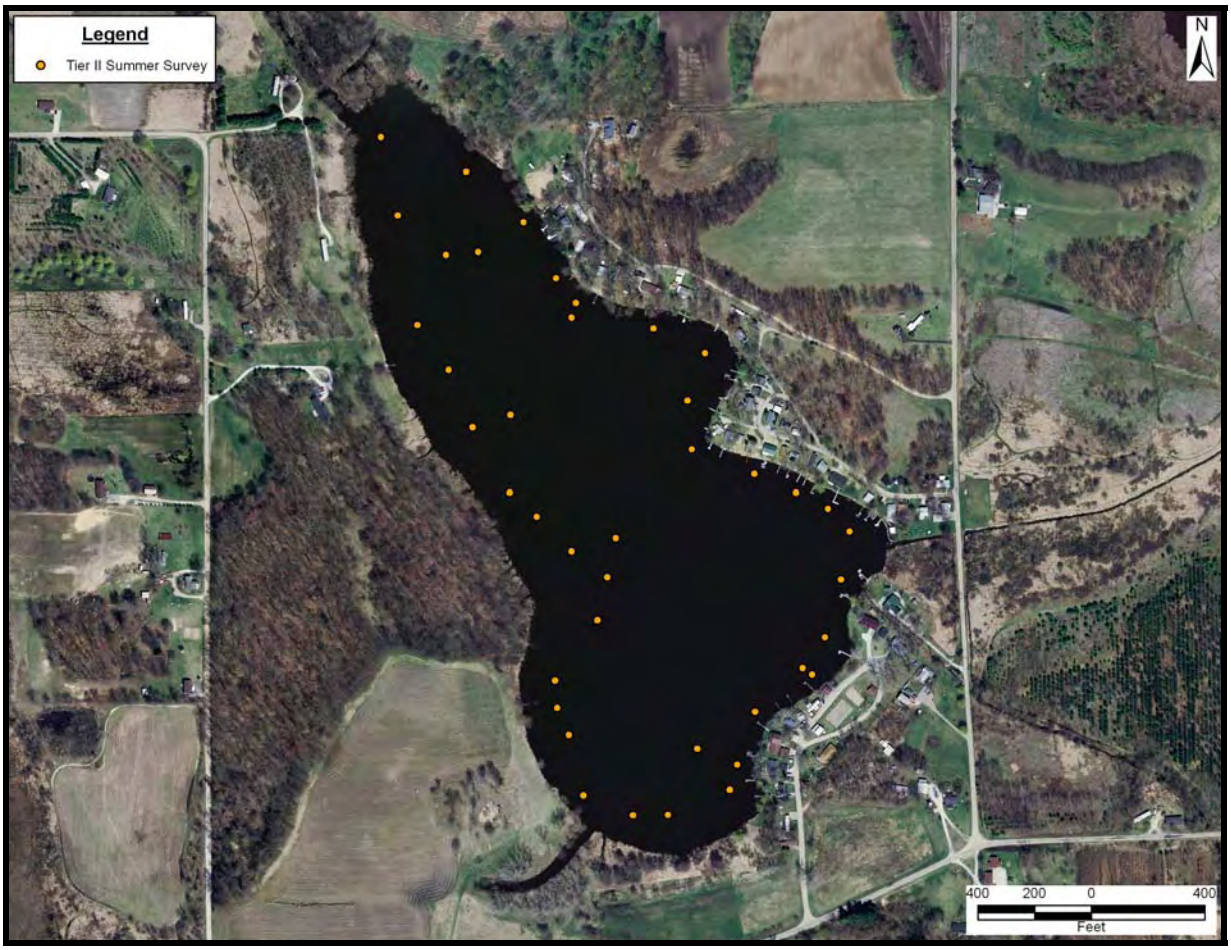

Figure 24. Locations sampled during Rock Lake Tier II survey which occurred on August 4, 2008.

During the 2008 summer survey, Rock Lake possessed greater rake diversity, native rake diversity, site species diversity, and site species native diveristy than northern Indiana lakes surveyed by Pearson (2004; Table 20). Rock Lake possessed fewer species each year than the average determined by Pearson (2004). In addition, Rock Lake has poorer species richness and native species richness than the lakes surveyed by Pearson (2004).

Table 19. Rock Lake summer Tier II survey metrics and data as collected August 4, 2008.

Occurrence and abundance of submersed aquatic plants in Rock Lake.					
County:	Kosciusko/Fulton	Sites with plants:	18	Mean species/site:	0.51
Date:	8/4/2008	Sites with native plants:	18	Standard error (ms/s):	0.10
Secchi (ft):	2.5	Number of species:	3	Mean native species/site:	0.51
Maximum plant depth (ft):	10	Number of native species:	3	Standard error (mns/s):	0.10
Trophic status:	Eutrophic	Maximum species/site:	2	Species diversity:	0.43
Total sites:	40			Native species diversity:	0.43

All depths (0-10 feet)		Frequency of Occurrence	Rake score frequency per species				Plant Dominance
Scientific Name	**Common Name**		**0**	**1**	**3**	**5**	
Stuckenia pectinatus	Sago pondweed	37.50	62.50	37.50	0.00	0.00	7.50
Ceratophyllum demersum	Coontail	12.50	87.50	12.50	0.00	0.00	2.50
Chara species	Chara species	2.50	97.50	2.50	0.00	0.00	0.50
Filamentous algae	Filamentous algae	10.00					
Depth: 0-5 feet		**Frequency of Occurrence**	**Rake score frequency per species**				**Plant Dominance**
Scientific Name	**Common Name**		**0**	**1**	**3**	**5**	
Stuckenia pectinatus	Sago pondweed	40.00	60.00	40.00	0.00	0.00	8.00
Ceratophyllum demersum	Coontail	15.00	85.00	15.00	0.00	0.00	3.00
Chara species	Chara species	5.00	95.00	5.00	0.00	0.00	1.00
Depth: 5-10 feet		**Frequency of Occurrence**	**Rake score frequency per species**				**Plant Dominance**
Scientific Name	**Common Name**		**0**	**1**	**3**	**5**	
Stuckenia pectinatus	Sago pondweed	33.33	66.67	33.33	0.00	0.00	6.67
Ceratophyllum demersum	Coontail	9.52	90.48	9.52	0.00	0.00	1.90
Filamentous algae	Filamentous algae	19.05					

Table 20. A comparison of the aquatic plant communities in Rock Lake to the average values for plant community metrics found by Pearson (2004) in his survey of 21 northern Indiana lakes. Bolding indicates that the value exceeds Pearson average.

Metric	8/20 2004	5/16 2005	8/8 2005	8/1 2006	8/4 2008	Indiana Average
Number of species	5	2	2	3	3	8
Number of native	4	1	2	3	3	7
Rake Diversity (SDI)	**0.7**	-	-	-	0.53	0.62
Native Rake Diversity	**0.59**	-	-	-	0.53	0.5
Species Richness (avg)	0.65	0.08	0.20	0.20	0.51	1.61
Native Species	0.38	0.05	0.20	0.20	0.51	1.33
Site Species Diversity	**0.74**	-	-	0.53	0.43	0.66
Site Species native	**0.66**	-	-	0.53	0.43	0.56

Macrophyte Inventory Discussion

The submergent plant diversity and density is limited in Rock Lake and this may have been due to the recent eradication of Eurasian watermilfoil. Native plants may have not had adequate time to establish themselves in the littoral zone during our survey where the milfoil had been very dense. Alternatively, the diversity may be low due to the low transparency in Rock Lake. The diversity and density of aquatic plants generally decline as water quality becomes poorer. Algal blooms can also shade out some species during the summer and can limit plant growth.

Considering the number of variables that impact the plant community such as boat-traffic, herbicide use, and changes in nutrient availability or temporal variables such as climatic conditions, we cannot easily summarize the cause and effect for the existing plant communities within Rock Lake. Multiple years of aquatic macrophyte surveys are needed to accurately determine whether the plant community may be changing with time now that the Eurasian

watermilfoil has been eradicated. Still, general trends emerge from the data that are useful for the purpose of management decisions. Table 21 details changes in the site frequency and dominance of Eurasian watermilfoil between 2004, 2005, and 2008 within Rock Lake.

Table 21. Variation in site frequency and dominance of Eurasian watermilfoil within Rock Lake during the summer assessment.

Lake	Date	Eurasian watermilfoil		Sago Pondweed	
		Site Frequency	Dominance Index	Site Frequency	Dominance Index
Rock Lake	8/20/2004	27.5	5.5	20	4.5
	5/16/2005	3.4	0.7	present	None given
	8/8/2005	0	0	15.2	3.6
	8/1/2006	0	0	16.7	3.3
	8/4/2008	0	0	37.5	7.5

These data serve as a baseline by which future variations in the plant community can be compared. Additionally, these data should allow for some determination of future changes in the plant community due to herbicide treatment or other factors (i.e. climate).

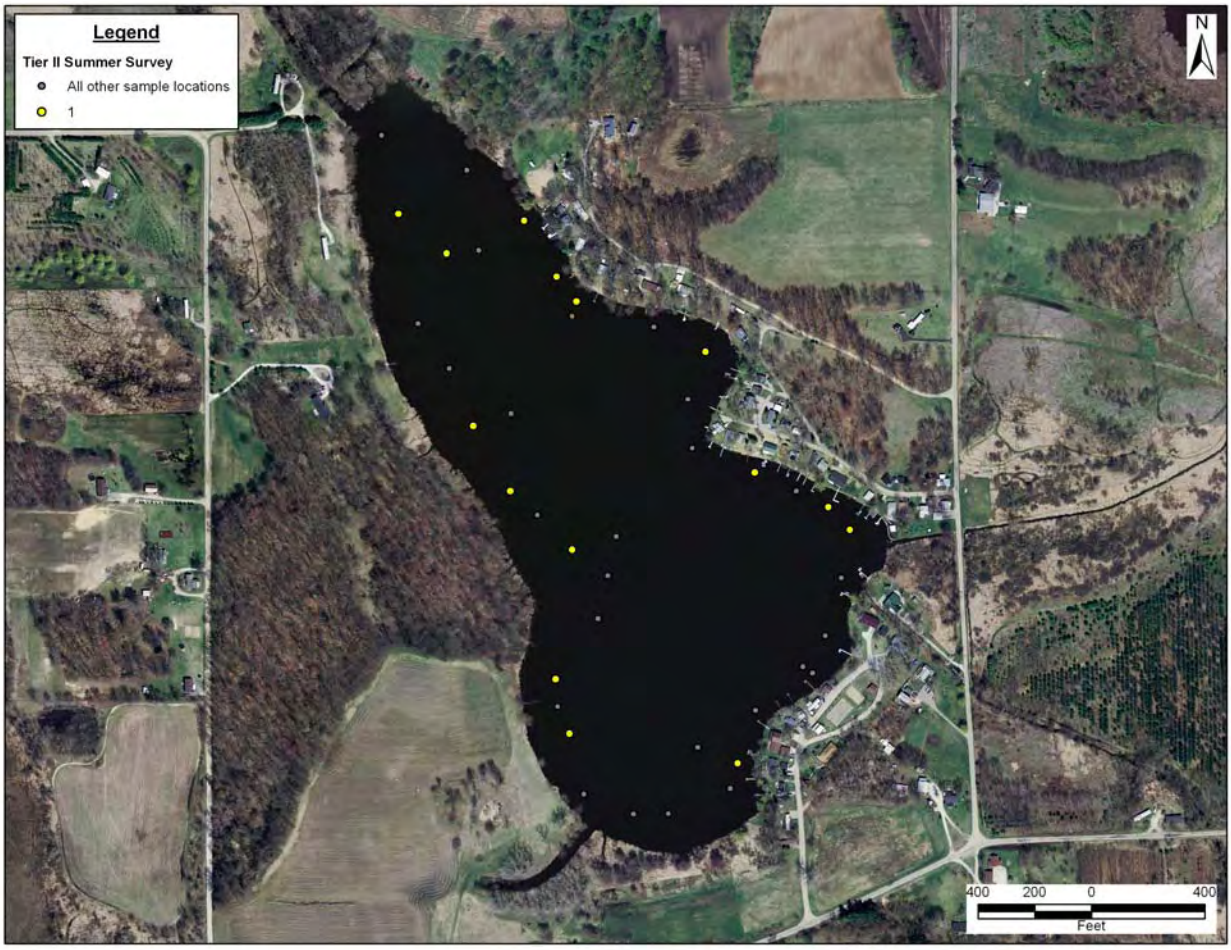

Figure 25: Prevalence of sago Pondweed in Rock Lake during the 2008 survey.

Nuisance and Exotic Plants

Although nuisance species were limited to only two shoreline emergent plants at Rock Lake (common reed and reed canary grass), lake users should be aware of several plants that have historically caused problems in other northern Indiana lakes. The two most common aggressive submergent exotics are Eurasian watermilfoil (Figure 26) and curly-leaf pondweed (Figure 27). The two most common emergent exotic plant species are purple loosestrife (Figure 28) and reed canary grass (Figure 29). As exotic invasive species, these species have the potential to proliferate if left unmanaged.

Figure 26. Eurasian watermilfoil (*Myriophyllum spicatum*) and Figure 27. Curly-leaf pondweed (*Potamogeton crispus*).

Figure 27. Purple loosestrife (*Lythrum salicaria*) and Figure 28. Reed canary grass (*Phalaris arundinacea*).

Eurasian watermilfoil is an aggressive, non-native species common in northern Indiana lakes. It often grows in dense mats excluding the establishment of other plants. For example, once the plant reaches the water's surface, it will continue growing horizontally across the water's surface. This growth pattern has the potential to shade other submergent species preventing their growth and establishment. In addition, Eurasian watermilfoil does not provide the same habitat potential for aquatic fauna as many native pondweeds. Its leaflets serve as poor substrate for aquatic insect larva, the primary food source of many panfish. Although Eurasian watermilfoil has been observed in Rock Lake in previous years, it was not identified in the lake during the summer survey.

Depending upon water chemistry, curly-leaf pondweed can be more or less aggressive than Eurasian watermilfoil. It is not present in Rock Lake at this time; however, lake users should be educated on this species as well in case it does appear in the lake. Like many exotic invasive species, curly-leaf pondweed gains a competitive advantage over native submergent species by sprouting early in the year. The species can do this because it is more tolerant of cooler water temperature than many of the native submergent species. Curly-leaf pondweed experiences a

die back during early to mid summer. This die back can degrade water quality by releasing nutrients into the water column and increasing the biological oxygen demand.

Purple loosestrife is an aggressive, exotic species introduced into this country from Eurasia for use as an ornamental garden plant. Like Eurasian watermilfoil, purple loosestrife has the potential to dominate, 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 emergent species 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. Although Rock Lake does not have any purple loosestrife growing around the lake right now, homeowners should be aware of the impacts and seek to eliminate it should it occur in the future.

Like purple loosestrife, reed canary grass is native to Eurasia. Farmers used (and many likely still use) the species for erosion control along ditch banks or as marsh hay. The species escaped via ditches and has spread to many of the wetlands in the area. Swink and Wilhelm (1994) indicate that reed canary grass commonly occurs at the toe of the upland slope around a wetland. Reed canary grass was often observed above the ordinary high water mark around the lakes. 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 function and value to wildlife.

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

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

3.2 Stream Assessment

Two stream sites under base flow and storm flow conditions were sampled in Rock Lake's watershed on June 24, 2008 and June 4, 2008, respectively (Table 22). The LARE sampling protocol requires assessing water quality of each designated stream site once during base flow and once during storm flow. This is because water quality characteristics change markedly between these two flow regimes. A storm flow sample will be influenced by runoff from the land,

which usually contains soil and associated nutrients. A base flow sample represents the 'usual' water characteristics of the stream.

Table 22. Location of stream sampling sites.

Site No.	Stream Name	Sampling Location	Latitude	Longitude
1	Landis Ditch	CR 750W	-85.974831	41.041668
2	Lautzenhizer Ditch	CR 750W	-85.974854	41.040253

3.2.1 Stream Sample Site Descriptions

Site 1 – Landis Ditch (Figures 30 and 31). The sampling area was bounded by residential areas and agricultural open/idle pasture. The riparian zone extended approximately 10 feet (3 m) on the left side of the stream, and from 30-150 feet (10-50 m) on the right side. Riparian vegetation was dominated by tall grasses, with sparse trees and shrubs on the right (south) bank. Moderate instream cover was provided by overhanging vegetation, rootwads, aquatic macrophytes and woody debris. Bank stability was low, with signs of moderate erosion on both banks. The stream showed evidence of recent channelization with little or no recovery. Sinuosity was not present, and no pools or riffles were observed at the site. The substrate of the sampling area was dominated by silt. Substrate stability was poor with extensive embeddedness.

Figure 30 and 31. Rock Lake – Stream Site 1, Landis Ditch Facing east, upstream (left) and Facing west, downstream (right).

Site 2 – Lautzenhiser Ditch (Figures 32, 33 and 34). The land adjacent to the ditch was comprised of residential areas and recovering forest. The left bank abutted a grassy field, with the riparian zone varying from 3 to 16 feet (1 to 5 m) in width. The riparian zone of the right bank consisted of recovering forest that extended more than 165 feet (50 m) away from the stream. Riparian vegetation was dominated by shrubs and young trees on both banks. Overhanging vegetation, woody debris and rootwads provided a moderate degree of instream cover. Bank stability was low, with evidence of moderate erosion. The substrate composition at this site was almost entirely silt, though there were several cobbles and boulders. Sinuosity was moderate north of the road, and the stream appeared to be recovering from past channelization. More recent channelization work was evident west of the site, where the surrounding land use

became more residential in nature. Instream conditions were poor with low substrate stability, extensive embeddedness and poor pool/riffle development.

Figure 32. Rock Lake – Stream Site 2, Lautzenhiser Ditch (Facing west - across road)

Figure 33. Rock Lake - Stream Site 2, Lautzenhiser Ditch (Facing east, upstream)

Figure 34. Rock Lake Stream Site 2, Lautzenhiser Ditch (facing east)

3.2.2 Stream Water Quality

Conductivity, temperature, and dissolved oxygen were measured *in situ* at stream sites with an YSI Model 85 meter. Stream water velocity was measured using a Marsh-McBirney Flo-Mate current meter. The cross-sectional area of the stream channel at each site was measured and discharge calculated by multiplying water velocity by the cross-sectional area. In addition, water samples were collected for the following parameters:

- pH
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- nitrate-nitrogen (NO_3^-)
- ammonia-nitrogen (NH_4^+)
- total Kjeldahl nitrogen (TKN)
- total suspended solids (TSS)
- turbidity
- *E. coli* bacteria

The stream water samples were placed in appropriate bottles (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. The *E. coli* bacteria samples were taken to Sherry Laboratories in Warsaw, 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, 21th Edition (APHA, 2005).

Physical parameter results measured during base and storm flow sampling of Rock Lake inlet streams (Site 1: Landis Ditch, Site 2: Lautzenhizer Ditch) are presented in Table 23. Stream discharges measured during base and storm flow conditions are shown in Figure 35. The stream cross-section is shown in Figure 36.

Table 23. Physical Characteristics of the Rock Lake watershed stream samplings on June 4, 2008 (storm flow) and June 24, 2008 (base flow).

Site	Date	Timing	Flow (cfs)	Temp (°C)	D.O. (mg/L)	D.O. Sat. (%)	Cond. (µmhos)	TSS (mg/L)	Turbidity (NTU)
1	6/4/08	Storm	1.041	20.1	4.5	49	419	4.31	6.4
	6/24/08	Base	0.820	17.9	4.7	50	269	3.45	3.5
2	6/4/08	Storm	0.037	22.0	5.5	61	296	7.04	6.6
	6/24/08	Base	0.150	13.3	5.6	51	330	6.50	6.5

Small streams are typically well oxygenated because of the turbulent flow, but in the case of the Rock Lake incoming streams at both of the sampling sites had relatively low dissolved oxygen content. Dissolved oxygen concentrations in the Rock Lake streams ranged from a low of 4.5 mg/L to a high of 5.6 mg/L. D.O. saturation was a maximum of 50 percent at site 1, and 61 percent at site 2. Oxygen saturation occurs in flowing water because the turbulence helps equilibrate oxygen concentrations with the atmosphere, resulting in 100 percent saturation. Supersaturated conditions (>100 percent) result from intense photosynthesis which, in a stream, comes primarily from periphyton (algae attached to rocks) and from rooted aquatic plants. Undersaturated (<100 percent) stream water is indicative of excessive oxygen consumption, usually from BOD. Both sites had low oxygen concentrations during both base-flow and storm-flow conditions. Oxygen concentration and saturation in the Rock Lake tributary streams were likely reduced because of biological oxygen demand from decaying detritus, the lack of rock riffles, and corresponding reductions in turbulent flow.

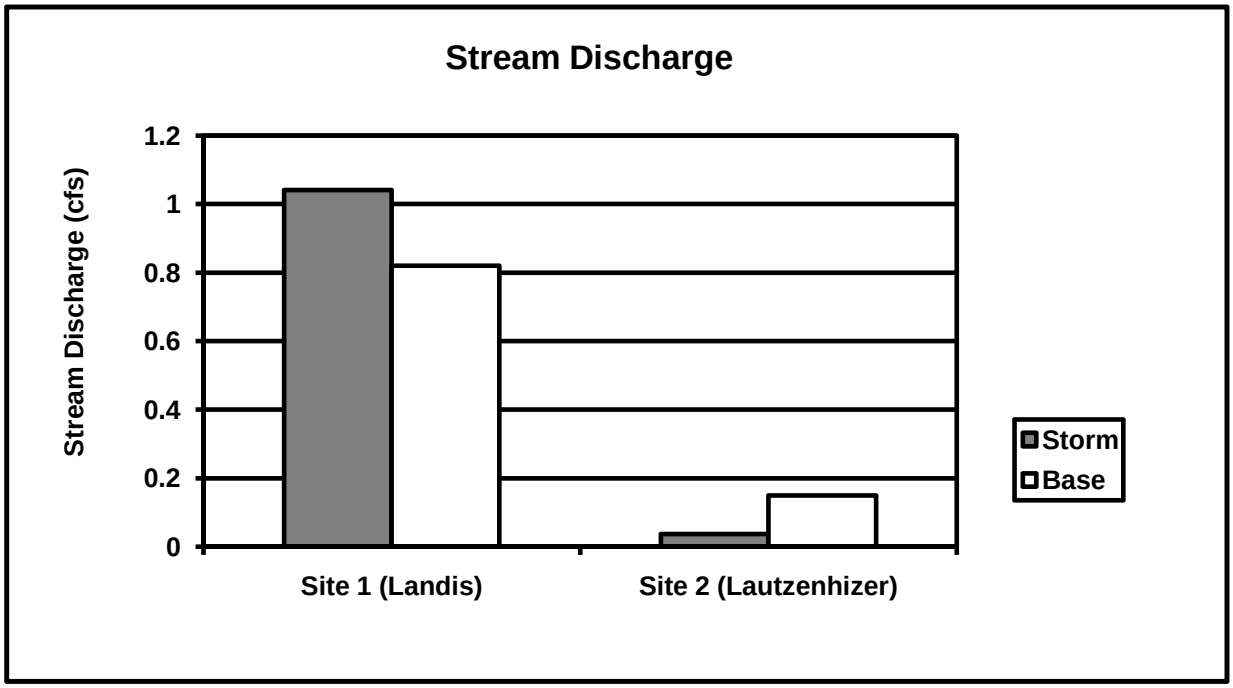

Figure 35. Discharge measurements during base flow and storm flow sampling of Rock Lake inlet streams.

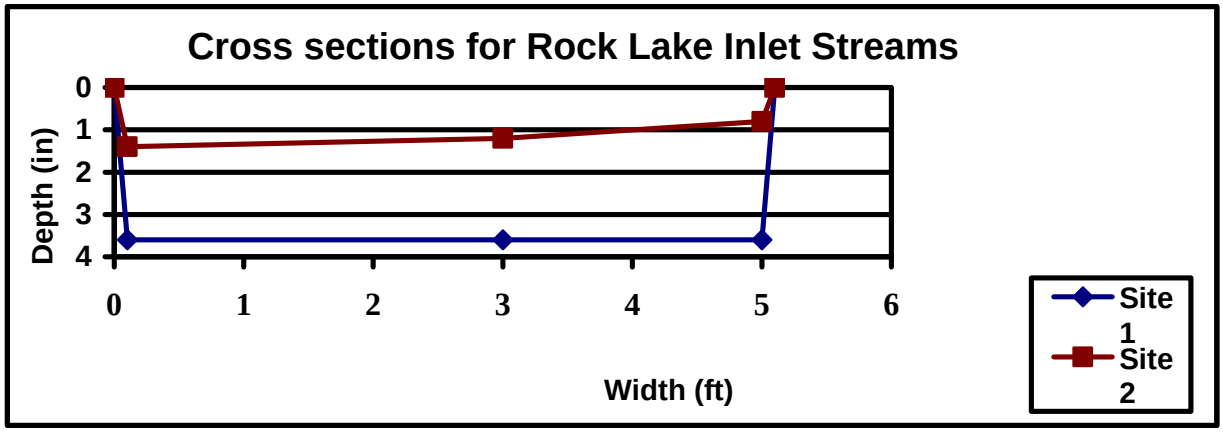

Figure 36. Physical dimensions at the sampling locations at Rock Lake inlet streams.

Temperatures were warmer under storm flow conditions as compared to base flow. This is largely due to variations in the weather and the time of day that samples were collected. Low stream flow coupled with light to moderate stream cover made both sites vulnerable to solar heating.

Storm flow turbidity was higher at stream Site 1 as compared to base flow turbidity. The erosive force of storm runoff often washes soil and other particulates from the land into streams, resulting in higher turbidity and TSS concentrations. High storm flow turbidity as compared to base flow turbidity levels can indicate watershed disturbance. Site 1 had nearly twice the turbidity levels during storm flow versus base flow. Site 2 showed little difference between storm flow and base flow turbidity. However, the June 4, 2008 storm flow discharge of Site 2 was lower than the base flow discharge measurement taken on June 24, 2008. The storm event of June 4, 2008 may not have produced representative storm flows, or the post-storm sampling may not have coincided with peak stream flows.

In a direct relation to the turbidity, concentrations of total suspended solids (TSS) usually increase with increased stream flow because of instream scouring and inputs from overland flow from surrounding lands. Both sites had marginally higher storm flow TSS concentrations. The higher TSS levels are likely due to organic materials found within the ditches themselves and in sediment eroded from the ditch banks, roads, and a few unvegetated areas within each of the subwatersheds.

The chemical and bacterial characteristics are shown in Table 24. In a recent study of 85 relatively undeveloped basins across the United States, the USGS reported the following median concentrations: ammonia (NH3) at 0.020 mg/L, nitrate (NO_3^-) at 0.087 mg/L, soluble reactive phosphorus (SRP) at 0.010 mg/), and total phosphorus (TP) at 0.022 mg/L (Clark et al. 2000). Except for three instances, nutrient concentrations within the Rock Lake streams all exceeded these median concentrations, some parameters by an order of magnitude.

Table 24. Chemical and bacterial characteristics of the Rock Lake watershed stream samplings on June 4, 2008 (storm flow) and June 24, 2008 (base flow).

Site	Date	Timing	pH	Turb. (NTU)	NH_3 (mg/L)	NO_3^- (mg/L)	TKN (mg/L)	TP (mg/L)	SRP (mg/L)	E. coli (#/100 ml)
1	**6/4/08**	Storm	7.3	6.4	0.261	0.144	2.748	0.091	0.021	350
	6/24/08	Base	7.5	3.5	0.319	0.371	1.405	0.094	0.023	1480
2	**6/4/08**	Storm	8.0	6.6	0.201	0.026	2.909	0.100	0.010*	235
	6/24/08	Base	7.5	6.5	0.417	0.092	3.413	0.151	0.010*	690

* Method Detection Limit; Site 1 = Landis Ditch; Site 2 = Lautzenhizer Ditch

The median nitrate (NO_3^-) concentration of wadeable streams found by the Ohio EPA to support modified warmwater habitat (MWH) is 1.6 mg/L (Ohio EPA 1999). The Site 1 and Site 2 concentrations are well below the Ohio EPA median for both flow regimes.

Typically, storm flow concentrations of Total Kjeldahl Nitrogen (TKN) exceed base flow since runoff liberates organic material stored within the stream and in adjacent riparian areas. This occurred at Site 1; however, the base flow TKN concentration was higher than storm flow concentration at Site 2. Since the base flow discharge at Site 2 was higher than the storm flow discharge, the higher TSS concentration during base flow is not surprising.

Both sites had relatively high ammonia concentrations at base flow, suggesting a nearby source of this nutrient or low turbulent flow conditions. Fertilizer runoff from agricultural land uses adjacent to each stream may have contributed to the elevated ammonia nitrogen concentrations but because the streams have little gradient the ammonia nitrogen may also be generated from decaying organic matter in the streams.

Since phosphorus readily adsorbs onto soil particles and organic matter, eroded soil carried by overland flow can contain a significant amount of phosphorus. Consequently, total phosphorus (TP) concentrations typically increase during storm events in disturbed watersheds. Neither of the sites exhibited this behavior. Lower storm flow TP concentrations at both sites suggest less availability of this nutrient and possible interception by the vegetated stream riparian zone, especially at Site 1. Since much of the watershed is vegetated, very little increase in TSS was observed during storm flows.

Three of the four samples from the Rock Lake streams exceeded the Indiana state *E. coli* standard for recreational waterbodies of 235 col/100ml. The *E. coli* concentrations ranged from 235 col/100ml at Site 2 (storm flow) to 1480 col/100ml at Site 1 (base flow). These high *E. coli* concentrations likely resulted from inadequate septic systems, instream processes, or from wildlife as there were no livestock operations noted during the watershed tour.

3.2.3 Stream Habitat and Macroinvertebrates

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of in-stream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. An example of the QHEI data sheet is provided in Appendix A.

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. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate, thus sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, represents 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 are evaluated to comprise this metric score.

A wooded riparian buffer 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 and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of erosion in the stream, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is 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).

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 gradients in elevation will have negative effects on habitat quality. Moderate gradients 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 is used to evaluate 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 segments around Indiana have indicated that values greater than 64 are considered *fully supporting* of aquatic life use, scores between 51–64 are *partially supporting*, and scores less than 51 are *non-supporting* (IDEM, 2002).

Table 25 presents the Qualitative Habitat Evaluation Index (QHEI) scoring results for Landis Ditch and Lautzenhizer Drain and includes the maximum possible score for each metric evaluated. The Indiana Department of Environmental Management considers habitat with QHEI

scores below 51 as nonsupporting of fish populations (IDEM, 2002). QHEI scores for both of the sampling sites indicated severe impairment, with the silty substrate and lack of pool/riffle habitat contributing significantly to the low QHEI scores. This is not surprising as both sample sites are in artificial ditches with low gradients and silty substrate.

Table 25. QHEI Scores for the Rock Lake inlet stream sampling sites, November 29, 2007.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Max. Possible Score	20	20	20	10	12	8	10	**100**
Site 1	3	5	6	8	4	1	6	**33**
Site 2	9	16	7	6	5	2	6	**41**

Site 1 = Landis Ditch; Site 2 = Lautzenhizer Drain (Data collected by Commonwealth Biomonitoring, Inc.)

Macroinvertebrates were collected during base flow conditions on November 29, 2007 by Commonwealth using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes; a third researcher aided in the collection for 10 minutes, for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level according to McCafferty (1998) and Peckarsky and Penton (1990). The family-level approach was used to collect data comparable to that collected by IDEM in the state, because it allows for increased organism identification accuracy and because several studies support the adequacy of family-level analysis (Furse et al., 1983, Ferraro and Cole, 1995, Marchant et al, 1995, Bowman and Bailey, 1997, Waite et al., 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have and assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). A higher value on the HBI scale indicates greater impairment. In addition to the HBI, macroinvertebrate results were analyzed by applying an adaptation of the IDEM mIBI (IDEM, 1996). The mIBI scores allow comparison with data compiled by IDEM for wadeable riffle-pool streams. IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected from throughout Indiana. The data were lognormally distributed for each of the metrics. Each metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Table 26 lists the eight scoring metrics used in this study with classification scores of 0-8. The mean of the eight metrics is the mIBI score. 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.

Results of the macroinvertebrate samples were used to calculate a macroinvertebrate index of biotic integrity (mIBI, Table 26). Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition can reflect water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995)

Table 26. Benthic Macroinvertebrate Scoring Criteria Used by IDEM.

	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
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

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

Table 27 presents the Modified Index of Biotic Integrity (mIBI) scores as well as the individual classification scores for each site. The low scores are likely due to the lack of habitat in Landis Ditch and in Lautzenhizer Drain. Because these natural streams have been straightened and deepened to improve drainage, there are few habitat features remaining that would promote diversity in the aquatic macro-invertebrate community. Specific habitat features that would improve the diversity are overhead cover, pools, riffles, and a variable substrate. The existing substrate in both ditches is predominantly silt. Since many aquatic macroinvertebrates breathe through gills or gill like structure, silt prohibits respiration by clogging the gills.

Table 27. Classification Scores and mIBI Scores for the Rock Lake inlet stream sampling sites, November 29, 2007.

	Site 1	Site 2
HBI	2	0
No. Taxa (family)	2	2
% Dominant Taxa	0	0
EPT Index	2	2
EPT Count	2	2
EPT Count/Total Count	2	0
EPT Abun./Chir. Abun.	2	0
Chironomid Count	4	2
mIBI Score	**1.6**	**1.0**

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired;
Site 1 = Landis Ditch; Site 2 = Lautzenhizer Drain

3.3 Watershed Assessment

During November 2007 JFNew conducted a driving (windshield) tour of the watershed and then in May of 2008 we conducted a walking tour of the drains after obtaining permission from the landowners. The tours of the watershed found very few issues or hotspots that could be significant nutrient sources. The majority of the two main streams (Landis and Lautzenhizer Drains) have well vegetated buffers Figures 37-51. The majority of both ditches were constructed through wetlands, contributing a natural source of organic matter and nutrients to Rock Lake. Landis Ditch had adjacent farming practices that were likely contributing significant nutrient and sediment loading to Rock Lake. Landis Drain had one parcel, containing approximately ¼ mile of the drain, with minimal vegetated buffers. Lautenhizer Drain had adjacent farming along a ½ mile section; however, there was a significant vegetated buffer between the ditch and the agricultural field ranging from 10-30 feet (3-10 m).

Figures 37 and 38. Landis Ditch 1/4 mile west of CR 700 W. in Kosciusko County.

Figures 39 and 40. Landis Ditch east of CR 700 W. in Kosciusko County.

Figure 41. Facing east at Landis Ditch from CR 700 W. Kosciusko County

Figures 42 and 43. Upper end of Landis Ditch east of CR 700 W. and north of CR 1300 S, Kosciusko County.

Figure 44 and 45. Lautzenhizer Drain just south of Rock Lake and north of CR 145 S.

Figures 46 and 47. Lautzenhizer Drain just north of Mud Lake, and south of CR 145 S.

Figure 48. Lautzenhizer Drain north of CR 200S flowing south to Mud Lake.

Figures 49 and 50. Lautzenhizer Drain facing south from CR 200 S. and north from ½ mile south of CR 200S.

Figure 51. Facing south at Lost Lake and the beginning of Lautzenhizer Drain, ½ mile south of CR 200 S.

As a whole, very few problems were noted in the landscape or with the existing drains. The only exception to a relatively undisturbed landscape was a few maintenance issues (tile repair) at the upper end of Landis Drain (Figures 52 and 53). The upper end of Lautzenhizer Drain had recent beaver activity (which would help trap and sequester nutrients), where a dam was being constructed in the ditch; however, it in unknown whether the property owner would allow the dam to remain. It had backed up about 2 feet of water for less than 150 feet of ditch at the time of the site visit.

Figures 52 and 53. Agricultural Drainage tile "blowout" (left) and resulting sediment in Landis Ditch downstream.

4.0 DISCUSSION

4.1 Lake Water Quality

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. But, how much phosphorus or nitrogen is too much or, what level of transparency is too poor?

To answer these questions, limnologists must compare data from the lake in question to standards, if they exist, to other lakes, or to criteria that most limnologists agree upon. There are no nutrient standards for Indiana lakes so we must compare the Rock Lake results with data from other lakes and with generally accepted criteria.

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).

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, 0.01475 mg/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 0.008 mg/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 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 percent 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 thresholds 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 Rock Lake. The IAC sets only nitrate-nitrogen and ammonia-nitrogen standards for waterbodies in Indiana. The IAC standard for ammonia-nitrogen depends upon the water's pH and temperature, since both can affect ammonia-nitrogen's toxicity. The Rock Lake samples did not exceed the state standard for either nitrate-nitrogen or ammonia-nitrogen.

Results of studies conducted by Richard Vollenweider (1975) in the 1970's are often used as guidelines for evaluating concentrations of water quality parameters. 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, 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.

Vollenweider (1975), developed mean values for each of the tropic states (Table 28). 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). Remember that these are only guidelines – similar concentrations in your lake may not cause problems if something else is limiting the growth of algae or rooted plants.

Table 28. Mean values of some water quality parameters and their relationship to lake production. (after Vollenweider, 1975).

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (mg/L or PPM)	0.008	0.027	0.084	>0.750
Total Nitrogen (mg/L or PPM)	0.661	0.753	1.875	-
Chlorophyll *a* (µg/L or PPB)	1.700	4.700	14.300	-

When compared to levels reported by Vollenweider, the 2008 results for Rock Lake June 24, 2008 samples were within eutrophic ranges for total phosphorus, total nitrogen, and chlorophyll-*a* (Table 29). Rock Lake also showed no indication of internal loading of phosphorus from the sediments on the date of sampling.

Table 29. Summary of mean total phosphorus, total nitrogen, Secchi disk transparency, and Chlorophyll *a* results for Rock Lake.

Parameter	Rock
Total Phosphorus (mg/L or PPM)	0.1365
Total Nitrogen (mg/L or PPM)	2.5485
Secchi disk transparency (ft)	0.6 meters
Chlorophyll *a* (µg/L or PPB)	57.8300
Sediment phosphorus release factor[1]	1

[1]***Hypo SRP concentration/Epi SRP concentration.***

A wide variety of conditions, including geography, morphometry, time of year, and watershed characteristics, can influence the water quality of lakes. To help place lake data into perspective, consider the following data for 456 Indiana lakes collected during July and August 1994-2004 under the Indiana Clean Lakes Program (Table 30). The set of data summarized in the table represent mean concentrations of epilimnetic and hypolimnetic samples for each of the 456 lakes.

Table 30. Water Quality Characteristics of 456 Indiana Lakes Sampled From 1994 through 2004 by the Indiana Clean Lakes Program. Medians 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*	Plankton	Bl-Green Dominance (%)
Median	6.9	0.275	0.818	1.660	0.12	0.17	12.9	35570	53.80
Maximum	32.8	9.400	22.500	27.050	2.84	2.81	380.4	753170	100.00
Minimum	0.3	0.010	0.004	0.230	0.01	0.01	0.013	39	0.08

Table 31 compares the median of selected water quality parameters for Rock Lake to the median value for all Indiana lakes. Rock Lake's water quality parameter values for Secchi disk transparency, nitrate nitrogen, total nitrogen, and chlorophyll-*a* were all worse than median statewide values. Water concentrations for ammonia, soluble reactive phosphorus, and total phosphorus were better relative to the median statewide concentrations. However, ammonia may be lower in concentration because of the complete mixing of the lake. The lower values for SRP and TP are more difficult to explain, and may be due to the fact that much of the phosphorus is tied up in the existing macrophyte community. Rock Lake featured a dense and diverse plankton population with low (19.8 percent) blue-green dominance relative to median Indiana lake values. Green algae were the most abundant phyla observed, with 60.5 percent dominance.

Table 31. Comparison of Rock Lake lakes to the Median for All Indiana Lakes for Selected Water Parameters.

	Secchi Disk	NO^3	NH^4	TKN	SRP	TP	Chl *a*	Plankton	Bl-gr dominance
Rock Lake	Worse	Worse	Better	Worse	Better	Better	Worse	Worse	Better

Indiana and many other states use a Trophic State Index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake. Parameters and values used to calculate the Indiana TSI are provided for reference in Appendix A. The Indiana TSI ranges from 0 to 75 total points and is grouped into the following three classifications (IDEM, 1986):

TSI Total	Water Quality Classification
0-15	highest quality (oligotrophic)
16-30	intermediate quality (mesotrophic)
31-45	low quality (eutrophic)
46-60	lowest quality (hypereutrophic)

Rock Lake was assessed in 1991 and 1998 by the Clean Lakes Program and in 2008 under the current study (Table 32). The Indiana TSI results from each of the three assessments differ by only six points, indicating that, according to the Indiana TSI, Rock Lake water quality has remained relatively unchanged, as a borderline eutrophic lake, for each sampling period.

Table 32. Rock Lake: Indiana Trophic State Index 1991, 1998, and 2008.

	1991	1998	2008
Rock Lake	31	33	27

Source: Indiana Department of Environmental Management. "Clean Lakes Program." 1989-2002 and current study.

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, as well as the time of year sampling was conducted can cause changes in TSI score that do not necessarily indicate a long-term change in lake condition. The Indiana TSI has not been statistically validated and relies heavily on algae as opposed to nutrient concentrations and transparency in the total score. For these reasons, the Carlson TSI is also useful in evaluating Indiana lake data.

Carlson (1977) 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 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 54).

Carlson's scale is also divided into four lake productivity categories: oligotrophic, mesotrophic, eutrophic, and hypereutrophic. Using Carlson's TSI, a lake with a summertime Secchi disk depth of 3 feet (1 m) would have a TSI of 60 points. This lake would be in the Eutrophic category. Because the index was constructed using relationships among transparency, chlorophyll, and total phosphorus, a lake having a Secchi disk depth of 3 feet would also be expected to have approximately 20 µg/L chlorophyll *a* and 50 µg/L total phosphorus.

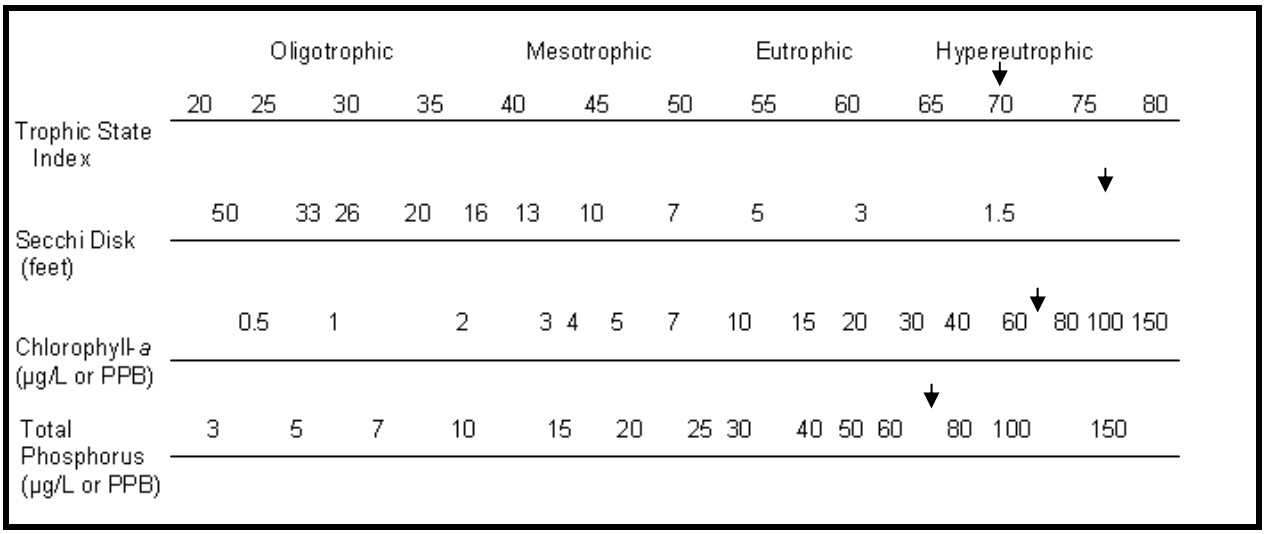

Figure 54. Carlson's Trophic State Index with Rock Lake scores indicated with arrows.

The results of the evaluation using Carlson's Trophic State Index show that, during the June 24, 2008 sampling event, Rock Lake fell into the hypereutrophic category for each index parameter -Secchi disk transparency, total phosphorus, and chlorophyll. The 1998 Rock Lake assessment yielded the same Carlson's TSI score (Table 33). 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. Rock Lake appears to be consistent from year to year with the limited data available with Carlson's and the Indiana TSI.

Table 33. Rock Lake: Carlson's Trophic State Index 1991, 1998, and 2008.

Year	Secchi (m)	Chlorophyll a (mg/m3)	TSI (Chl)	TSI (TP Avg)	TSI (TP epi)	TSI (Secchi Disc)	TSI (Combined)
2008	0.6	57.83	70	75	74	67	70
1998	0.6	53.20	70	87	72	67	70
1991	0.5	N/A	N/A	75	69	70	N/A

Source: Indiana Department of Environmental Management. "Clean Lakes Program." 1991, 1998 and current study.

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

Overall, the water quality of Rock Lake is below the median of Indiana's lakes. The lake can be considered as eutrophic (nutrient rich) based upon the 2008 data. Rock Lake is subject to both internal and external nutrient loading. The relatively small volume of Rock Lake does not sufficiently dilute nutrients washing in from its watershed and the lake then acts as a nutrient sink. The lake's shallow depth promotes macrophyte and algal growth, which temporarily utilize the phosphorus, and then act as a source when the plants die back. However, comparing the 2008 sampling data with data gathered up to 17 years ago indicates that the condition of the lake has been relatively stable between sampling periods. To summarize current water quality issues:

1. Phosphorus loadings to Rock Lake from its watershed plus internal phosphorus loading exceed permissible rates needed to maintain good water quality by 77 percent. Agricultural activity along inflowing streams likely contributes to the elevated phosphorus loadings from the watershed as well as decaying organic matter in the streams and in the lake. The elevated phosphorus loading is driving the macrophyte and algae growth.

2. The very deepest water contains no oxygen. This is due to the decomposition of organic matter (dying plants) on the sediments by bacteria that consume oxygen in the process. The sources of this organic matter are likely algae and rooted plants produced within the lake, and organic material washed into the lake from the watershed. Anoxic conditions in the deep waters allow ammonia concentrations to increase at certain times of the year.

3. Anoxic conditions in the deep waters were allowing phosphorus release from the sediments during the 1998 sampling. However, there was no evidence of this on our 2008 sampling date, possibly due to the early summer sampling date or the complete mixing of the lake at the time of the sampling. Internal phosphorus release from the sediments can help fuel algal growth and this, along with hypolimnetic oxygen concentrations should be monitored in the future.

4.2 Aquatic Macrophytes and Fisheries

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. 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 coverage of these plants for successful spawning, rearing, and protection for predators. For example, bluegill require an area to be approximately 15-30 percent covered with aquatic plants for successful survival, while northern pike achieve success in areas where rooted plants cover 80 percent 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. Aquatic plants such as pondweed, coontail, duckweed, watermilfoil, and arrowhead, also provide a food source to waterfowl. Duckweed in particular has been noted for its high protein content and consequently has served as feed for livestock. Turtles and snakes utilize emergent vegetation as basking sites. Finally, amphibians rely on the emergent vegetation zones of lakes and ponds as primary habitat.

Approximately 60 percent of Rock Lake is less than 5 feet deep and is supporting aquatic macrophytes. According to the average Secchi disk reading of approximately 2 feet over the last 15 years, this is also about the maximum depth of available light penetration in summer. If the lake's water clarity were improved to an Indiana median Secchi disk reading of 6.9 feet, with the lake's maximum depth at 16 feet, it is possible that the entire lake could become vegetated (although only submergent vegetation would be found in water over six feet deep). While a well vegetated lake bottom would support a great diversity of wildlife, the fishery would tend towards more and smaller prey species (like bluegill), because of the additional cover and subsequent protection from predatory bass. Additionally, recreation on the lake, other then fishing, would become problematic.

Based on the depth-volume curve and the historic data, a minimum of 98 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). This is likely due to the frequent mixing of the surface and bottom waters. Therefore, unlike many northern Indiana lakes in summer, almost the entire lake volume is available for fish. Normally the colder bottom waters become anoxic because oxygen producing algae grow in the surface waters. The algae then die, decompose and use up oxygen in the colder bottom layers frequently causing anoxia, or lack of oxygen. Under anoxic conditions, the iron in iron phosphate, a common precipitate in lake sediments, is reduced, and the phosphate ion is released into the water column. This phosphate ion is readily available to algae, and can therefore spur algal growth. The total phosphorus concentration in the lake during the June 2008 sample was 40 to 50 times that of soluble reactive phosphorus, suggesting that most of the available phosphorus was bound up in algae or macrophytes. Reducing the population of either one may result in an increased population of the other. The nutrient data suggests that Rock Lake was a eutrophic lake during the assessments of the 1990's but is tending toward hypereutrophic with continued nutrient cycling.

The fish community, while not being sampled in the previous 12 years, had shown good growth rates and size of the bluegill (the most abundant game fish at the time). Largemouth bass, while numerous (up to 8.8 percent of the population), were relatively small indicating an overharvest of larger individuals. This may have changed in the last 12 years with the

implementation of the 14-inch minimum size limit. If this minimum size limit is observed on Rock Lake, the largemouth bass fishing quality should continue to improve. Gizzard shad replaced crappie (both black and white) as the third most dominant species between 1977 and 1997. If that trend has continued, gizzard shad will compete with bluegill for food resources and potentially cause stunting of the bluegill population. Whole lake treatments to reduce gizzard shad numbers have been completed by IDNR personnel on other public freshwater lakes in northern Indiana and may become necessary on Rock Lake in the future.

Gizzard shad may be affecting water quality in Rock Lake along with the abundant carp. Gizzard shad promote nutrient cycling in the lake by feeding on both phytoplankton and zooplankton and in turn being fed upon by largemouth bass. Carp are bottom feeders. The carp continually disturb the bottom substrate while grazing for invertebrates. The substrate disturbance allows nutrients that have settled to the bottom attached to particles, to be recycled back into the water column. Once the nutrients are back in the water column they are available for algae production. Algae production promotes gizzard shad and zoo plankton growth.

4.3 Stream Habitat and Water Quality

According to the metrics used to measure streams, the two Rock Lake tributaries are severely degraded. However, the streams are man-made features in a former wetland landscape and therefore an evaluation that ranks them against pristine natural channels may not be appropriate. The QHEI evaluations from each site describe moderate to poor substrate quality. As expected in muck bottom artificial drainages there is a complete absence of riffle and pool development within the stream channels. The mIBI scores reflect severely impaired habitat quality at both sites. Both of the Rock Lake stream beds have considerable silt deposition. The silt and or muck may be as much from eroding embankments and natural substrate as from surface erosion in the watershed. Extensive substrate embeddedness caused by the silt severely limits habitat diversity within the stream channel by filling in and closing off pore spaces among rocks and gravel that benthic organisms would inhabit. This sediment condition is reflected in the poor substrate scores of the QHEI evaluations - the two sites received sediment scores of 5 and 3 out of a possible 20.

Despite the poor substrate of each study site, both sites have low total suspended solids (TSS) concentrations in the flowing water during storm flow events. When compared with base flow conditions, TSS concentrations are typically higher during storm flow due to the dislodgment of sediments in the stream bed and bank by turbulent waters and due to erosion of topsoil on adjacent slopes and fields. However, for each of the Rock Lake stream sites there was little difference between base flow and storm flow TSS concentrations (Figure 55). When considering storm flow and base flow discharge volumes for each of the sites, it is evident that the June 4, 2008 storm flow samplings may not have been representative of true storm flow conditions even though one inch of rain fell in the 24 hour period before the samples were taken. This is likely due to the fact that the extensive wetlands upstream of the sample sites absorb and retain a lot of the runoff, releasing the water gradually to the ditches. Storm flow discharges, measured on June 4, 2008 did not vary significantly from base flow discharge rates measured on June 24, 2008. Lautzenhizer Ditch actually had higher discharge during the June 24, 2008 base flow sampling than the June 4, 2008 storm flow sampling, further supporting the evidence that upstream wetlands are detaining storm water.

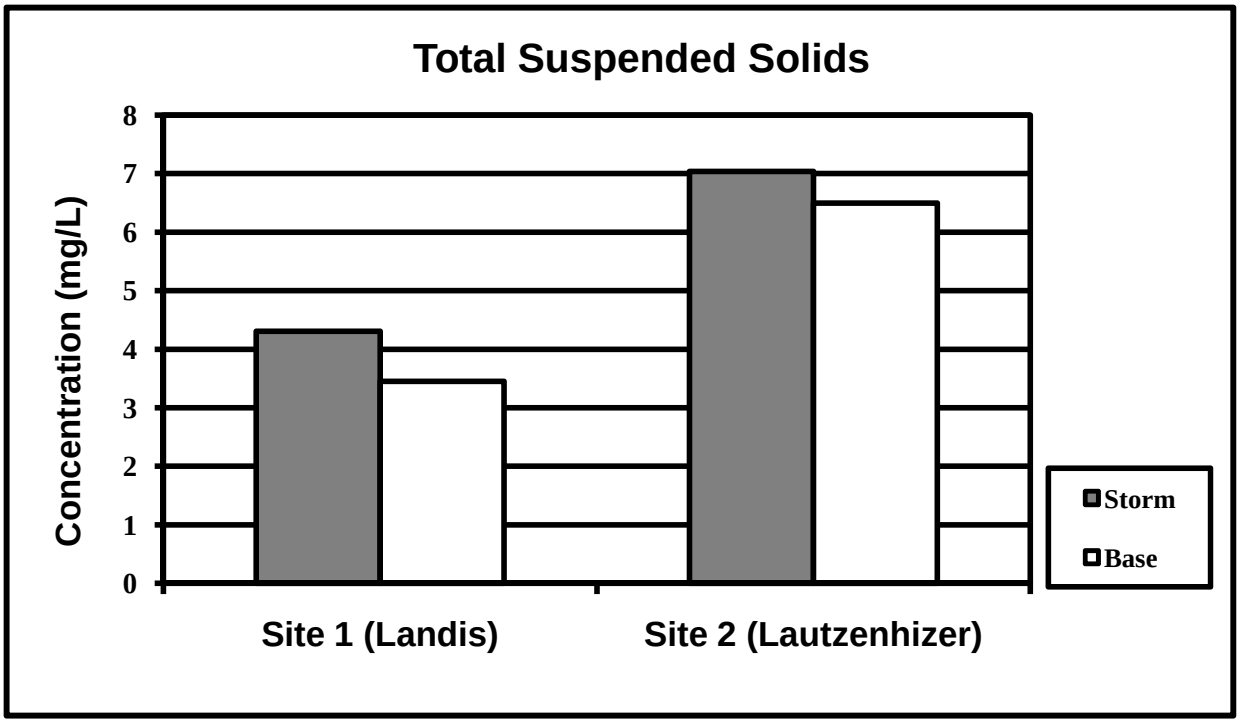

Figure 55. TSS Concentrations during Storm Flow and Base Flow Conditions.

The supply of sediment that is transported along the stream bed (versus suspended sediments) usually originates from the stream itself (Richards 1982). Since both sites show moderate bank erosion, a large source of siltation could be autochthonous, stressing the importance of bank stability. Channel alterations such as ditching, dredging, straightening and other modifications also affect stream habitat diversity. Changing the natural drainage patterns within a stream reach impacts riffle and pool development, resulting in less diverse habitat for macroinvertebrates and fish. Temperature, dissolved oxygen concentrations, and suspended sediment loads are some water chemistry parameters that are influenced by variations in channel morphology. Both of the Rock Lake stream sites showed evidence of channelization. One of the stream sites showed evidence of recent channelization with minimal signs of recovery, while the second site appeared to have been channelized at an earlier date and had signs of moderate recovery. Other riparian zone alterations, such as canopy removal of the riparian area, have significantly degraded the stream reaches. As reflected in the QHEI evaluations both of the sites studied show negative habitat impacts according to the respective channel morphology scores. Canopy removal is parallel with the vegetative buffer strip removal, which morphologically makes the channel more susceptible to bank erosion. The Rock Lake study sites had low sinuosity, which implies a lack of erosion and deposition zones, decreasing the predictable patterns of riffle-pool sequencing. Straight reaches along both drainages are indicators that these streams have been modified and lack the natural sinuosity that leads to development of pools and riffles.

Riffles and pools are important habitats that support a diverse set of aquatic macroinvertebrates and fish. Riffles typically provide oxygenation of the water column and sorted gravels while pools provide deeper areas, slower velocity and fine particles. The riffle-pool sequence and the variation of materials and bed slopes that occur between the two create a diverse habitat for periphyton, macroinvertebrates and fish, collectively known as the stream biota. The lack of riffle-pool development in a stream is normally associated with stream channelization.

Associated with channelization and manipulation of the adjacent landscape is increased erosion and siltation of the streambed and embankments, which then interferes with typical sorting of particles that form both riffles and pools (Allan 1995).

An effective riparian zone buffers stream systems from the surrounding land use. Both of the study sites have an impaired riparian zone. Both of the stream reaches at the sample locations had only a narrow riparian zone on one bank. Stable, woody vegetation zones adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). For example, wooded riparian zones stabilize streambanks, slow run off, collect sediment, and store nutrients that would otherwise be loaded into the stream system. The fact that both of the study sites had an impaired riparian zone may help explain why the sites had poor QHEI scores and impaired mIBI scores. In addition to decreased riparian buffering, the primary agricultural land uses adjacent to the stream reaches necessitate even wider stream buffers. Agricultural contributions to sediment and nutrient loading account for a large percentage of source inputs. Of the total 4.9 billion metric tons of soil eroded annually in the U.S., 80 percent results from agriculture. Of the water quality pollutants entering waterways, 46 percent of sediment, 47 percent of total phosphorus, and 52 percent of total nitrogen originate from agriculture (Gianessi et al 1986). Riparian vegetation that is variable in height and density can alleviate portions of nutrient and sediment input by taking up or trapping these nutrients before they reach the stream. Mowed, grassy vegetation adjacent to streams does little to slow flows into the stream and therefore is less capable of trapping sediments and nutrients generated from agricultural activities.

Each of these physical factors contributes to habitat quality, and their absence or degradation at both of the sites help to explain the macroinvertebrate community evaluations of the study. The mIBI scores indicated severe impairment at both sampling sites. In a healthy stream system, a diverse community of both tolerant and intolerant taxa is expected. Impacts of degradation will tend to limit or eliminate intolerant organisms that are incapable of persisting in such systems. The Hilsenhoff Biotic Index (HBI) metric of the mIBI rates the tolerance of the sampled community. There were few intolerant macroinvertebrates observed within the two sample sites. As a result, the sample sites had HBI scores of 0 and 2 indicating severe impairment.

Healthy benthic communities require both suitable habitat in which to live and sufficient water quality to meet their needs. An optimum habitat with very poor water quality cannot support a healthy benthic community nor could great water quality along with poor habitat. Adequate habitat and water quality must both be present.

Rock Lake tributary streams are characterized by elevated concentrations of *E. coli* bacteria during base flow (1480 and 690 colony forming units per 100 ml water in Landis and Lautzenhizer Drains respectively, while 235 is the Indiana standard for no bodily contact). The dissolved oxygen concentration of the two drains was at 50 to 60 percent at both base and storm flows (streams normally should be close to 100 percent), which is likely explained by the lack of riffle habitat and decomposing organic matter. This is supported in Landis Ditch by the high ammonia nitrogen concentration (0.372 mg/l) recorded at base flow. Total phosphorus, was high (0.1 to 0.15 mg/l) in both streams during storm flow and in Lautzenhizer Drain at base flow but SRP was relatively low (<0.023 mg/l) in all samples collected indicating that phosphorus is bound to organic matter (living or dead). This is supported by the relatively low TSS concentrations correlated with total phosphorus. Elevated nitrogen and phosphorus concentrations promote excessive growth of aquatic plants including algae (organic matter). Decaying organic matter and the resulting biological oxygen demand contributes to the

depressed oxygen concentrations. In this way, land use activities can have a cascading effect throughout the stream ecosystem.

4.4 Watershed Tour

The large percentage of old field, forest, and wetlands in the subwatershed of Landis and Lautzenhizer Drains (over 28 percent) is a positive for long term water quality in Rock Lake (USGS EROS, 1998). The adjacent wetlands and vegetated uplands absorb a lot of the impacts from heavy rains, decreasing the peak flows and thus decreasing erosion during and immediately following the rains. Another 20 percent of the watershed is pastured. While not as helpful as natural vegetated communities, pastures have significantly less runoff then tilled agricultural fields. Only 51 percent of the watershed is currently in production according to the USGS EROS (1998) survey. That is much lower than most northern Indiana watersheds which tend to be between 70 and 90 percent. The above information is important for lake water quality because management of phosphorus and sediment can then focus on smaller identified issues instead of large scale agricultural runoff.

Only one issue noted during the watershed tour stands out as an identifiable source of nutrients and sediment to the waterways. A property that is actively being farmed in the headwaters of Landis Ditch is contributing a noticeable amount of sediment to the drain, and potentially high ammonia and phosphorus in the runoff due to narrow riparian buffers. The ¼ mile of open ditch with additional drainage tile has a riparian grass buffer of less than 15 feet (4 m) or less. The tile has several large blowholes or collapsed sections where the field is eroding directly into the tile system and being carried to the open ditch. The ditch downstream had multiple accumulations of sediment in the main channel. The riparian buffer is being maintained by burning and or mowing. Increasing the size of the buffer to a minimum 30 feet on each side of the drain and repairing the drainage tile up stream would resolve much of the issue.

4.5 Priority Areas for Conservation, restoration, and Acquisition

The west side of Rock Lake is undeveloped agricultural and forested areas. If these areas were to be developed for residential use in the future, additional nutrients would affect the water quality in Rock Lake. If there were an opportunity to preserve areas in the Rock Lake watershed this parcel or parcels should be considered a top priority.

One property at the upper end of Landis Ditch is contributing more sediment to Rock Lake than any other parcel. The parcel contains ¼ mile of open ditch with additional drainage tile upstream. Tile systems are in disrepair. This property should be targeted for restoration of ditch buffers or filter strips, and tile repair if it continues to be utilized for row crop agriculture.

4.6 Public Meeting Documentation

Two public meetings were held. One meeting was held May 10, 2008 to introduce the project and a final meeting was held on June 20, 2009. Approximately 15-20 residents attended each meeting, representing about ½ of the residences on the lake. A survey of issues was distributed at the first meeting (Appendix D). No surveys were returned. The majority of the concerns brought forth at the meeting concerned the safety of the water and the abundance of aquatic vegetation. At the final meeting a draft handout summarizing the Diagnostic Study was handed out to all who attended. This handout was subsequently updated and is included in Appendix E. Since the annual meeting held at a private residence represents about half of the residences on the lake, this meeting is the best way to keep the public (lake residents) informed about lake water quality issues.

5.0 SUMMARY

Rock Lake is a 56-acre (22.6-ha) slightly impounded lake that drains approximately 1,818 acres (735.7 ha or 2.84 square miles) of eastern Fulton and southwestern Kosciusko County, Indiana. The maximum depth is 16 feet (4.9 m); however, 45 percent of the lake is less than 4 feet (1.2 m) deep. Two major inlets drain 83 percent of the entire Rock Lake watershed from the south and east, Lautzenhizer Drain (1,127 acre 456.1 ha) and Landis or Bucher Drain (389 acre 157.4 ha). Water discharges through the northwest corner of Rock Lake forming Chippewanuck Creek, which empties into the Tippecanoe River north and east of Rochester. The lake is held at its current level by a steel sheetpile weir structure that is 1.8 feet higher than the water level downstream. An earthen berm with a maximum height of five feet extends from the weir across the northern end of the lake on what used to be a marshy outlet with a poorly defined channel. The muck soils continue north of the lake for several miles, indicating that Rock Lake was much larger at one time.

The glacial end moraines which form the southern and eastern boundary of the watershed are 80 feet higher then Rock Lake. The Lautzenhizer and Landis drainages are artificial ditches created in the broad valley of shallow lacustrine (lake) areas that made up the headwaters of Chippewanuck Creek. The drainage ditches were created to farm the rich organic matter formed in these shallow lakes and adjacent wetlands. Lost Lake (approximately 20 acres or 8 ha) and Mud Lake (approximately 10 acres or 4 ha), and Rock Lake are remnants of a much larger marsh and shallow lake. The soils are dominated by Kosciusko sandy loams on the ridges, Houghton and Palms muck in the low lying areas, Morley silt loam on the nearly level high ground and Pewamo silt loams on the sloping drainages. Although 10 percent of the watershed is still considered wetland, there was approximately an 84 percent loss of wetlands in the watershed due to drainage of hydric soils for farming and or development. Potentially highly erodible and highly erodible soils cover nearly 33 percent of the watershed and 92 percent of the ground is listed as severely limited for septic tank absorption fields. Rock Lake's watershed is relatively undeveloped with less then 0.2 percent of the watershed acreage developed. However, the highest development density is on Rock Lake's eastern shoreline with approximately 30 residential structures on 12 acres adjacent to the lake. Most of the development of the Rock Lake shoreline occurred between 1940 and 1965.

Rock Lake has historically, and continues to have, water quality below the Indiana mean. Secchi disk transparencies have varied between 1.5 feet and 3.2 feet (0.46 m and 1 m) between 1975 and the 2008. This relatively low clarity is due to plankton production which thrives on the high total phosphorus concentrations averaging 0.15 mg/L (about 5 times more than the concentration needed to support eutrophic conditions). This high phosphorus concentration supports an aquatic macrophyte community that currently covers more than one-third of the lakes surface area. As clarity increases this macrophyte community would likely expand to greater depths. The extensive macrophyte community in turn supports a healthy fishery. Although only two fish surveys have been conducted, the lake had 18 species during each survey with healthy populations of bluegill, crappie, and largemouth bass. Gizzard shad were becoming more abundant and should be watched to make sure they do not overpopulate.

Since the lake is shallow, complete mixing of the lake occurs keeping most of the water column supplied with oxygen and providing the fish use of the entire lake volume. This mixing of oxygen rich surface waters with oxygen poor bottom waters also keep the nutrients (primarily phosphorus) cycling throughout the lake. Carp were observed in large numbers during one of several site visits. Carp are bottom feeders which stir up the sediment. Stirring up the

sediments recycles the nutrients that have settled, making them available for algae production, and thus decreasing water clarity.

Only three species of submerged aquatic macrophytes have been identified during the plant surveys conducted. One of them, Eurasian watermilfoil, is an invasive non-native aquatic macrophyte that was a nuisance levels until controlled with aquatic herbicides in 2005 (Aquatic Control, 2006). The other two are coontail and sago pondweed, neither of which were abundant. Recently, large-leaf pondweed was spotted near the developed shoreline. The overall number of submergent species is low for a shallow lake, therefore; lake residents are encouraged to allow other submergent species to grow, while keeping a watch for the invasive species. Yellow pond lily (spatterdock) and white water lily were by far the dominant floating leaved aquatic macrophytes. The shoreline (emergent) community consisted of a wide variety of native plants on the northeast side of the lake and water willow growing in shallow water along the developed shoreline. Common reed was recently found at the northeast corner of the lake. This is an extremely aggressive species that should be controlled immediately.

The IDNR – Division of Water has been looking into the stability of the dam and spillway at the north end of the lake. Currently the sheetpile weir structure that forms the outlet appears to be in good working order; however, the berm that was built across the muck bottom outlet to guide water to the new weir has been breached on the east end and the sheetpile may not be structurally sound below the existing grade (personal communication, David Nance, IDNR) The breach does not present any immediate danger to the lake levels as it is at or near the same level as the weir and there does not appear to be any erosion taking place. It is more likely that this breach has occurred gradually over the years or the berm was never continued to higher ground on the east. To date, the IDNR does not have definite plans in place for a repair.

Improving the water quality and clarity of Rock Lake will require the combined efforts of lakeshore property owners as well as a few of the major landholders in the watershed. Early efforts should be spent reducing phosphorus inputs from the landscape. One agricultural field was identified that may have a significant input; however shoreline owners or near shore owners also need to address animal waste handling; their use of phosphorus in such things as lawn and garden fertilizer; detergents and other soaps; and in their maintenance of septic systems. The increasing number of geese on the lake needs attention. Geese feces contribute to the phosphorus issues as well as bacterial contamination (measured as *E coli*.) Further study of the role that carp are playing in the nutrient cycling of the lake is also warranted.

This phosphorus concentration in the lake is likely fueling the macrophyte and algae growth. If the macrophytes are reduced by chemical means, the algae will become denser in successive years. If water clarity is improved, the macrophyte community may become more dense and extensive. These factors need to be considered before any management decisions are made on the lake.

6.0 RECOMMENDATIONS

1) Implement the following recommendations to reduce phosphorus loading to Rock Lake by 508Kg/yr (775 of total current loading).
2) Consider working with the landowner at the upstream end of Landis Ditch to fix drainage tiles and install wider riparian buffer or filter strips. At a minimum contact the Kosciusko County Natural Resource Conservation Service (NRCS) and the Soil and Water Conservation District (SWCD) to see if they are willing to work with the landowner.
3) Stay in communication with IDNR Division of Water personnel on the issue of the dam.
4) Work with IDNR fisheries biologists to address fish management issues including carp, gizzard shad, and stocking. Encourage IDNR to perform another fish survey.
5) Consider obtaining a permit from IDNR Division of Fish and Wildlife to oil the eggs of Canada geese around the lake.
6) Consider the following Homeowner Best Management Practices
    a) Promote or insist on the use of Phosphorus free fertilizer (middle number in three number fertilizer content label = 0) for all residents adjacent to the lake or adjacent to roads which have drains leading to the lake. Excess fertilizer washes to the lake during rain events and feed algae as well as it feeds your lawn.
    b) Reduce the direct discharge of stormwater to the lake from roof tops or roads. Rainwater off roofs and roads can and should be directed to rain barrels, rain gardens, or other storage areas to remove pollutants (including phosphorus) before it reaches the lake. The temporary storage and slow release of this water will remove many of the pollutants associated with storm water.
    c) Insist that all disturbed land adjacent to the lakeshore, or to roads where runoff is directed to the lake through storm drains that lead to the lake, have adequate erosion control throughout the construction period.
    d) Do not encourage the removal of native plants at the shoreline including emergent vegetation in the shallow waters. These native plants are using up nutrients that could otherwise be used for algae production. The plants also absorb wave energy, keeping your lake calmer, and reducing or eliminating the need for shoreline protection measures.
    e) Remove all pet waste from yards adjacent to the lake and dispose of the waste in a location where it will not decompose and add to the nutrients in the lake.
    f) Do not encourage geese and or ducks by feeding them. Any concentration of wildlife increases the risk of contamination from *E. Coli* and other pathogens found in their waste and please do not dispose of the waste from geese into the lake.
7) Participate in the Hoosier RiverWatch Program within the Rock Lake sub-watershed. The Hoosier RiverWatch Program trains and equips local volunteers to monitor and assess stream ecological conditions. Nearly 200 volunteer groups participate in this program.
8) Participate in the Clean Lakes program as a volunteer lake water quality monitor. Volunteers take monthly water quality measurements throughout the summer and submit them to the lead investigator for long term water quality monitoring.

7.0 RECOMMENDED TREATMENTS- A BRIEF FEASIBILITY ANALYSIS

7.1 Predicted Success and potential timelines for installation

Landis Ditch tile repair and buffer installation

The Landis ditch is exporting a large amount of sediment during each storm event as evidenced by the doubled turbidity in the ditch immediately following a storm and by the large amount of unconsolidated sediment lying in the ditch bottom just east of 700 W. Road in Kosciusko County. This 40 acre parcel is the only agricultural field in the subwatershed that has the capability of eroding any significant amount of sediment to Landis Ditch. Fixing the collapsed tile and adding filter strips (minimum 30 feet from the top of banks) along Landis Ditch would virtually eliminate the sediment loading to Landis Ditch beyond maintenance of the ditch banks. This work should be completed before the 2010 crop is planted.

Carp reduction

Reducing the population of carp within the lake would have the predictable impact of reducing nutrient resuspension. There is no way to predict how much this would reduce phosphorus within the water column without a detailed study of the population size and affect of each individual or by eliminating the population and sampling the water column before and for many months after the removal. Consider writing or calling the IDNR fisheries biologist and asking them to put this on their schedule in the next five years.

Goose reduction

Geese are contributing nutrients in Rock Lake through their fecal matter. Reducing the population levels of geese in Rock Lake would have a positive affect on water quality. However, it is impossible to predict how much of the total phosphorus levels in the lake could be reduced by reducing the population of geese without knowing the number of geese removed and the amount of time thy spend on the lake. Consider beginning egg oiling treatments next spring by obtaining your free permits this winter (2010).

7.2 Cost estimates

Landis Ditch tile repair and buffer installation

Installing a 60 foot wide buffer strip on each side of Landis Drain for approximately 1500 feet (4 acres or 1.7 ha) would cost approximately $1,600.00. Installing new tile along approximately 500 feet that is damaged on the property would be approximately $1,500 assuming it is a private drainage tile.

Carp reduction

Carp reduction would be performed by the IDNR if the IDNR decides it is a worthwhile activity. The IDNR would not charge for this action.

Goose reduction

Goose reduction actions are generally completed for less than $20.00 and volunteer time. The permit is free. The only cost is for the vegetable oil, and for the fuel used to power the boat.

7.3 Potential Sources of funding

Landis Ditch tile repair and buffer installation

The tile repair would have to be initiated and paid for entirely by the landowner or by cash donations from private citizens or groups. The buffers or filters can be installed privately or by signing up for Conservation Reserve Program (CRP) funding through the Natural Resource Conservation Service (NRCS). If the landowner utilizes the NRCS and signs up for CRP then

the NRCS will cost share the filter strips or buffers at 50 percent and pay the landowner an annual rental fee up to 15 years.

Carp reduction
There is no funding needed or available for carp reduction.

Goose reduction
There is no funding needed for Goose reduction efforts.

7.4 Motivating factors for participation
Landis Ditch tile repair and buffer installation
The landowner can receive annual payments on ground installed into a filter strip or buffer and farm his remaining ground without safety hazards. Also there will be less need to clean the drainage ditch.

Carp reduction
Cleaner and clearer water (less nutrients)

Goose reduction
Cleaner water (less *E. coli* and nutrients)

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APPENDIX A:

SELECTED WATER QUALITY PARAMETER DEFINITIONS

ROCK LAKE DIAGNOSTIC STUDY REPORT
KOSCIUSKO AND FULTON COUNTIES, INDIANA

JFNew

APPENDIX A – Selected Water Quality Parameter Definitions

Temperature. Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. 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 (EPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana streams. For example, temperatures during the month of May should not exceed 80° F (23.7^o C) by more than 3° F (1.7^o C). June temperatures should not exceed 90° 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. Cold-water fish such as trout generally require higher concentrations of D.O. than warm water fish such as bass or Bluegill. The IAC sets minimum D.O. concentrations at 6 mg/L for cold-water fish. 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 storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity measurements.

pH. The pH of water is a measure of the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

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

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).

Nitrogen. Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed", or converted, by Blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

> ***Nitrate (NO_3^-)*** – Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams that support modified warmwater habitat (MWH) was 1.6 mg/L. Modified warmwater habitat was defined as: aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate concentrations exceeding 10 mg/1 in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).
>
> ***Ammonia (NH_4^+)*** – Ammonia is a form of dissolved nitrogen that is the preferred form for algae use. It is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. In addition, bacteria produce ammonia as a by-product as they decompose dead plant and animal matter. Both temperature and pH govern the toxicity of ammonia for aquatic life.
>
> ***Organic Nitrogen (Org N)*** – Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus. Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth in freshwater. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than what is attached to soil particles, and there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

> ***Soluble reactive phosphorus (SRP)*** – SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves.

Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/L are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/L (or 30μg/L) can cause algal blooms in lakes and reservoirs. The Ohio EPA (1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/L.

Total Suspended Solids (TSS). A TSS measurement quantifies all particles suspended and dissolved in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. Although the State of Indiana sets no standard for TSS, total dissolved solids should not exceed 750 mg/L. In general, TSS concentrations >80 mg/L have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria.** *E. coli* is one member of a group of bacteria that comprise the Fecal Coliform Bacteria and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 colonies/100 ml in any one sample within a 30-day period or a geometric mean of 125 colonies per 100 ml for five samples collected in any 30-day period. A study conducted by students at IU SPEA in the spring of 2000 found average fecal coliform levels of <200 colonies/100 ml in unglaciated, gravel-bottom creeks in the Stephen's Creek Watershed in Monroe County, Indiana (Klumpp et al., 2000). In general, fecal coliform bacteria have a life expectancy of less than 24 hours.

Secchi Disk Transparency. This refers to the depth to which the black & 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 lands, and riverbanks. Bottom sediments may be resuspended by bottom feeding fish such as carp, or in shallow lakes, by motorboats or strong winds.

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

Plankton. Plankton are important members of the aquatic food web. The plankton include the algae (microscopic plants) and the zooplankton (tiny shrimp-like animals that eat algae). Determined by filtering water through a net having a very fine mesh (63-micron openings = 63/1000 millimeter). The plankton net is towed up through the lake's water column from the one percent light level to the surface. Algae are reported as *natural units*, which records one colonial filament of multiple cells as one natural unit and one cell of a singular alga also as one natural unit. Of the many different algal species present in the water, we are particularly interested in the Blue-green algae. 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 of 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.

The Indiana TSI

The Indiana TSI (IDEM, 1986) ranges from 0 to 75 total points. The TSI totals are grouped into the following three lake quality classifications:

TSI Total	Water Quality Classification
0-15	highest quality (oligotrophic)
16-30	intermediate quality (mesotrophic)
31-45	low quality (eutrophic)
46-60	lowest quality (hypereutrophic)

A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI score that do not necessarily indicate a long-term change in lake condition.

The Indiana Trophic State Index

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% 50 119%	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% 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

APPENDIX B:

ENDANGERED, THREATENED AND RARE SPECIES IN ROCK LAKE

ROCK LAKE DIAGNOSTIC STUDY REPORT
KOSCIUSKO AND FULTON COUNTIES, INDIANA

JFNew

DNR Indiana Department of Natural Resources

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

October 10, 2007

Mr. Aaron Johnson
J.F. New and Associates
708 Roosevelt Road
Walkerton, IN 46574

Dear Mr. Johnson:

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

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

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

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

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

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

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Endangered, Threatened and Rare Species, and High Quality Natural Communities from the Rock Lake Watershed, Indiana

TYPE	SPECIES NAME	COMMON NAME	FED	STATE	TRS	LASTOBS	COMMENTS
Vascular Plant	Eriophorum viridicarinatum	Green-keeled Cotton-grass		SR	030N005E 20	1940-09	

Fed: LE = listed federal endangered; C = federal candidate species

State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SG = state significant; WL = watch list; no rank = not ranked but tracked to monitor status

Grank: Heritage Global Rank: G1 = critically imperiled; G2 = imperiled; G3 = rare or uncommon; G4 = widespread but with long term concerns; G5 = widespread and secure; GU = unranked

Srank: State Heritage Rank: S1 = critically imperiled; S2 = imperiled; S3 = rare or uncommon; S4 = widespread but with long term concerns SNR = not ranked; B = breeding rank; SNA = not resident in state in non-breeding season

Indiana County Endangered, Threatened and Rare Species List

County: Fulton

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Alasmidonta viridis	Slippershell Mussel			G4G5	S2
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	S1
Fusconaia subrotunda	Longsolid		SE	G3	S1
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G4	S2
Lampsilis ovata	Pocketbook			G5	S2
Ligumia recta	Black Sandshell			G5	S2
Obovaria subrotunda	Round Hickorynut		SSC	G4	S2
Plethobasus cyphyus	Sheepnose	C	SE	G3	S1
Pleurobema clava	Clubshell	LE	SE	G2	S1
Pleurobema plenum	Rough Pigtoe	LE	SE	G1	S1
Pleurobema pyramidatum	Pyramid Pigtoe		SE	G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot		SE	G3T3	S1
Simpsonaias ambigua	Salamander Mussel		SSC	G3	S2
Toxolasma lividus	Purple Lilliput		SSC	G2	S2
Villosa fabalis	Rayed Bean	C	SSC	G1G2	S1
Villosa lienosa	Little Spectaclecase		SSC	G5	S2
Fish					
Ammocrypta pellucida	Eastern Sand Darter			G3	S2
Coregonus artedi	Cisco		SSC	G5	S2
Etheostoma camurum	Bluebreast Darter			G4	S1
Etheostoma maculatum	Spotted Darter		SSC	G2	S1
Etheostoma tippecanoe	Tippecanoe Darter		SSC	G3G4	S1
Hybopsis amblops	Bigeye Chub			G5	S2
Ichthyomyzon bdellium	Ohio Lamprey			G3G4	S2
Percina evides	Gilt Darter		SE	G4	S1
Amphibian					
Necturus maculosus	Common mudpuppy		SSC	G5	S2
Rana pipiens	Northern Leopard Frog		SSC	G5	S2
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Emydoidea blandingii	Blanding's Turtle		SE	G4	S2
Sistrurus catenatus catenatus	Eastern Massasauga	C	SE	G3G4T3T4	S2
Bird					
Ardea herodias	Great Blue Heron			G5	S4B
Botaurus lentiginosus	American Bittern		SE	G4	S2B
Buteo platypterus	Broad-winged Hawk	No Status	SSC	G5	S3B
Cistothorus palustris	Marsh Wren		SE	G5	S3B
Cistothorus platensis	Sedge Wren		SE	G5	S3B
Gallinula chloropus	Common Moorhen	No Status	SE	G5	S3B
Ixobrychus exilis	Least Bittern		SE	G5	S3B
Rallus limicola	Virginia Rail		SE	G5	S3B
Sterna forsteri	Forster's Tern			G5	SHB
Tyto alba	Barn Owl		SE	G5	S2
Mammal					
Condylura cristata	Star-nosed Mole		SSC	G5	S2?
Lynx rufus	Bobcat	No Status		G5	S1
Myotis sodalis	Indiana Bat or Social Myotis	LE	SE	G2	S1
Spermophilus franklinii	Franklin's Ground Squirrel		SE	G5	S2
Taxidea taxus	American Badger			G5	S2
Vascular Plant					
Bidens beckii	Beck Water-marigold		ST	G4G5T4	S1
Carex atlantica ssp. capillacea	Howe Sedge		SE	G5T5?	S1
Carex bebbii	Bebb's Sedge		ST	G5	S2

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Indiana County Endangered, Threatened and Rare Species List

County: Fulton

Species Name	Common Name	FED	STATE	GRANK	SRANK
Carex pseudocyperus	Cyperus-like Sedge		SE	G5	S1
Carex sparganioides var. cephaloidea	Thinleaf Sedge		SE	G5	S2
Cirsium hillii	Hill's Thistle		SE	G3	S1
Crataegus succulenta	Fleshy Hawthorn		SR	G5	S2
Eriophorum viridicarinatum	Green-keeled Cotton-grass		SR	G5	S2
Geranium bicknellii	Bicknell Northern Crane's-bill		SE	G5	S1
Lathyrus venosus	Smooth Veiny Pea		ST	G5	S2
Stenanthium gramineum	Eastern Featherbells		ST	G4G5	S1
High Quality Natural Community					
Forest - upland mesic	Mesic Upland Forest		SG	G3?	S3
Savanna - sand dry	Dry Sand Savanna		SG	G2?	S2
Savanna - sand dry-mesic	Dry-mesic Sand Savanna		SG	G2?	S2S3
Wetland - fen	Fen		SG	G3	S3
Wetland - marsh	Marsh		SG	GU	S4

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Indiana County Endangered, Threatened and Rare Species List

County: Kosciusko

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Alasmidonta viridis	Slippershell Mussel			G4G5	S2
Epioblasma obliquata perobliqua	White Cat's Paw Pearlymussel	LE	SE	G1T1	S1
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	S1
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G4	S2
Lampsilis ovata	Pocketbook			G5	S2
Ligumia recta	Black Sandshell			G5	S2
Pleurobema clava	Clubshell	LE	SE	G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot		SE	G3T3	S1
Toxolasma lividus	Purple Lilliput		SSC	G2	S2
Toxolasma parvum	Lilliput			G5	S2
Villosa fabalis	Rayed Bean	C	SSC	G1G2	S1
Villosa lienosa	Little Spectaclecase		SSC	G5	S2
Insect: Lepidoptera (Butterflies & Moths)					
Capis curvata	A Noctuid Moth		ST	G4	S2S3
Catocala praeclara	Praeclara Underwing		SR	G5	S2S3
Chortodes inquinata	Tufted Sedge Moth		ST	GNR	S1S2
Dasychira cinnamomea	A Moth		SR	G4	S1
Euphydryas phaeton	Baltimore		SR	G4	S2
Euphyes bimacula	Two-spotted Skipper		ST	G4	S2
Exyra rolandiana	Pitcher Window Moth		SE	G4	S1S2
Fixsenia favonius	Northern Hairstreak		SR	G4	S1S2
Hemileuca sp. 3	Midwestern Fen Buckmoth		ST	G3G4Q	S1?
Hesperia leonardus	Leonard's Skipper	No Status	SR	G4	S2
Iodopepla u-album	A Noctuid Moth		SR	G5	S2
Leucania multilinea			ST	G5	S1S2
Lycaena helloides	Purplish Copper		SR	G5	S2S4
Lytrosis permagnaria	A Lytrosis Moth		ST	G3G4	S2
Macrochilo absorptalis	A Moth		SR	G4G5	S2S3
Papaipema appassionata	The Pitcher Plant Borer Moth		SE	G4	S1
Papaipema speciosissima	The Royal Fern Borer Moth		ST	G4	S2S3
Pieris oleracea	Eastern Veined White		SE	G4G5	S1
Fish					
Acipenser fulvescens	Lake Sturgeon		SE	G3G4	S1
Ammocrypta pellucida	Eastern Sand Darter			G3	S2
Coregonus artedi	Cisco		SSC	G5	S2
Hybopsis amblops	Bigeye Chub			G5	S2
Notropis heterolepis	Blacknose Shiner			G4	S2
Percina evides	Gilt Darter		SE	G4	S1
Amphibian					
Ambystoma laterale	Blue-spotted Salamander		SSC	G5	S2
Hemidactylium scutatum	Four-toed Salamander		SE	G5	S2
Necturus maculosus	Common mudpuppy		SSC	G5	S2
Rana pipiens	Northern Leopard Frog		SSC	G5	S2
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Clonophis kirtlandii	Kirtland's Snake		SE	G2	S2
Emydoidea blandingii	Blanding's Turtle		SE	G4	S2
Nerodia erythrogaster neglecta	Copperbelly Water Snake	PS:LT	SE	G5T2T3	S2
Sistrurus catenatus catenatus	Eastern Massasauga	C	SE	G3G4T3T4	S2
Bird					
Ardea herodias	Great Blue Heron			G5	S4B
Botaurus lentiginosus	American Bittern		SE	G4	S2B
Certhia americana	Brown Creeper			G5	S2B

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Indiana County Endangered, Threatened and Rare Species List

County: Kosciusko

Species Name	Common Name	FED	STATE	GRANK	SRANK
Chlidonias niger	Black Tern		SE	G4	S1B
Circus cyaneus	Northern Harrier		SE	G5	S2
Cistothorus palustris	Marsh Wren		SE	G5	S3B
Cistothorus platensis	Sedge Wren		SE	G5	S3B
Dendroica cerulea	Cerulean Warbler		SSC	G4	S3B
Empidonax alnorum	Alder Flycatcher			G5	S2B
Falco peregrinus	Peregrine Falcon	No Status	SE	G4	S2B
Grus canadensis	Sandhill Crane	No Status	SSC	G5	S2B,S1N
Ixobrychus exilis	Least Bittern		SE	G5	S3B
Mniotilta varia	Black-and-white Warbler		SSC	G5	S1S2B
Nycticorax nycticorax	Black-crowned Night-heron		SE	G5	S1B
Rallus elegans	King Rail		SE	G4	S1B
Rallus limicola	Virginia Rail		SE	G5	S3B
Vermivora chrysoptera	Golden-winged Warbler		SE	G4	S1B
Mammal					
Condylura cristata	Star-nosed Mole		SSC	G5	S2?
Lutra canadensis	Northern River Otter			G5	S2
Mustela nivalis	Least Weasel		SSC	G5	S2?
Myotis sodalis	Indiana Bat or Social Myotis	LE	SE	G2	S1
Taxidea taxus	American Badger			G5	S2
Vascular Plant					
Actaea rubra	Red Baneberry		SR	G5	S2
Andromeda glaucophylla	Bog Rosemary		SR	G5	S2
Arethusa bulbosa	Swamp-pink		SX	G4	SX
Aster borealis	Rushlike Aster		SR	G5	S2
Bidens beckii	Beck Water-marigold		ST	G4G5T4	S1
Carex aurea	Golden-fruited Sedge		SR	G5	S2
Carex bebbii	Bebb's Sedge		ST	G5	S2
Carex chordorrhiza	Creeping Sedge		SE	G5	S1
Carex disperma	Softleaf Sedge		SE	G5	S1
Carex echinata	Little Prickly Sedge		SE	G5	S1
Carex flava	Yellow Sedge		ST	G5	S2
Carex pseudocyperus	Cyperus-like Sedge		SE	G5	S1
Cornus amomum ssp. amomum	Silky Dogwood		SE	G5T5	S1
Cornus canadensis	Bunchberry		SE	G5	S1
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper		SR	G5	S2
Cypripedium candidum	Small White Lady's-slipper		WL	G4	S2
Drosera intermedia	Spoon-leaved Sundew		SR	G5	S2
Eleocharis geniculata	Capitate Spike-rush		ST	G5	S2
Eriophorum angustifolium	Narrow-leaved Cotton-grass		SR	G5	S2
Eriophorum gracile	Slender Cotton-grass		ST	G5	S2
Eriophorum viridicarinatum	Green-keeled Cotton-grass		SR	G5	S2
Geranium robertianum	Herb-robert		ST	G5	S2
Juglans cinerea	Butternut		WL	G3G4	S3
Lathyrus ochroleucus	Pale Vetchling Peavine		SE	G4G5	S1
Lemna perpusilla	Minute Duckweed		SX	G5	SX
Lemna valdiviana	Pale Duckweed		SE	G5	S1
Malaxis unifolia	Green Adder's-mouth		SE	G5	S1
Matteuccia struthiopteris	Ostrich Fern		SR	G5	S2
Myriophyllum verticillatum	Whorled Water-milfoil		SR	G5	S2
Panax trifolius	Dwarf Ginseng		WL	G5	S2
Panicum boreale	Northern Witchgrass		SR	G5	S2
Platanthera psycodes	Small Purple-fringe Orchis		SR	G5	S2
Potamogeton epihydrus	Nuttall Pondweed		SE	G5	S1
Potamogeton friesii	Fries' Pondweed		ST	G4	S1

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Indiana County Endangered, Threatened and Rare Species List

County: Kosciusko

Species Name	Common Name	FED	STATE	GRANK	SRANK
Potamogeton oakesianus	Oakes Pondweed		SE	G4	S1
Potamogeton praelongus	White-stem Pondweed		ST	G5	S1
Potamogeton pusillus	Slender Pondweed		WL	G5	S2
Potamogeton richardsonii	Redheadgrass		SR	G5	S2
Potamogeton strictifolius	Straight-leaf Pondweed		ST	G5	S1
Prunus pensylvanica	Fire Cherry		SR	G5	S2
Scirpus subterminalis	Water Bulrush		SR	G4G5	S2
Selaginella apoda	Meadow Spike-moss		WL	G5	S1
Sparganium androcladum	Branching Bur-reed		ST	G4G5	S2
Spiranthes lucida	Shining Ladies'-tresses		SR	G5	S2
Stenanthium gramineum	Eastern Featherbells		ST	G4G5	S1
Tofieldia glutinosa	False Asphodel		SR	G5	S2
Utricularia resupinata	Northeastern Bladderwort		SX	G4	SX
Vaccinium oxycoccos	Small Cranberry		ST	G5	S2
Wolffiella gladiata	Sword Bogmat		SE	G5	S1
Zannichellia palustris	Horned Pondweed		SR	G5	S2
Zigadenus elegans var. glaucus	White Camas		SR	G5T4T5	S2
High Quality Natural Community					
Forest - upland dry-mesic	Dry-mesic Upland Forest		SG	G4	S4
Forest - upland mesic	Mesic Upland Forest		SG	G3?	S3
Lake - lake	Lake		SG	GNR	S2
Wetland - beach marl	Marl Beach		SG	G3	S2
Wetland - bog acid	Acid Bog		SG	G3	S2
Wetland - bog circumneutral	Circumneutral Bog		SG	G3	S3
Wetland - fen	Fen		SG	G3	S3
Wetland - fen forested	Forested Fen		SG	G3	S1
Wetland - marsh	Marsh		SG	GU	S4
Wetland - meadow sedge	Sedge Meadow		SG	G3?	S1
Wetland - swamp shrub	Shrub Swamp		SG	GU	S2

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APPENDIX C:

RAW DATA

ROCK LAKE DIAGNOSTIC STUDY REPORT
KOSCIUSKO AND FULTON COUNTIES, INDIANA

JFNew

1250
Landis Ditch
Co Line
Lautzenhiser Ditch
200

Project ID:	Rock Lake	
Sample Type	Kick Sample	
Stream/Reach:	Landis Ditch	
Sample Date:	29-Nov-07	
Location	Site 1	CR 1000 S

QHEI Habitat Parameters

1. Substrate	3	range (0-20)
2. Cover	5	range (0-20)
3. Channel	6	range (0-20)
4. Riparian	8	range (0-10)
5. Pool/Current Quality	4	range (0-12)
6. Riffle/Run Quality	1	range (0-8)
7. Gradient	6	range (0-10)
Total Habitat Score	33	range (0-100)

Ohio EPA Biotic Index Score - Genus/species Level

	Data	Score
1.Genus/species Taxa Richness	13	2
2.Number mayfly taxa	1	0
3.Number caddisfly taxa	1	2
4. Number dipteran taxa	8	4
5 % mayfly composition	7	2
6. % caddisfly compostion	5	2
7.% tanitarsini midge compostion	4	2
8.% Other dipteran and non-insects	80	0
9.% Tolerant organisms	7	6
10. Percent in Dominant Group	80	0
IBI		20
"Standardized" IBI		33

IDEM mIBI Score - Family Level

	Data	Score
1. Hilsenhoff Biotic Index	5.9	2
2. Number of Families	6	2
3. Number of Individuals	56	0
4. Percent Dominant	80	0
5. EPT Index	2	2
6. EPT Count	7	2
7. EPT Count / Total Count	0.12	2
8. EPT Count / Chironomid Count	0.15	2
9. Chironomid Count	45	4
10. Individuals per Square	18	0
mIBI		1.6
"Standardized" IBI		20

Raw Data

Chironomidae	Procladius sublettei	
	Natarsia baltimoreus	5
	Orthocladius obumbratus	7
	Parametriocnemus lundbecki	13
	Rheocricotopus robacki	10
	Corynoneura spp.	2
	Chironomus spp.	4
	Paratendipes albimanus	2
	Microspectra polita	2
Tipulidae	Pseudolimnophila spp.	1
Baetidae	Procleon spp.	4
Limnephilidae	Limnephilus spp.	3
Dytiscidae	Agabus spp.	1
Amphipoda	Gammarus spp.	2
Total		56

Diagnosis

This site had a biotic index value very similar to its habitat value.
This indicates that there are no obvious water quality problems.

Project ID:	Rock Lake	
Sample Type	Kick Sample	
Stream/Reach:	Lautzenhiser Ditch	
Sample Date:	29-Nov-07	
Location	Site 2	CR 675 W

QHEI Habitat Parameters

1. Substrate	9	range (0-20)
2. Cover	6	range (0-20)
3. Channel	7	range (0-20)
4. Riparian	6	range (0-10)
5. Pool/Current Quality	5	range (0-12)
6. Riffle/Run Quality	2	range (0-8)
7. Gradient	6	range (0-10)
Total Habitat Score	41	range (0-100)

Ohio EPA Biotic Index Score - Genus/species Level

	Data	Score
1.Genus/species Taxa Richness	12	2
2.Number mayfly taxa	1	0
3.Number caddisfly taxa	1	2
4. Number dipteran taxa	5	2
5 % mayfly composition	3	2
6. % caddisfly compostion	1	2
7.% tanitarsini midge compostion	8	2
8.% Other dipteran and non-insects	66	0
9.% Tolerant organisms	51	0
10. Percent in Dominant Group	68	0
IBI		12
"Standardized" IBI		20

Raw Data

Chironomidae	Parametriocnemus lundbecki	15
	Chironomus spp.	42
	Microspectra polita	8
Tipulidae	Pseudolimnophila spp.	5
Ptychopteridae		1
Baetidae	Procleon spp.	3
Limnephilidae	Limnephilus spp.	1
Dytiscidae	Agabus spp.	2
Helodidae		2
Coenagrionidae	Argia spp.	6
	Hyalella spp.	4
	Lumbriculidae	6
Total		95

IDEM mIBI Score - Family Level

	Data	Score
1. Hilsenhoff Biotic Index	7.9	0
2. Number of Families	10	2
3. Number of Individuals	95	2
4. Percent Dominant	68	0
5. EPT Index	2	2
6. EPT Count	4	2
7. EPT Count / Total Count	0.04	0
8. EPT Count / Chironomid Count	0.06	0
9. Chironomid Count	65	2
10. Individuals per Square	19	0
mIBI		1.0
"Standardized" IBI		12

Diagnosis

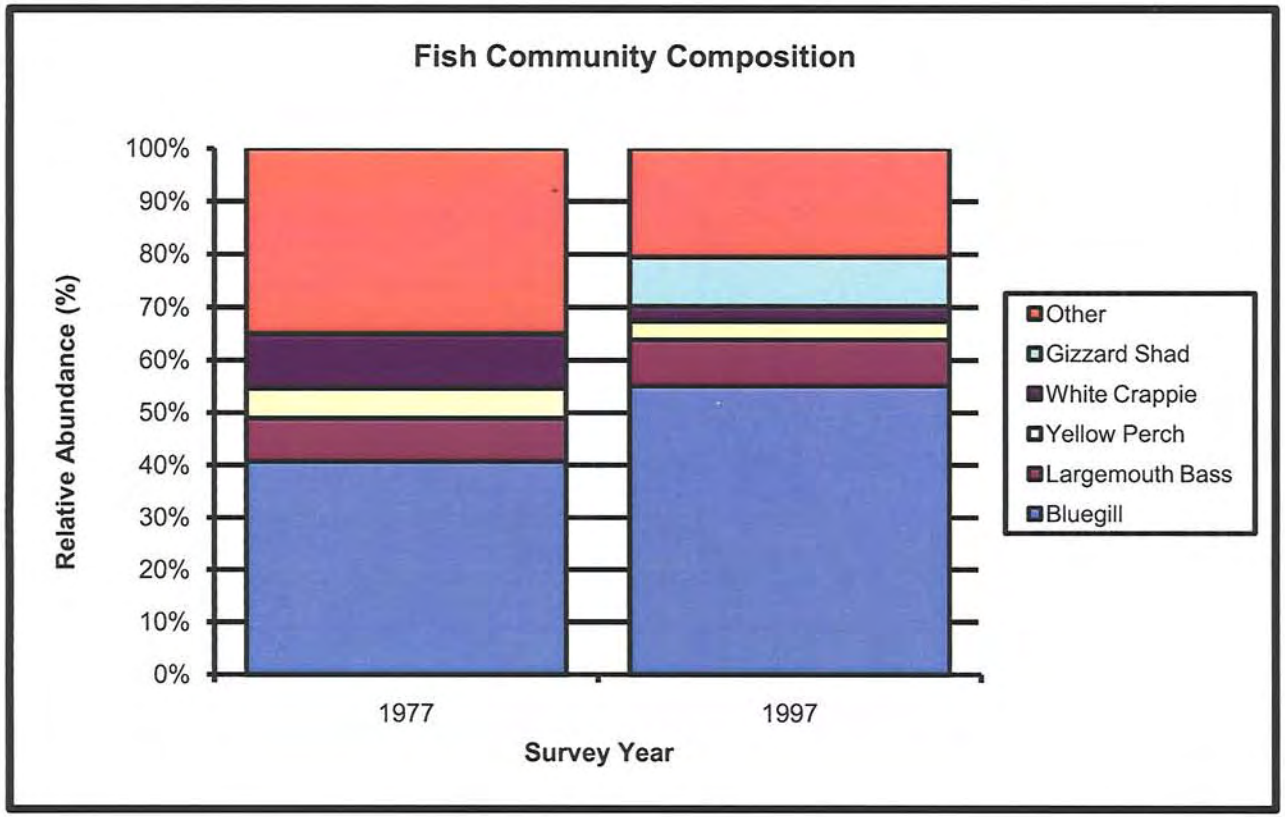
Despite having better habitat than the other inlet to Rock Lake, the biotic integrity of this site was lower, indicating water quality problems. The site was dominated by tolerant midge larvae, indicating periodically low dissolved oxygen levels. Organic loading may be high in this subwatershed.

Common Name	Scientific Name	1977	1997
Sunfish Family			
Bluegill	*Lepomis macrochirus*	X	X
Black Crappie	*Pomoxis nigromaculatus*	X	X
Hybrid Sunfish		X	
Largemouth Bass	*Micropterus salmoides*	X	X
Longear Sunfish	*Lepomis megalotus*	X	X
Pumpkinseed	*Lepomis gibbosus*	X	X
Warmouth	*Lepomis gulosus*	X	X
White Crappie	*Pomoxis annularis*	X	X
Catfish Family			
Black Bullhead	*Ameiurus melas*		X
Brown Bullhead	*Ameiurus nebulosus*	X	X
Channel Catfish	*Ictalurus punctatus*		X
Yellow Bullhead	*Ameiurus natalis*	X	X
Minnow Family			
Common Carp	*Cyprinus carpio*	X	X
Golden Shiner	*Notemigonus crysoleucas*	X	X
Sucker Family			
Golden Redhorse	*Moxostoma erythrurum*	X	
Spotted sucker	*Minytrema melanops*	X	X
White Sucker	*Catostomus commersoni*	X	X
Herring Family			
Gizzard Shad	*Dorosoma cepedianum*	X	X
Gar Family	-		
Spotted Gar	*Lepisosteus oculatus*	X	X
Pike Family			
Northern Pike	*Esox lucius*	X	
Perch Family			
Yellow Perch	*Perca flavescens*	X	X
Number Species		18/1 hybrid	18

		1977		1997	
Common Name	**Scientific Name**	#	%	#	%
Bluegill	*Lepomis macrochirus*	273	40.7%	371	55.0%
Black Bullhead	*Ictalurus melas*			4	0.6%
Black Crappie	*Pomoxis nigromaculatus*	52	7.8%	5	0.7%
Brown Bullhead	*Ameiurus nebulosus*	8	1.2%	25	3.7%
Channel Catfish	*Ictalurus punctatus*			1	0.1%
Common Carp	*Cyprinus carpio*	6	0.9%	8	1.2%
Gizzard Shad	*Dorosoma cepedianum*	1	0.1%	63	9.3%
Golden Redhorse	*Moxostoma erythrurum*	1	0.1%		
Golden Shiner	*Notemigonus crysoleucas*	76	11.3%	28	4.2%
Hybrid Sunfish		1	0.1%		
Largemouth Bass	*Micropterus salmoides*	55	8.2%	59	8.8%
Longear Sunfish	*Lepomis megalotus*	17	2.5%	9	1.3%
Northern Pike	*Esox lucius*	2	0.3%		
Pumpkinseed	*Lepomis gibbosus*	22	3.3%	6	0.9%
Spotted Gar	*Lepisosteus oculatus*	15	2.2%	26	3.9%
Spotted Sucker	*Minytrema melanops*	3	0.4%	5	0.7%
Warmouth	*Lepomis gulosus*	3	0.4%	6	0.9%
White Crappie	*Pomoxis annularis*	69	10.3%	19	2.8%
White Sucker	*Catostomus commersoni*	24	3.6%	6	0.9%
Yellow Bullhead	*Ameiurus natalis*	4	0.6%	9	1.3%
Yellow Perch	*Perca flavescens*	38	5.7%	24	3.6%
Total # Collected		670		674	
Number Species		18/1 hybrid		18	
Total # Species	20/1 hybrid				

Rock Lake

Survey Year	Species	Relative Abundance (%)
1977	Bluegill	40.7
1997	Bluegill	55.0
1977	Largemouth Bass	8.2
1997	Largemouth Bass	8.8
1977	Yellow Perch	5.7
1997	Yellow Perch	3.6
1977	Gizzard Shad	0.1
1997	Gizzard Shad	9.3
1977	White Crappie	10.3
1997	White Crappie	2.8
1977	Other	35.0
1997	Other	20.5



Occurrence and abundance of submersed aquatic plants in Rock Lake.					
Total Sites:	40	Mean species / site:	0.51	Native diversity:	0.43
Littoral Sites:	31	Maximum species / site:	2	Species diversity:	0.43
Littoral Depth (ft):	10	Number of species:	3	SE Mean natives / site:	0.10
Date:	8/4/2008	Littoral sites with plants:	18	Mean natives / site:	0.51
Lake:	Rock	Secchi(ft):	2.5	SE Mean species / site:	0.10

All depths (0-10')		Frequency of	Frequency per Species				Plant
Scientific Name	**Common Name**	**Occurrence**	**0**	**1**	**3**	**5**	**Dominance**
Stuckenia pectinatus	Sago pondweed	37.50	62.50	37.50	0.00	0.00	7.50
Ceratophyllum demersum	Coontail	12.50	87.50	12.50	0.00	0.00	2.50
Chara species	Chara species	2.50	97.50	2.50	0.00	0.00	0.50
Filamentous algae	Filamentous algae	10.00					

0-5' Stratum		Frequency of	Frequency per Species				Plant
Scientific Name	**Common Name**	**Occurrence**	**0**	**1**	**3**	**5**	**Dominance**
Stuckenia pectinatus	Sago pondweed	40.00	60.00	40.00	0.00	0.00	8.00
Ceratophyllum demersum	Coontail	15.00	85.00	15.00	0.00	0.00	3.00
Chara species	Chara species	5.00	95.00	5.00	0.00	0.00	1.00
Filamentous algae	Filamentous algae	0.00					

5-10' Stratum		Frequency of	Frequency per Species				Plant
Scientific Name	**Common Name**	**Occurrence**	**0**	**1**	**3**	**5**	**Dominance**
Stuckenia pectinatus	Sago pondweed	33.33	66.67	33.33	0.00	0.00	6.67
Ceratophyllum demersum	Coontail	9.52	90.48	9.52	0.00	0.00	1.90
Filamentous algae	Filamentous algae	19.05					

Discharge Measurement

Site: 1 Date: 6/9/08 Time: 10:15
Project #: 070772 Project Name:
Crew Members: TE & SP Equipment:
Physical Site Description: slow flow, muck/silt bottom
GPS Coordinates:

If the stream is <2" deep:
Stream Width:_____feet
Stream Depths: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____feet
U: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____ft/s
U_{max}:_____ft/s

$\frac{12}{5} = 2.4$

If the stream is >2" deep:
Stream Width (W): 12.5 feet
Interval Width (IW) (If W<15', then IW=W/5. If W>15, then IW=W*0.1): 2.4 feet

Segment	SI_0 Location	SI_0 Depth (ft)	SI_1 Location	SI_1 Depth (ft)	½ IW Location	½ IW Depth (ft)	$U_{0.4}$ Set Depth	$U_{0.4}$ Rate (ft/s)	$U_{0.8}$ Set Depth	$U_{0.8}$ Rate (ft/s)	$U_{0.2}$ Set Depth	$U_{0.2}$ Rate (ft/s)
1	0	0.1	2.4	0.7	1.2	0.3	0.3	Ø				
2	2.4	0.7	4.8	1.6	3.6	1.0	1.0	0.16				
3	4.8	1.6	7.2	1.55	6.0	1.5	1.5	0.35				
4	7.2	1.55	9.6	1.1	8.4	1.4	1.4	0.10				
5	9.6	1.1	12.8	0.2	10.8	0.8	0.8	0.03				
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

W=8.7

Field Crew Leader Signature: _____

WATER QUALITY SAMPLING FIELD LOG SHEET

SITE NUMBER AND LOCATION: Rock Lake Site 1 , Landis Ditch

DATE: 6/4/08 PROJECT NAME: Rock Lake Diagnostic Study

TIME: 10:15

FIELD CREW: SP & TE

WEATHER CONDITIONS: stormevent ~ 0.8" last 24HRS

OTHER OBSERVATIONS: relatively low flow

EQUIPMENT CALIBRATION (Date): 6/4/08

FIELD PARAMETERS		REPLICATE (if taken)	
pH: 7.34	pH:	RPD =	
Temperature: 20.1	Temperature:	RPD =	
Dissolved Oxygen: 4.54	Dissolved Oxygen:	RPD =	
DO % Saturation: 48.8%	DO % Saturation:	RPD =	
Conductivity: 419	Conductivity:	RPD =	
Calculated Flow: 1.041 cfs			

Relative Percent Difference (RPD)= $\frac{(\text{sample}_1\text{-sample}_2)}{((\text{sample}_1+\text{sample}_2)/2)}$

LAB PARAMETERS

E. Coli: ✓

Ammonia: ✓

Nitrate+Nitrite: ✓

Kjeldahl Nitrogen: ✓

Total Phosphorus: ✓

Soluble Reactive Phosphorus: ✓

Total Suspended Solids: ✓

~~Turbidity:~~ ___

~~Biological Oxygen Demand:~~ ___

Field Crew Leader Signature: Sara J Pal

Discharge Measurement

Site: Rock Lake Stream 2
Date: 6-4-2008 Time: 11:05
Project #: 070772.00
Project Name: Rock Lake Diagnostic Study
Crew Members: TE, SP
Equipment: Flow Mate
Physical Site Description: muck bottom, wetland stream
GPS Coordinates: _____

If the stream is <2" deep:
Stream Width: _____ feet
Stream Depths: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____ feet
U: _____, _____, _____, _____, _____, _____, _____, _____, _____, _____ ft/s
U_{max}: _____ ft/s

If the stream is >2" deep:
Stream Width (W): 4.4 feet
Interval Width (IW) (If W<15', then IW=W/5. If W>15, then IW=W*0.1): .8 feet

Segment	SI_0 Location	SI_0 Depth (ft)	SI_1 Location	SI_1 Depth (ft)	½ IW Location	½ IW Depth (ft)	$U_{0.4}$ Set Depth	$U_{0.4}$ Rate (ft/s)	$U_{0.8}$ Set Depth	$U_{0.8}$ Rate (ft/s)	$U_{0.2}$ Set Depth	$U_{0.2}$ Rate (ft/s)
1	0	.01	.8	.01	.4	.01	.01	0				
2	.8	.01	1.6	.2	1.2	.15	.15	0				
3	1.6	.2	2.4	.3	2.0	.3	.3	.13				
4	2.4	.3	3.2	.25	2.8	.35	.35	.22				
5	3.2	.25	4.4	.1	3.6	.45	.45	.31				
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Field Crew Leader Signature: _____

WATER QUALITY SAMPLING FIELD LOG SHEET

SITE NUMBER AND LOCATION: Rock Lake Site 2, Lautzenhizer Ditch

DATE: 6-4-2008 PROJECT NAME: Rock Lake Diagnostic Study

TIME: 11:05 am

FIELD CREW: TF, SP

WEATHER CONDITIONS: overcast, 70°F

OTHER OBSERVATIONS:

EQUIPMENT CALIBRATION (Date): 6-4-2008

FIELD PARAMETERS		REPLICATE (if taken)	
pH: 7.45	pH: 7.45	RPD =	
Temperature: 22°C	Temperature: 21.9°C	RPD =	
Dissolved Oxygen: 5.48	Dissolved Oxygen: 5.42	RPD =	
DO % Saturation: 61.1	DO % Saturation: 61.0	RPD =	
Conductivity: 296	Conductivity: 296	RPD =	
Calculated Flow: 0.037 cfs			

Relative Percent Difference (RPD)= $\frac{(sample_1 - sample_2)}{((sample_1 + sample_2)/2)}$

LAB PARAMETERS

E. Coli: X

Ammonia: X

Nitrate+Nitrite: X

Kjeldahl Nitrogen: X

Total Phosphorus: X

Soluble Reactive Phosphorus: X

Total Suspended Solids: X

Turbidity: X

Biological Oxygen Demand: ___

Field Crew Leader Signature: _____

LABORATORY REPORT

SHERRYLaboratories
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Customer: 471
J. F. New & Associates

Sample: 142365
Site 1 (North Site)

Mailing:

708 Roosevelt Rd
Walkerton, IN 46574

Desc Code: E COLI
Date Sampled: 06/24/08
Time Sampled: 08:30
Date Received: 06/24/08
Date Reported: 06/25/08
P.O. Number:

Billing:
Tom Estrem
708 Roosevelt Rd
Walkerton, IN 46574

Certified Public Health Laboratory: MC-43-1
USDA Laboratory Code: 3659
560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax: 574-269-6569

This report printed from Sherrylabs.com

Test Description	Result	Units	MDL	Lab Method #	Date and Time	Run No.	Analyst
		QC-If Applicable					
E Coli	1480	/100		9223B	06/24/08 14:00	118780	KK
Reference Method: QT 9223B E Coli			Comments:				

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

All testing is conducted in accordance with the following regulations as applicable: 40 CFR Part 136, 40 CFR Part 261, or PL 91-597.

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Approved By: Stacy D West

LABORATORY REPORT

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Customer: 471 Sample: 142367

J. F. New & Associates Site 2 (South Site)

Mailing:

708 Roosevelt Rd
Walkerton, IN 46574

Desc Code: E COLI
Date Sampled: 06/24/08
Time Sampled: 09:00
Date Received: 06/24/08
Date Reported: 06/25/08
P.O. Number:

Billing:
Tom Estrem
708 Roosevelt Rd
Walkerton, IN 46574

Certified Public Health Laboratory: MC-43-1
USDA Laboratory Code: 3659
560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax: 574-269-6569

This report printed from Sherrylabs.com

Test Description	Result	Units QC-If Applicable	MDL	Lab Method #	Date and Time	Run No.	Analyst
E Coli *Reference Method: QT 9223B E Coli*	690	/100	Comments:	9223B	06/24/08 14:00	118780	KK

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

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Approved By: Stanley D West

LABORATORY REPORT

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Customer: 471 **Sample: 142366**

J. F. New & Associates Site 1 Dup

Mailing:

708 Roosevelt Rd
Walkerton, IN 46574

Desc Code: E COLI
Date Sampled: 06/24/08
Time Sampled: 08:30
Date Received: 06/24/08
Date Reported: 06/25/08
P.O. Number:

Billing:
Tom Estrem
708 Roosevelt Rd
Walkerton, IN 46574

Certified Public Health Laboratory: MC-43-1
USDA Laboratory Code: 3659
560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax: 574-269-6569

This report printed from Sherrylabs.com

Test Description	Result	Units	MDL	Lab Method #	Date and Time	Run No.	Analyst
		QC-If Applicable					
E Coli	1050	/100		9223B	06/24/08 14:00	118780	KK
Reference Method: QT 9223B E Coli			Comments:				

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

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Approved By: Stanley D West

Laboratory Report

SHERRYLaboratories

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Customer: 0030471
J. F. New & Associates

Mailing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Billing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Sample: W140926
Rock 1
Desc Code: E COLI
Date Sampled: 6/4/2008 Time: 10:15 AM
Date Received: 6/4/2008 11:50:08 AM
Date Reported: 6/9/2008
P.O. Number:
PWS_ID:
Status: Reported

Certifications: IN# M-43-01, IN# C-02-02
IN# C-18-02, IN# C-03-02
USDA Laboratory Code #: 3659
560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax:574-269-6569

Test Description	Result	MDL	Units	Lab Method #	Batch #	Date and Time	Analyst
Reference Method:			QC-If Applicable				
E Coli	350		/100	9223B	118406	6/4/2008 12:40:00 PM	KK
Ref: QT 9223B E Coli			Comments:				

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

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Approved By: Stanley D West

Laboratory Report

SHERRYLaboratories

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Customer: 0030471
J. F. New & Associates

Mailing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Billing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Sample: W140927
Rock 2
Desc Code: E COLI
Date Sampled: 6/4/2008 Time: 11:05 AM
Date Received: 6/4/2008 11:50:27 AM
Date Reported: 6/9/2008
P.O. Number:
PWS_ID:
Status: Reported

Certifications: IN# M-43-01, IN# C-02-02
IN# C-18-02, IN# C-03-02
USDA Laboratory Code #: 3659
560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax:574-269-6569

Test Description	Result	MDL	Units	Lab Method #	Batch #	Date and Time	Analyst
Reference Method:			QC-If Applicable				
E Coli	230		/100	9223B	118406	6/4/2008 12:40:00 PM	KK
Ref: QT 9223B E Coli			Comments:				

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

All testing is conducted in accordance with the following regulations as applicable: 40 CFR Part 136, 40 CFR Part 261, or PL 91-597.

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Approved By: Stanley D West

Laboratory Report

SHERRYLaboratories

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Customer: 0030471
J. F. New & Associates

Mailing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Billing Address:
J. F. New & Associates
Lynn Cudlip
708 Roosevelt Rd
Walkerton, IN 46574

Sample: W140928
Rock Dup
Desc Code: E COLI
Date Sampled: 6/4/2008 Time: 11:05 AM
Date Received: 6/4/2008 11:50:45 AM
Date Reported: 6/9/2008
P.O. Number:
PWS_ID:
Status: Reported

Certifications: IN# M-43-01, IN# C-02-02
IN# C-18-02, IN# C-03-02
USDA Laboratory Code #: 3659

560 S. Zimmer Road - P.O. Box 1849
Warsaw, Indiana 46581-1849
Voice: 574-267-3305 / Fax:574-269-6569

Test Description	Result	MDL	Units	Lab Method #	Batch #	Date and Time	Analyst
Reference Method:			QC-If Applicable				
E Coli	240		/100	9223B	118406	6/4/2008 12:40:00 PM	KK
Ref: QT 9223B E Coli			Comments:				

A result of "ND" indicates None Detected. For bacteriological results "ND" indicates negative. Zeros to the right of the decimal point and/or to the right of a digit are not significant. ie: 10.00 = 10; 1.00 = 1; 1.10 = 1.1 MDL - Minimum Detection Level concentration reportable >0 with 99% confidence in an aqueous matrix.

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Approved By: Stanley D West

HERRY Laboratories
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Sherry Laboratories - Chain of Custody Record

Laboratory Number: W140926-928

Client Information:		Billing Information:	PO Number:	Project Name/Number:	Page 1 of 1
Company Name:	JFNew	Same		Rocklake 070772	**Matrix Code**
Contact Name:	Sara Peel		Quote Number:		DW = Drinking Water WW = Waste Water GW = Ground Water
Address:	708 Roosevelt Road			Sampler's Signature: Sara Peel	AQ = Aqueous OT = Other SL = Sludge SOL = Solid O = Oil SO = Soil F = Food SW = Swab
			Required QC Level		NG = Natural Gas NGL = Natural Gas Liquid PW = Produced Water CF = Completion Fluid
City, State Zip:	Walkerton IN 46574				
Phone Number:	574-586-3400 Ext: 341	Ext:	Bill Monthly	Shipping Method:	
Fax Number:	574-586-3446		☑ Yes	UPS / FedEx / Airborne	
E-mail Address:	speel@jfnew.com		☐ No	DHL / Sherry / Hand / Mail	

Which Regulations Apply:
☐ RCRA ☐ Drinking Water
☐ POTW ☐ Distribution
☐ NPDES ☐ Special
☐ USDA/FDA ☐ State
☐ RECAP/RISC ☐ Other

Turn Time
☒ Standard
RUSH
☐ 1 Day
☐ 2 Day
☐ Other
(Rush turn times will incur a surcharge and must be pre-approved by lab.)

Sample ID/Description	Collection Information: Date	Time	Grab / Composite	Matrix	Container: Quantity	Type P=Plastic, G=Glass, V=Vial	Pres. HCl, HNO_3, H_2SO_4, NaOH, $Na_2S_2O_3$	Requested Tests: E coli									Comments
Rock 1	6/4/08	10:15am	G		1	P		✓									
Rock 2	6/4/08	11:05am	G		1	P		✓									
Rock dup	6/4/08	11:05am	G		1	P		✓									

	Relinquished by	Date/Time	Received by	Date/Time
1	Shawn Est	6-4-08/ 11:40am	Kathy Lane	6-4-08 11:40A
2				
3				

Field Notes:

Received at lab on ice? ☑ Yes ☐ No Temp: 15.3 C

All samples submitted to Sherry Laboratories for analysis are accepted on a custodial basis only. Ownership of the material remains with the client submitting the samples. Sherry Laboratories reserves the right to return unused sample portions.

9301 Innovation Drive, Suite 125
PO Box 569
Daleville, IN 47334-0569
765-378-4103
Fax: 765-378-4109

629 Washington St.
Suite 300
Columbus, In 47201
812-375-0531
Fax: 812-375-0731

2121 E Washington Blvd..
Fort Wayne, In 46803
260-424-1622
Fax: 260-442-9124

560 South Zimmer Road
P.O. Box 1849
Warsaw, IN 46581-1849
574-267-3305
Fax: 574-269-6569

2417 W. Pinhook Rd
Lafayette, LA 70508
337-235-0483
Fax: 337-233-6540

2129 Willow Street
Scott, LA 70583
337-232-3568
Fax: 337-232-3621

HERRY Laboratories
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Sherry Laboratories - Chain of Custody Record

Laboratory Number:

Client Information:		Billing Information:		PO Number:	Project Name/Number:	Page 1 of 1
Company Name:	JFNew	Same			Rock Lake 070772	**Matrix Code**
Contact Name:	Sara Peel			Quote Number:		DW = Drinking Water WW = Waste Water GW = Ground Water
Address:	705 Roosevelt Road				Sampler's Signature: Sara Peel	AQ = Aqueous OT = Other SL = Sludge SOL = Solid O = Oil SO = Soil
				Required QC Level		F = Food SW = Swab NG = Natural Gas
City, State Zip:	Walkerton IN 46574					NGL = Natural Gas Liquid PW = Produced Water
Phone Number:	574-586-3400 Ext: 341		Ext:	Bill Monthly	Shipping Method:	CF = Completion Fluid
Fax Number:	574-586-3446			☑ Yes	UPS / FedEx / ~~Airborne~~	
E-mail Address:	Specrayjfnew.com			☐ No	DHL / Sherry / Hand / Mail	

Which Regulations Apply:
☐ RCRA ☐ Drinking Water
☐ POTW ☐ Distribution
☐ NPDES ☐ Special
☐ USDA/FDA ☐ State
☐ RECAP/RISC ☐ Other

Turn Time
☒ Standard
RUSH
☐ 1 Day
☐ 2 Day
☐ Other
(Rush turn times will incur a surcharge and must be pre-approved by lab.)

Sample ID/Description	Collection Information: Date	Time	Grab / Composite	Matrix	Quantity	Type P=Plastic, G=Glass, V=Vial	Pres. HCl, HNO_3, H_2SO_4, NaOH, $Na_2S_2O_3$	E. coli									Comments
Rock 1	6/4/08	10:15am	G		1	P		✓									
Rock 2	6/4/08	11:05am	G		1	P		✓									
Rock dup	6/4/08	11:05am	G		1	P		✓									

	Relinquished by	Date/Time	Received by	Date/Time
1	Shawn Est	6-4-08/ 11.40am	Kathy Lane	6-4-08 11:40A
2				
3				

Field Notes:

Received at lab on ice? ☑ Yes ☐ No Temp: 15.3 C

All samples submitted to Sherry Laboratories for analysis are accepted on a custodial basis only. Ownership of the material remains with the client submitting the samples. Sherry Laboratories reserves the right to return unused sample portions.

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Fax: 765-378-4109

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Suite 300
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812-375-0531
Fax: 812-375-0731

2121 E Washington Blvd..
Fort Wayne, In 46803
260-424-1622
Fax: 260-442-9124

560 South Zimmer Road
P.O. Box 1849
Warsaw, IN 46581-1849
574-267-3305
Fax: 574-269-6569

2417 W. Pinhook Rd
Lafayette, LA 70508
337-235-0483
Fax: 337-233-6540

2129 Willow Street
Scott, LA 70583
337-232-3568
Fax: 337-232-3621

Depth	POTPEC	CERDEM	FILALG	CHARA	X_COOR	Y_COOR
4	1	1			585968.256	4543970.624
7					585901.305	4543996.456
5		1			585896.247	4544048.925
4	1				585915.237	4544100.060
4					585859.765	4544126.709
9			p		585771.747	4544138.545
4	1				585776.574	4544154.465
6	1		p		585755.169	4544180.795
4	1			1	585720.447	4544240.731
5					585658.324	4544295.221
8		1	p		585567.003	4544332.827
10	1				585585.069	4544248.229
9	1				585636.772	4544205.916
8					585671.500	4544209.287
6					585605.875	4544130.467
5					585639.806	4544082.320
6	1	1			585665.431	4544020.606
10					585706.067	4544033.834
4	1				585705.311	4543950.628
7					585734.306	4543924.741
7	1				585771.709	4543887.515
8					585819.517	4543901.836
6					585810.196	4543859.504
7					585799.448	4543813.777
4	1				585754.017	4543748.546
7					585756.549	4543718.696
8	1				585769.068	4543689.847
3					585784.334	4543625.007
3					585837.770	4543603.405
5		1			585875.548	4543603.915
4					585941.867	4543630.955
5	1				585950.186	4543657.869
10			p		585906.811	4543674.962
4					585969.162	4543714.850
7					586020.492	4543761.902
3					586030.536	4543754.999
6					586044.409	4543794.982
5					586061.374	4543856.952
7	1				586070.731	4543908.909
4	1				586047.503	4543933.210
5					586013.136	4543950.688

APPENDIX D:

PUBLIC MEETINGS

ROCK LAKE DIAGNOSTIC STUDY REPORT
KOSCIUSKO AND FULTON COUNTIES, INDIANA

JFNew

Appendix D- Public meeting Summary

1) A public meeting was held on May 10, 2008 to formally introduce the project to the general membership of the Rock Lake Conservation and Improvement Club. The presentation was conducted by Sara Peel of JFNew to 16 members of the club. A survey (attached) was handed out at the meeting to engage the members in a discussion about their lake. The number one problem identified at the meeting was the over abundance of vegetation.

2) A Public meeting was held June 10, 2009 to report on the draft Diagnostic Study. Approximately 20 people attended the annual meeting of the Rock Lake Conservation and Improvement Club. JFNew went through the results of the study and held discussions about some of the topics. The club members are satisfied with the present condition of the lake which is primarily used for fishing. They were asked to treat a small patch of Phragmites on the northeast corner of the lake and keep an eye out for purple loosestrife and Eurasian water milfoil. It was agreed that additional LARE funding would not be sought due to the fact that there really wasn't any significant projects identified that would help improve the water quality of Rock Lake. The residents were informed about the IDNR-Engineering branch's concern on the dam and one of the members offered to assist IDNR with verbal details on the initial construction of the dam. Their name was passed to Dave Nance at IDNR for follow-up. It was agreed that the members would pursue the issue of oiling goose eggs to control their population. The group was also informed about the high quality woodlot across the lake (west side) and in my opinion, its potential for a nature preserve. Apparently one landowner owns the majority of property on the west side of the lake.

5/10/08

ATTENDANCE LIST

NAME	ADDRESS (PLEASE PRINT)	PHONE	EMAIL
LARRY MONTGOMERY	1115 LENNOX ST ANDERSON		
Ed Horning			
Charles Miller	Box 522	574-893-4570	cemillere mac.com
also David Osborn	Snelleville, IN.		
" Scott Miller	New Palestine, Ind.		
Bob Ward	3701 IRONWOOD WAY	ANDERSON, IN 46011	
Ellen Ward	"	"	
JIM & DEBBIE BOLDEN			
Matt Kendall	12385 S. ST. RD. 13	North Manchester IN 46962	
BRUCE & CHRIS MCNEILLEILEY	450 CLYDE AV.	CALUMET CITY IL 60409	
DARRAL & JUDY McNEILLEY	1198 S. LAKESHORE		
Les & Mary Whitesel	1208 S. Lakeshore Dr.	AKRON	

Rock Lake Watershed Diagnostic Study
Preliminary Meeting
May 10, 2008

The following are questions to consider regarding Rock Lake. The questions are only meant to stimulate thought and generate conversation. We do not need to address each question at the meeting. Some may not be relevant to Rock Lake. Additionally, residents will have differing opinions on the severity of different problems. Each opinion is important to us. Our (JFNew's) goal with this introductory meeting is to learn about the lakes from those who spend the most time on it (you!) and understand your perceptions of the lakes.

Miscellaneous:
1. What is the #1 problem on the lake?

2. What are problems #2-5?

3. Were there any historical problems that are no longer problems?

4. If you could change one thing about your lake, what would it be?

Water Clarity/Quality:
1. In your opinion, has the lake's water clarity been improving, declining, or stayed the same over the past several years? Do you have any thoughts on why it has been improving or declining?

2. Is the lake's water clarity worse at certain times of the year (i.e. summer, fall, spring)? After rain storms? After heavy boating use?

3. Is the water clarity worse in certain parts of the lake?

Fishing:
1. Has the fishing been improving, declining, or stayed the same over the past several years? Do you have any thoughts on why the change has occurred?

2. Has there been any recent stocking? What has the residents' response to stocking been?

3. What do most people fish for (in your opinion)?

Recreation:

1. Is crowding/overcrowding a problem? When is it a problem?

2. Is there a problem with boat speed?

3. Are there user conflicts?

Erosion/Sedimentation:

1. Are there shoreline erosion problems? Where?

2. Is there an accumulation of sediment in any parts of the lake? Where?

3. Are any of the streams around the lake a problem?

Bonus:

1. What do you hope to get out of this diagnostic study?

APPENDIX E:

BROCHURE

ROCK LAKE DIAGNOSTIC STUDY REPORT
KOSCIUSKO AND FULTON COUNTIES, INDIANA

JFNew

Understanding Your Watershed:

- ★ Rock Lake lies in the Headwaters of the Mississippi River Basin. Water flows from Rock Lake north to the Tippecanoe River and then southwesterly to the Wabash and Ohio Rivers.
- ★ Rock Lake receives water from two primary tributaries, Lautzenhizer Drain and Landis Drain. Lautzenhizer Drain begins at Lost Lake and flows through Mud Lake before entering Rock Lake. Landis Drain begins in farmland 3/4 mile east of the lake.
- ★ The Rock Lake watershed encompasses 1818 acres (2.8 square miles) within Kosciusko and Fulton Counties.
- ★ The drainage area (Watershed) of Rock Lake is just over 30 times the size of the lake.
- ★ Land use within the watershed is:

Crop Land	50%	Open water	5%
Grassland	20%	Wetland	6%
Forest	18%	Residential	1%

- ★ Three major soil associations including Kosciusko-Ormas loamy sands, Morley-Blount-Pewamo silt loams and Houghton-Palms muck soils dominate the Rock lake watershed.
- ★ 92% of the soils in the watershed are severely limited for use as septic tank absorption fields.
- ★ About 30% of the soils in the Rock Lake watershed are highly erodible.
- ★ While 141 Rare, Threatened, or Endangered species have been recorded in Fulton and Kosciusko Counties only one state threatened species has been documented in the Rock Lake Watershed, a plant by the name of Green-keeled cotton-grass.

For additional information on how to keep your lakes and watershed clean and healthy contact:

Lake and River Enhancement Program
Indiana Department of Natural Resources
(IDNR) Division of Fish & Wildlife
402 West Washington Street Room W273
Indianapolis, Indiana 46204
(317) 233-3871
www.in.gov/dnr/fishwild/l2364.htm

Fulton County
Soil and Water conservation District
1252 E 100 S , STE D
Rochester, IN 46975-8036
(219) 223-3220
http://www.fultonswcd.com

Kosciusko County
Soil and Water Conservation District
217 E. Bell Drive
Warsaw, IN 46582
(574) 267-7445 ext. 3
http://www.kosciuskoswcd.com

This pamphlet was produced by:

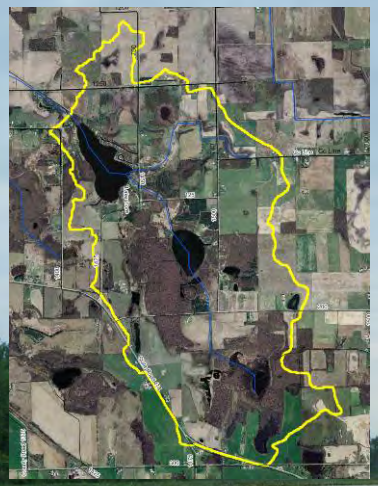
JFNew

708 Roosevelt Road
Walkerton, Indiana 46574
(574) 586-3400

If you have any questions regarding the study or pamphlet, please contact JFNew.

Rock Lake Diagnostic Study

Fulton / Kosciusko County



The study purpose was:

- ★ **Evaluate historical trends in the lake's water quality**
- ★ **Describe the existing condition of the lake and its watershed**
- ★ **Identify problems and make recommendations to address these problems**

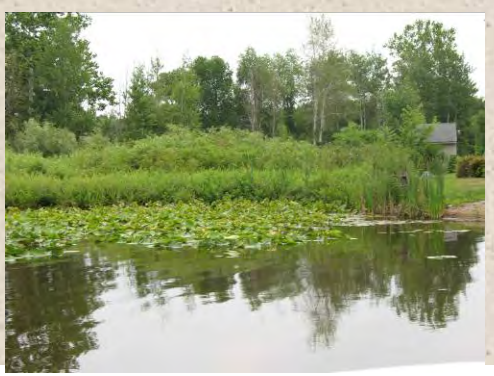
Rock Lake:

- ★ Rock Lake is a 56 acre impounded Lake in northern Indiana.
- ★ Rock Lake has had stable water clarity at 2 feet since 1976.
- ★ Phosphorus cycling in the lake is driving the aquatic plant and algae growth which controls the clarity of the water.
- ★ Water that flows into Rock Lake stays an average of 2 months before exiting. This "residence time" is relatively short and means water quality can be affected more by changes in watershed land use than by activities within the lake.
- ★ Rock Lake's relatively large watershed area to lake area ratio (30:1) suggests actions taken in the watershed can have a significant impact on the lake's health. Thus, management of landscape influences water quality more than in-lake actions.
- ★ Rock Lake has a maximum depth of 16 feet, with water levels controlled by a small low head dam at the outlet.
- ★ Approximately half of Rock Lake is less than 5 feet deep and supports rooted aquatic vegetation.
- ★ The rooted vegetation includes white water lily, pond lily, sago pondweed, coontail, and *Chara* (a bottom dwelling algae).
- ★ Rock Lake is highly productive (Eutrophic) due to high nutrient concentrations.

- ★ Rock Lake supports a healthy population of panfish and largemouth bass as well as at least 16 other fish species.
- ★ Lautzenhizer Ditch drains 1,127 acres (62% of watershed) and Landis Ditch drains 339 acres (21.4% of watershed)
- ★ At the time of sampling, Lautzenhizer and Landis Drains had higher nutrient concentrations compared to other Indiana streams during base and storm flow.

How to Manage the Lake:

Both in-lake and watershed management will be necessary to improve the lakes' water quality. Focus on personal actions and activities and how they might influence the lake.



Management Actions:

In-Lake Recommendations:

- ★ Monitor and control invasive species.
- ★ Reduce Phosphorus loading to the lake by 508kg/yr (77% of existing load).

How to get there:

- ★ Repair drain tile and install streamside buffers at upper end of Landis Ditch (photos).
- ★ Reduce the populations of Canada geese around the lake.
- ★ Work with DNR on potential carp control.
- ★ Implement homeowner best management practices spelled out below.

Upper end of Landis Ditch

What You Can Do:

- ★ Use phosphorus-free fertilizer.
- ★ Maintain septic systems annually.
- ★ Use only rock or native vegetation to protect shorelines from erosion.
- ★ Keep lawn clippings, leaves, and animal waste out of the water.
- ★ Harvest only the necessary and legal area (625 sq. ft. without a permit) of aquatic plants for your enjoyment of the lake.