An Analysis and Comparison of
the Chemistry and Biota of Three Strip
Mine Lakes in Spencer County, Indiana

A Senior Studies Report

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INTRODUCTION

Strip mining for coal is a relatively simple process, in theory. First, the land is explored - by either drilling the terrain for coal deposits or by "excavating shallow trenches or pits to expose the ore" (Doyle, 1976, p.4), and the presence of coal is determined. Once coal is found, the topsoil and rock are removed and deposited to the side of the area to be mined. The first cut is made and the coal is removed.

After all the desired mineral is extracted, a second cut is made parallel to the first. The spoils, or overburden, are placed in the first cut, and the coal of the second cut is removed. This process is continued in this fashion until the final cut is made. After the final cut has been made, a trench, the depth of the overburden and coal layer, remains behind; the trench is bound by the last cut and by the undisturbed tract of land - directly next to the mined area.

After the coal has been extracted, piles of spoil material remain. There is no definite contour to the land, and when precipitation occurs, water runs off the spoils and into depressions and unfilled cuts. Water begins to accumulate, and lakes begin to form.

The strip mine lakes studied were mined in such a way; however, strict federal law - first implemented in 1977 - required a change in coal mining procedures. As a result, the top soil and rock are removed (individually) and placed in separate piles. After the coal is extracted, the topsoil and rock are returned to their respective places. Trees, grass, and farm crops are then grown on the land.

Within the strata that lie above the coal layer are minerals called pyrite and marcasite. Prior to 1977, when the spoil material was placed in the open pit of the previous cut, the spoils were inverted - exposing the pyrite and marcasite to the atmosphere. When oxygen and water contact these two substances, two reactions occur.

First, iron sulfide, present among pyrite and marcasite, reacts with the water and oxygen to produce sulfuric acid:

$$2FeS_2 + 7O_2 + 2H_2O \text{ -----> } 2FeSO_4 + 2H_2SO_4$$

The products of this reaction react again, in the presence of atmospheric oxygen and bacteria, to produce ferrous sulfate:

$$4FeSO_4 + 2H_2SO_4 + 7O_2 \text{ -----> } 2Fe(SO_4)_3 + 2H_2O$$

These reactions produce an acidic by-product from the spoil materials which pollutes the water of the strip mine lakes.

Indiana Strip Mining

Most of Indiana is void of coal deposits (DOR, 1993). However, the southwestern section of the state contains a large amount of minable coal. Due to the need for electricity, southwestern Indiana's coal resources were first tapped in the middle 1800's. Deep mining occurred, but strip mining soon became the predominant method for mining coal.

However, no laws had been passed to regulate methods of coal mining. As a result, coal mining companies failed to reclaim the land that they had mined (Allen et. al., 1978). Many acres of unusable, unreclaimed land increased each year. "As a result the State of Indiana passed a law in 1941, requiring the planting of trees on spoil banks" (DOR, 1993, p.2). This forced the coal mining companies to reclaim the land that they had mined.

A 1967 revision in Indiana's reclamation law required coal mining companies to reclaim the land further by planting "farm crops, hay and grasses on mined land" (DOR, 1993, p.2). The law also required the companies to bury the acid forming materials. Areas reclaimed for the purpose of farming "were to be accessible by farm machinery" (DOR, 1993, p.2). This law upset many a coal mining company, but it aided in the preservation of the land.

In 1977, a federal law was passed - placing even more stringent requirements on reclamation laws. In addition to Indiana law, the new federal law required the coal mining companies to restore the land to its pre-mining condition; this required the companies to replace the underlying strata and topsoil to their proper places (DOR, 1993; Allen et. al., 1978). "Because of the diverse mining conditions in the United States, Congress intended that the states become the primary regulator" (DOR, 1993, p.3) of mining procedures and laws concerning reclamation. In 1982, the State of Indiana Division of Reclamation gained "primacy" and administered the mining law - modified to incorporate new federal requirements (DOR, 1993; Dieter, 1984). Later, in 1982, a project was also begun to restore old abandoned mine sites to their pre-mining condition (Dieter, 1984).

As of 1993, 87% of the electricity used in Indiana had been provided for by coal alone. Most of this coal was mined in southwestern Indiana, a small portion of the Illinois Coal Basin - "one of the largest coal fields in the United States" (DOR, 1993, p.3). Of all the coal-producing states, Indiana ranks tenth - with approximately 30 million tons of coal mined each year.

Nearly 95% of coal mined in Indiana is extracted by way of surface mining, with Warrick, Pike, Daviess, and Greene counties producing the most coal. However, it is foreseen - in the near future - that mining in Indiana will take a major swing from surface mining to deep mining, for "90% of Indiana's remaining recoverable resources are feasible to be mined only by underground mining methods under current technology" (DOR, 1993, p.4). As a result, mining in the afore-mentioned counties will quickly die out, while mining in Sullivan, Gibson, Posey, and Knox counties will become dominant.

Study Area

The area studied (Figure 1) is located in Harrison Township of Spencer County, IN (T4S, R4W, SW 1/4 Section 7, NW 1/4 Section 18) and north of U.S. 460 (Indiana Highway - 62). There are 165.23 Acres of land on the property (Figure 2). Four lakes have been used for study: Lakes I, II, III, and - later added - Lake IV. The area had originally been strip mined between the years of 1937 and 1942. However, Breidenbach indicated that additional strip mining had occurred between the years of 1980 and 1983 (Breidenbach's notes inferred that mining had not been completed by the time he had finished his study of the area in May, 1983). The Indiana Office of Reclamation verified strip mining in the area as late as 1984 and 1985. As a result, some of the more recent mining altered the recovery processes of the lakes already present.

Previous Studies

In 1972, Michuel Coe studied the physico-chemical characteristics and biota of strip mine Lakes I, II, and III (Figure 3) - located on the property of Mr. Robert Davis (Appendix II). Coe reported the presence of access roads expanding throughout the area among the lakes present. He also observed the presence of a dam on the northeastern-most arm of Lake I. He noted that Lake I received drainage from nearby spoil banks and farmland. He also reported the presence of a small seasonal 'overflow channel' between the northwest arm of Lake III and another, smaller lake located northwest of Lake III. Lake III was also noted as receiving runoff from nearby spoil banks and farmland; runoff entered the lake from the southern tip of the lake by way of a 'seasonal stream'. Furthermore, Coe reported that Lake III had been successfully stocked with fish.

Figure 1. Topographic map of study area for Lakes I, II, III, and
(Dale Quadrangle - 1961)

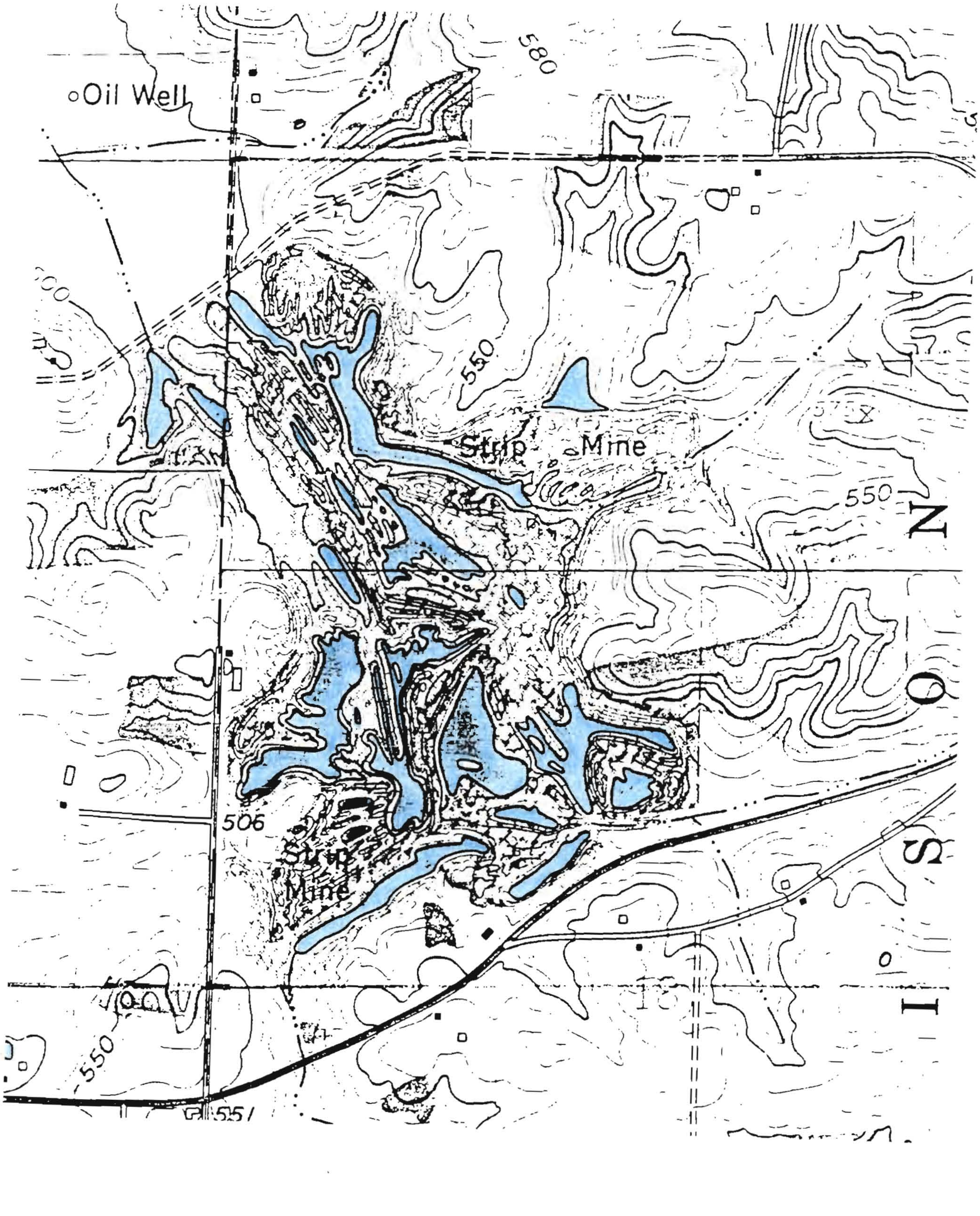

Oil Well
580
550
Strip Mine
550
506
Strip Mine
550
551
N
O
S
I

Figure 2. Area photograph of strip mined area. (1994)

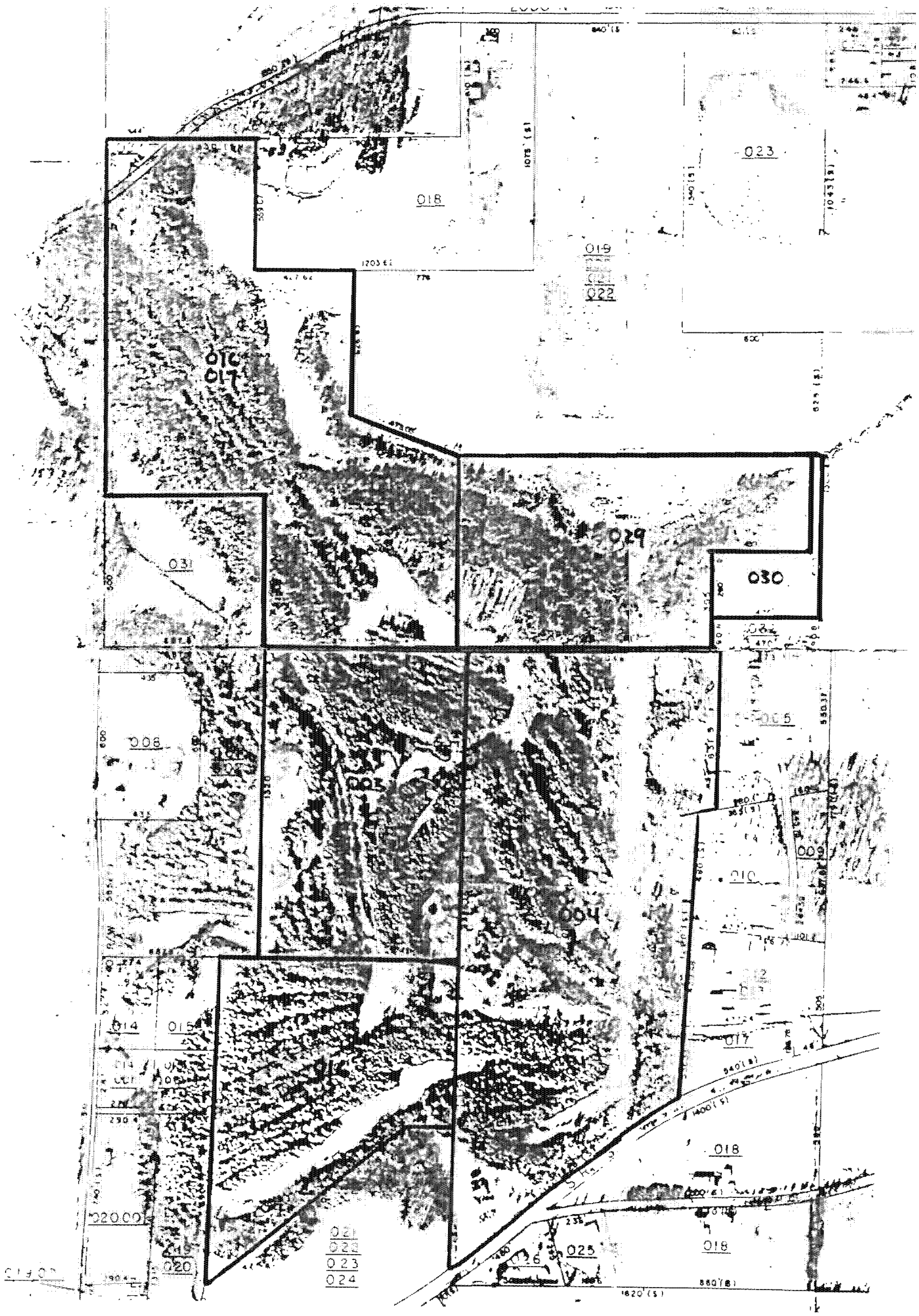
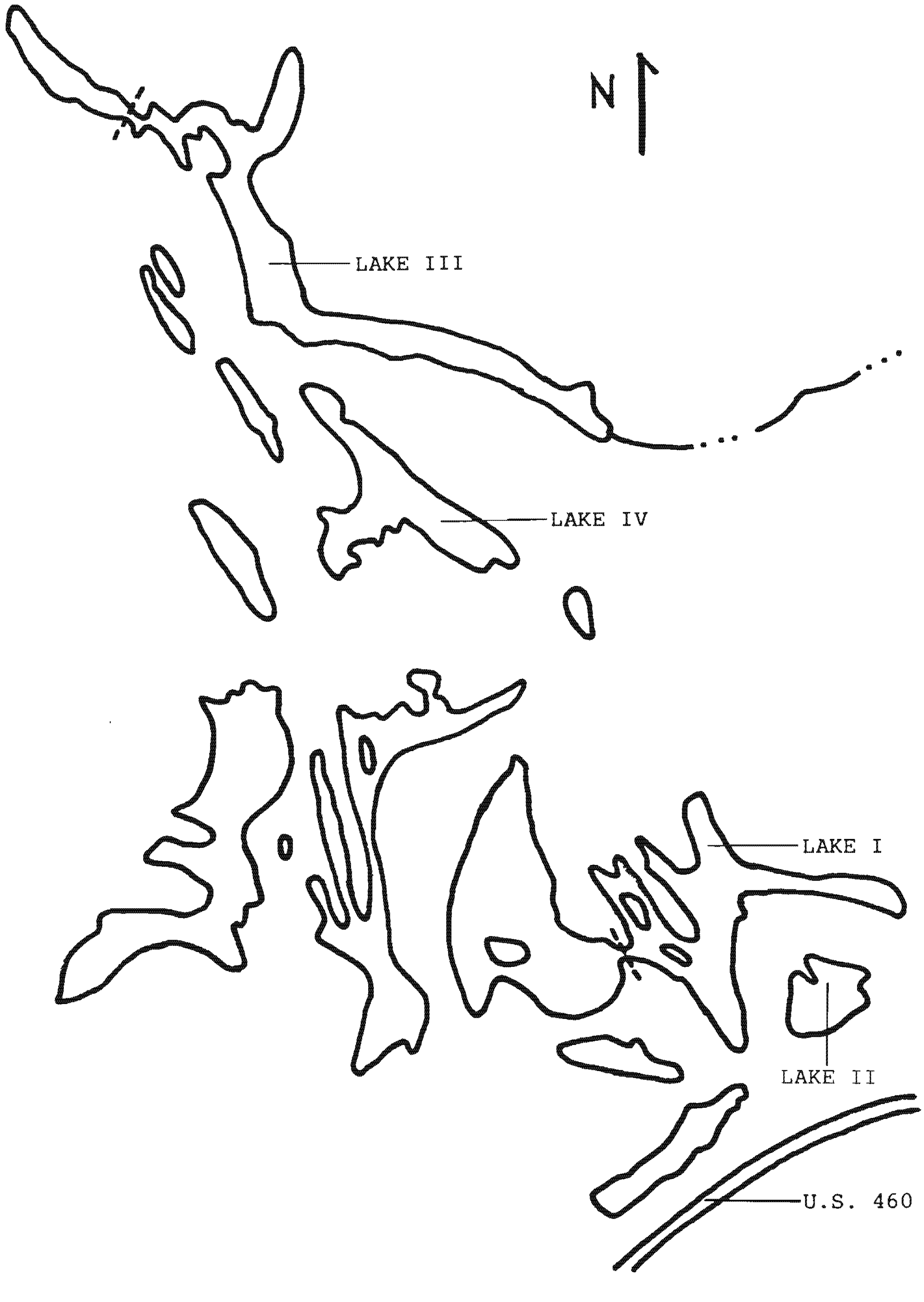

018
023
019
022
016
017
029
030
031
008
003
004
005
010
009
014
015
018
025
020
021
023
024

Figure 3. Identification of the four strip mine lakes.


N
LAKE III
LAKE IV
LAKE I
LAKE II
U.S. 460

In 1975, three studies were performed upon the strip mine lakes. Tom Gladieux focused on sulfates and pH as limiting factors in the soil, water, and benthos in the three lakes. Tim Dougal focused on broadening the information known about zooplankton and invertebrate populations within the lakes, and Greg Ernstberger studied the phytoplankton populations in the strip mine lakes. Gladieux noted access roads crossing the northeastern-most arm of Lake I and the southern tip of Lake III. The access road crossing the northeastern-most arm of Lake I was present in 1972, but the addition of the access road upon Lake III had been made since Coe's study; the access road on Lake I was constructed over a man-made dam.

Gladieux (1975) had also noted the 'seasonal stream' (feeding into Lake III) that Coe had reported three years earlier. Gladieux noted that a drainage pipe had been purposely placed under the roadway so that water flow from the stream into Lake III could continue. He also reported the presence of a metal cable, six inches below the water surface of the northwestern-most arm of Lake I. The cable had been stretched taut; the reason for this is unknown (the metal cable no longer exists). Finally, Gladieux reported the presence of trailers, small cottages, and crude dwellings along the shores of Lake III - though no permanent dwellings had been erected (Ernstberger indicated the presence of campsites along the shores of Lakes I and III as well). By analyzing Ernstberger's (1975) notes and inferring from them, these dwellings were probably a direct result of the development of the land for recreational use in 1974 and 1975.

This development of the land resulted in adverse effects on the lakes. By manipulating and moving the spoil materials and overburden along the lake shores, the potential for newly exposed spoil material to react with atmospheric oxygen and water increased. As a result of these actions /

reactions, there was an increase of acidic runoff into the lakes, causing an increase in the acidic concentration of the water. In the final analysis, the disturbance of the spoil materials created a setback in the recovery processes of the lakes (thus, lower pH readings than what Coe had originally indicated). [Dougal did not offer any notes / observations that did not coincide with Gladieux and Ernstberger.]

In 1981, Mark Toth studied the lakes for diatom populations and calcium / silicon concentrations. However, as Breidenbach (1983) indicated, Lake II had been filled in (between the years of 1975 and 1980). Two other lakes were added to the study: Twin Lakes North and South. These four lakes were studied and compared. Unfortunately, Toth did not record any observations of the area studied.

Between 1980 and 1982 the southeast arm of Lake I, the northeast arm of Lake III, and part of the southern tip of Lake III were filled in with spoil material from additional strip mining; the east shore of Lake III was also pushed westward with the overburden of the additional strip mining. Spoil material, and the products caused by oxidation reactions, seeped into the lakes; these actions caused an increase in the acidic concentrations of the lakes. Later, *Energy Supply Inc.* erected a service building east of Lake I. Materials from the production taking place there have leached into Lake I; farmland is still a source of runoff into Lake I. However, since E.S.I. has erected the building, the pH level of Lake I has risen from an acidic to alkaline level.

After Lake II was filled in, Lake IV was introduced into the study in 1982. Lake IV is located south of Lake III (Figure 3). Twin Lakes North and South were included in the next study (1983). Lakes I, III, IV, Twin Lake North, and Twin Lake South were studied by John Breidenbach. His study focused on the presence of zooplankton and the physico-chemical characteristics of the five lakes.

Breidenbach (1983) noted the presence of mining activity around Lakes I and III. He claimed that the mining had adverse effects on the recovery processes of the lakes. He also noted a decrease in the depths of Lakes I and III. This Breidenbach attributed to the "high degree of eutrophication" (1983, p.58) that had previously occurred and to the present occurrence of mining in the area. Breidenbach also indicated that recreation on the premises had been terminated because of misuse of the land; trash had been dumped and left behind.

Breidenbach (1983) had also sketched out the basic shapes of the three strip mine lakes. Comparing these drawings to Coe's, the changes in the lakes over the short period of time can easily be seen. Figure 4 shows the two sketches of Lake I adjacent to each other: by 1983, the southeast arm had been filled in (Figure 4c); meanwhile, Coe's (1972) sketch of Lake I indicates the presence of the southeast arm (Figure 4b).

Figure 5 illustrates the changes that have taken place in Lake III: Breidenbach (1983) shows that the southern tip and the northeast arm of the lake had been filled in (Figure 5b); however, Coe's (1972) sketch of Lake III does not show any such alterations (Figure 5a). Furthermore, Breidenbach (1983) made a sketch of Lake IV (Figure 5c). However, since his study was the first to include lake IV, no previous sketch exists. As a result, no comparisons can be made with previous studies.

<u>Current Study</u>

Lake IV appears to have undergone the most physical change. The two islands present in Breidenbach's (1983) sketch (Figure 5c) no longer appear

Figure 4. a. Topographic map of Lakes I, III, and IV.
b. Lake I in 1972.
c. Lake I in 1983.

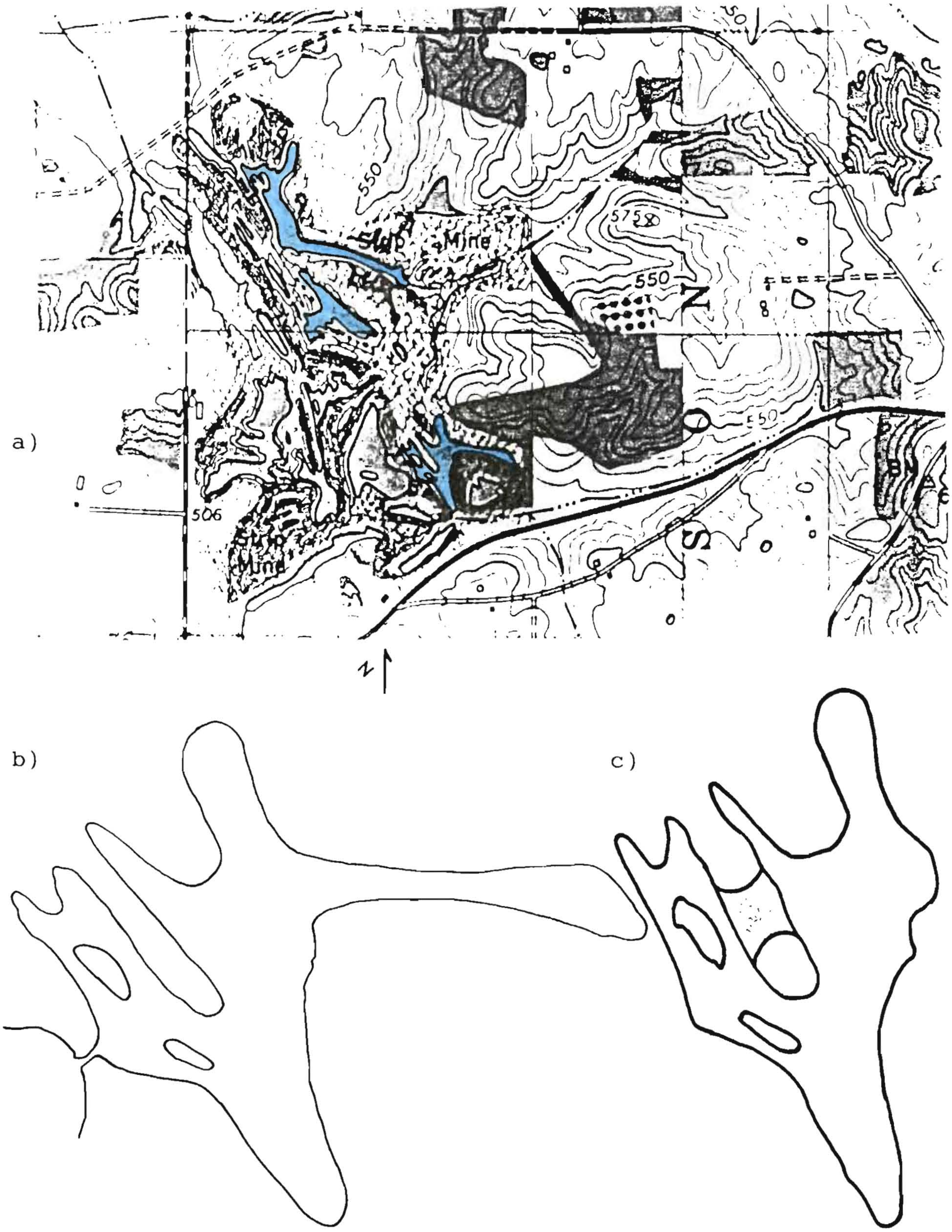
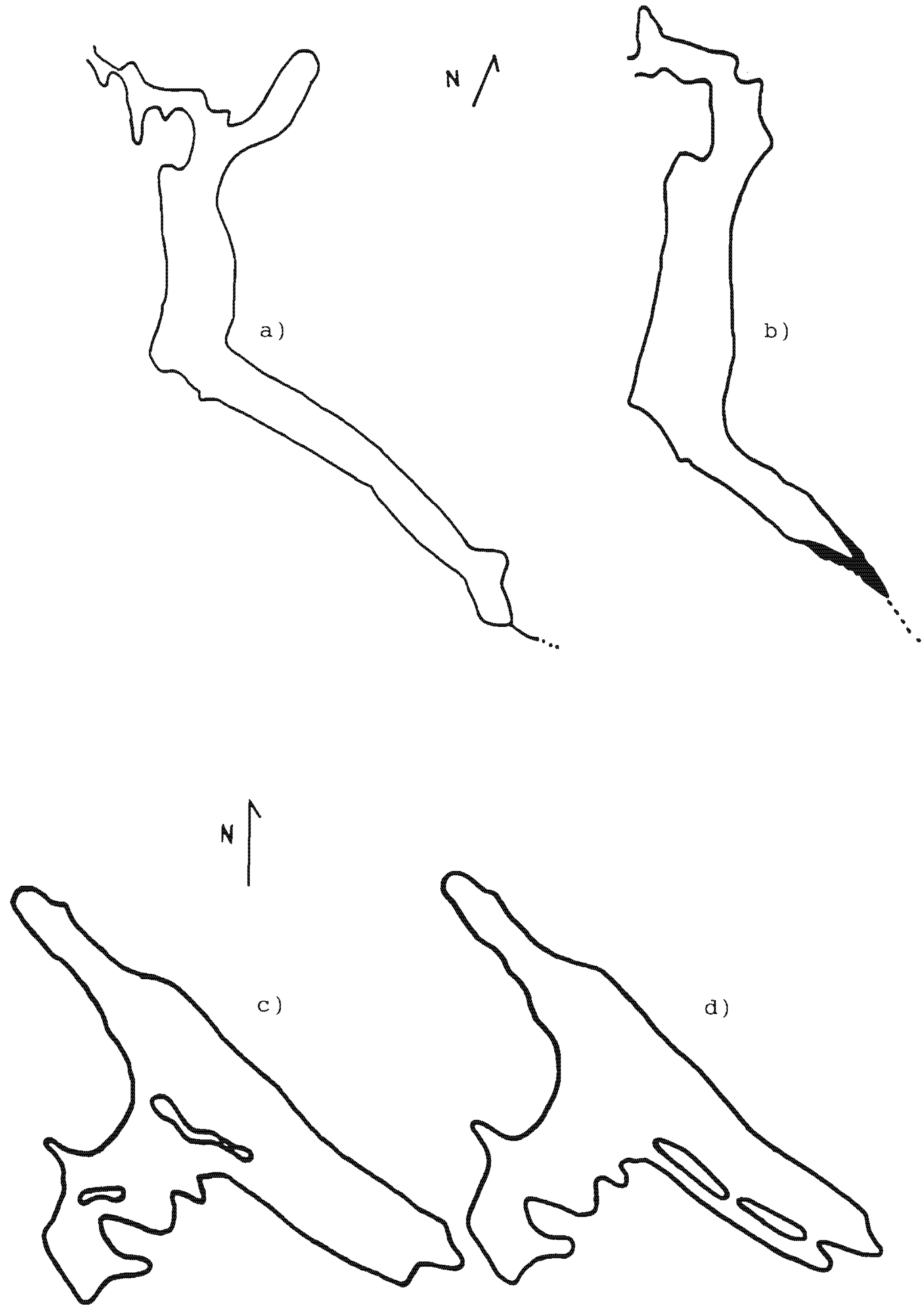

a)
550
575
Mine
550
550
506
Mine
N
b)
c)

Figure 5. a. Lake III in 1972.
b. Lake III in 1983.
c. Lake IV in 1983.
d. Lake IV in 1996.


N
a)
b)
N
c)
d)

as he had drawn them. The southern-most island no longer exists and the longer island northeast of the first has slowly eroded and become two individual islands (Figure 5d); it appears that Breidenbach had drawn the northern-most island too far west. A permanent dwelling was also constructed on the northeast shore of the lake; this house is located due south of the southern tip of Lake III. A dock was constructed west of the house. The remains of an old shed and a pile of trash were also observed west of the house.

Southeast of the house - across Lake IV - lay an old, collapsed shed; inside was the remains of a bed. West of this shed was a deteriorating dock. Southeast of Lake IV stood a one-room building; if it had been completed, this structure would have become a permanent shelter (however, it would not have been large enough to be considered a house). Furthermore, a 'seasonal stream' was observed at the northwest tip of the lake. A trail, or pathway (Appendix I), crossed over the tip of the lake. A drainage pipe had been placed under the pathway so that the flow of water could continue. This 'seasonal stream' flowed north and seemed to serve as an over-flow valve for Lake IV. Other piles of trash were also observed along the shores of Lake IV.

Lake I seems to possess the most life of the three strip mine lakes. A green alga was observed on the surface of the lake in November, 1995; a small amount of the substance was again observed in April, 1996. The northeastern-most arm of Lake I was closely examined. The arm was very shallow and polluted with trash. A large tractor tire, a discarded sink, several metal barrels, a John-Boat, and some plastic remains - which had blown over from E.S.I. - lay upon the shore and in the water itself.

Coe (1972) had indicated an access road and a man-made dam at the tip of the northeastern-most arm of Lake I. However, the access road now fails to entirely cross the tip of the arm. A small stream flows from the dam - northward; this helps serve as an overflow for the lake. A board, however, has been placed across the open area so that people might access the property by foot.

Trash had accumulated at the tip of the northeastern-most arm of Lake I; most of this appeared to have been the remains of wind-blown items belonging to E.S.I. Trash was also abundant among the land masses between each arm of Lake I. A small shed and two permanent dwellings were seen upon the land mass between the two northeast arms. Furthermore, a very large collection of used plastic products lay behind E.S.I. The ground is slightly sloped toward Lake I, and runoff from the plastic drains into the lake from the east shore. The runoff must have some effect on the concentration of the water, for the most recent pH reading indicate that the recovery rate of Lake I has surpassed the recovery rates of the other two. The drainage of water into the lake - from E.S.I. - would offer the best explanation.

Lake III (Figure 5b) appears to have undergone the least change of the three strip mine lakes. A natural dam has begun to form at the entrance to the northwestern-most arm of the lake. Twigs, branches, and mud have collected and begun to regulate water flow to the northwest arm. Furthermore, the access road - reported to have crossed the southern tip of Lake III by Gladieux in 1975 - no longer exists. The access road has been removed, and the stream flows into the lake.

Runoff had been observed flowing into Lake III in several places. Breidenbach (1983) had indicated that the northeast arm and southern tip of the lake had been filled in by additional strip mining in 1982. However, it appears as if water drainage from nearby farmland - to the east of the lake - runs across some of the exposed strata from the previous mining and drains into the lake. The results of such occurrences cause adverse effects on the water concentration and recovery process of the lake.

Fish and other aquatic biota are present in all three strip mine lakes.

The purpose of this paper is to further examine the recovery of physico-chemical and biotic characteristics of three strip mine lakes in Spencer County, Indiana and to compare and contrast findings with data from previous studies.

MATERIALS AND METHODS

Data were collected from Lakes I, III, and IV on November 1, 1995, April 13 and April 27, 1995.

Biotic Analysis

All samples were collected November 1, 1995; sample slides were examined November 1-3, 1995. Plankton samples were collected by using a plankton towing net six inches in diameter, sixteen inches deep, 81 cubic inches in volume, and made of #20 standard silk bolting cloth. A glass vial (approximately five inches in height and one inch in diameter) was attached to the end of the tow net. The net was towed behind a ten-foot inflatable raft across each lake twice. The first tow was taken at a depth of 1 to 3 feet, and the second tow was made at a depth of 4 to 6 feet. Each tow roughly followed the path of the longest distance on each lake. A total of six samples were collected from the three lakes.

Upon returning to the lab, the vials were placed in darkness, stored on ice, and the container lids were loosened to help preserve the specimens. The next two and one-half days were spent examining the samples under the microscope. Using a pipette, a small amount of the sample was taken from near the bottom of the container and placed on a slide. Each slide was examined at 3.2x magnification for the most abundant view of specimens. Then, within this area, every specimen identifiable at 40x magnification was recorded. Organisms were classified as specifically as possible. Five slides were made and examined from each sample, and data from each lake were compiled.

Literature used in the process of identification and classification included: Ward and Whipple (1945, 1959), Needham and Needham (1970), Vinyard (1974), Berk and Gunderson(1993), and Grell (1973).

Chemical Analysis

Water samples were taken on April 13, 1996 for chemical analysis. In the lab the water was tested for pH, dissolved oxygen content, calcium hardness, total hardness, copper, cyanide, total iron, phosphorus, potassium, silica, sulfates, and sulfides.

Two, one-half gallon (1.89 liters) samples were taken from the center of each lake. A weight was attached to each sample container and lowered into the water. When the sample was brought to the surface, it was capped and placed in a cooler partially filled with ice. A total of six samples were placed in the cooler.

Dissolved oxygen was determined for Lake IV by means of the Winkler Method; two tests were made for Lake IV. The average of the two dissolved oxygen readings was calculated and recorded; both tests recorded a dissolved oxygen content of 10.6 mg/L. Tests for Lakes I and III were made using a Hach Corporation Dissolved Oxygen Meter calibrated for 10.6 mg/L. Tests for pH were made at this same time. The Winkler Method is necessary to more accurately calibrate the dissolved oxygen meter.

Calcium hardness and total hardness tests were made using a Hach Corporation test kit (Model HA-4P). All other tests were made using a Hach Corporation Portable Colorimeter / pH Meter (Model DR/1).

RESULTS AND DISCUSSION

Discussion of Chemical Analysis

It is difficult to determine trends over the years for each chemical analyzed in the current study because the past chemical studies were not as inclusive. Also, this is only the second project to analyze Lake IV. However, some significant changes and trends can be noted for several chemicals. Calcium, total iron, and total hardness are at higher levels than have ever been recorded in past studies (Table 1). The pH readings were also markedly higher in all three lakes, particularly Lake I.

It is very possible that at least some of these recent changes have been due to the reshaping of some of the surrounding land. Since 1985, the entire area has remained relatively undisturbed. However, in 1984 - 1985 some additional strip mining was done east of Lake III which may have affected the quality of water run-off to the lake. Furthermore, during 1980 - 1983 strip mining occurred near Lake III which filled in the southern tip and northeast arm of Lake III. In addition, the southeast arm of Lake I was filled in and a building was erected in its place by E.S.I. The result of all this seems to have been a contamination of the lakes from the spoils which significantly increased the acidic levels.

Prior to the first study, the owner was developing access roads to different parts of the lakes to make them more suitable for recreation. These actions disturbed parts of spoil banks which exposed pyrite and marcasite to atmospheric oxygen and moisture which resulted in an acid by-product that drained into the lakes. As a result, the pH of the lakes markedly decreased during the seventies. Then again, during the second mining effort, the pH

Table 1. Comparison of chemical analysis results.

	Lake I					Lake III					Lake IV	
	'72	'75	'81	'83	**'96**	'72	'75	'81	'83	**'96**	'83	**'96**
Arsenic (μg/l)	<10	-	-	-	-	<10	-	-	-	-	-	-
Copper (mg/l)	-	0.05	-	-	0.0	-	0.05	-	-	0.025	-	0.0
Cyanide (mg/l)	-	-	-	-	0.0	-	-	-	-	0.0	-	0.0
Iron, total (mg/l)	0.08	-	-	0.03*	0.27	0.66	-	-	0.037*	0.66	0.033*	0.2
Nickel (mg/l)	-	0.5	-	-	-	-	0.5	-	-	-	-	-
Phosphorus (mg/l)	-	-	-	-	0.2	-	-	-	-	0.6	-	1.4
Potassium (mg/l)	-	-	-	-	6.6	-	-	-	-	6.1	-	3.5
Silica (mg/l)	-	-	2.2	-	2.5	-	-	6.6	-	4.0	-	1.0
Sulfates (mg/l)	30.0	55.0	-	47.3*	75.0	275.0	95.0	-	110.0*	88.0	115.7*	70.0
Sulfides (mg/l)	<0.1	-	-	0.023*	0.02	<0.1	-	-	0.03*	0.025	0.027*	0.0
Calcium (mg/l)	29.0	-	25.0	15.0*	103	50.0	-	48.0	18.0*	103	16.0*	51.4
Magnesium (mg/l)	7.2	-	-	-	-	32.5	-	-	-	-	-	-
Total hardness (mg/l)	104.0	-	-	23.0*	171	260.0	-	-	26.0*	188	28.7*	120
pH	7.4	7.2	-	6.87*	8.48	7.0	6.9	-	6.8*	7.57	6.9*	7.56
dissolved O_2 (mg/l)	8.01	-	-	7.58*	10.8	6.82	-	-	7.18*	11.3	7.85*	10.6
temperature (Celsius)	18.7*	-	12.0	-	7.0**	18.4*	-	12.5	-	7.0**	-	7.0**
light penetration (ft)	11.75	-	7.0	6.0	-	2.75	-	5.0	2.0	-	7.0	-

* = average of multiple readings
** = temp. at time of testing

once again dropped. However, since the last disturbance, the acidic levels of all three lakes seem to have recovered to more normal levels.

Gladieux (1975) had stated that as pH levels increased, the sulfate concentration decreased as well as the inverse. However, from an examination of all the data available to date, this statement does not seem to be true. For example, in 1983 the pH of Lake I was 6.87 while the sulfate concentration was 47.3 mg/l. However, in 1996, the pH was 8.48 and the sulfate concentration was 75.0 mg/l. If his statement were true, then the concentration should have been significantly lower than 47.3 mg/l.

There does, however, seem to be a direct correlation between calcium and pH levels. Both levels seemed to increase and decrease at the same time as observed in each of the past chemical studies (Table I).

Survey of Plankton

The "quantity number" on Tables 2-4 represents the total number of specimens which were identified from the analysis of all the slides from that particular lake. "Common" denotes a moderate number (approximately 6-12) of specimens which were identified on at least one of the slides. "Abundant" denotes a large number (over 12) of specimens which were identified on at least one or more slides.

There were 37 genera of specimens identified from Lake I. Twenty-three new specimens were identified with respect to all previous reports. Nineteen new specimens of algae were identified with respect only to Ernstberger's (1975) report. There were 36 genera of specimens identified from Lake III. Twenty-three new specimens were identified with respect to all previous reports. Eighteen new specimens of algae were identified with respect only to Ernstberger's (1975) report. There were twenty-three genera

Table 2. Lake I Plankton.

I.	Algae		
	A.	Chlorophyta	
		1. Mougeotia	13
		2. Zygnema	7
		3. Hydrodictyon	7
		4. Protococcus	1
		5. Ankistrodesmus	3
		6. Richteriella	1
		7. Oedogonium	6
		8. Pleurodiscus	1
		9. Desmidiaceae	1
		10. Genicularia	1
		11. Chlorophyceae	common
	B.	Chrysophyta	
		1. Mastogloia	1
		2. Synura	5
		3. Gyrosigma	1
		4. Cyclotella	1
		5. Melosira	1
		6. Amphora	1
		7. Dinobryon	3
		8. Frustulia	1
		9. Diatoma	1
		10. Asterionela	1
		11. Synedra	1
		12. Chrysophyceae	abundant
	C.	Unknown Sample	
		1. (bright blue ribbon)	1
II.	Protozoa		
	A.	Rhizopoda	
		1. Amoebaea	common
	B.	Cilliata	
		1. Thuricola	7
	C.	Unknown Sample	1
III.	Crustacea		
	A.	Copepoda	
		1. Diaptomus	1
		2. Cyclops	1
		3. Limnocalanus	1
	B.	Cladocera	
		1. Daphnia	3
		2. Ceriodaphnia	1
		3. (unknown)	1
	C.	Ostracoda	
		1. Ostracod	1
IV.	Rotifera		
	A.	Monogononta	
		1. Keratella	3
		2. Trichocerca	2
	B.	(unkown)	1
V.	Calanoida		
	A.	Osphranticum	1

Table 3. Lake III Plankton.

I.	Algae			
	A.	Chlorophyta		
		1.	Penium	1
		2.	Hydrodictyon	2
		3.	Protosiphon	1
		4.	Oedogonium	1
		5.	Chara	1
		6.	Closterium	1
	B.	Chrysophyta		
		1.	Xanthophyceae	1
		2.	Chrysophyceae	common
		3.	Ophiocytium	1
		4.	Pinularia	1
		5.	Nitzschia	4
		6.	Amphiprora	1
		7.	Diatomaceae	3
		8.	Stephanodiscus	1
	C.	Phyrrophyta		
		1.	Ceratium	4
	D.	Euglenophyta		
		1.	Euglena	1
	E.	Myxophyceae		
		1.	Anabaena	3
		2.	Spirulina	1
	F.	Unknown Samples		
		1.	bright blue ribbon	2
		2.	olive colored	1
		3.	red-pink colored	1
II.	Protozoa			
	A.	Rhizopoda		
		1.	Pelomyxa	2
		2.	Thecamoeba	1
	B.	Ciliata		
		1.	Paramecium	1
		2.	Spirotrichida	1
		3.	Vorticella	1
III.	Crustacea			
	A.	Cladocera		
		1.	Daphnia	19
		2.	Ceriodaphnia	2
	B.	Copepoda		
		1.	Diaptomus	3
		2.	Limnocalanus	2
		3.	Cyclops	1
IV.	Nemata			
	A.	Secernentea		1
V.	Rotifera			
	A.	Monogononta		
		1.	Keratella	4
VI.	Unknown			
	A.	insect sample		1

Table 4. Lake IV Plankton.

I. Algae	
A. Chlorophyta	
1. Zygnema	2
2. Hydrodictyon	1
3. Oedogonium	1
4. Chlorophyceae	common
B. Chrysophyta	
1. Dinobryon	1
2. Chrysophyceae	common
C. Cyanophyta	
1. Aphanocapsa	1
2. Coelosphaerium	1
D. Phyrrophyta	
1. Ceratium	5
E. Rhodophyta	
1. Batrachospermaceae	1
F. Myxophyceae	
1. Oscillatoria	2
2. Anabaena	1
G. Unknown Samples	
1. bright blue ribbon	1
2. uni-cellular	1
3. Cho(a)dat ?	1
II. Protozoa	
A. Rhizopoda	
1. Amoebaea	common
III. Crustacea	
A. Copepoda	
1. Diaptomus	3
2. Cyclops	1
3. Limnocalanus	1
B. Cladocera	
1. Daphnia	15
2. Eurycercus	1
IV Rotifera	
A. Monogononta	
1. Keratella	8
V. Unknown	
A. insect sample	3

of specimens identified from Lake IV. Eighteen new specimens were identified with respect to Breidenbach's (1983) report. Tables 2, 3, and 4 show all identified specimens from Lakes I, III, and IV respectively. Table 5 identifies specimens unique to each lake. Table 6 identifies specimens unique to two lakes and specimens common in all three.

Table 5. Specimens common only to one lake.

Lake I	Lake III	Lake IV
Mougeotia	Penium	Aphanocapsa
Protococcus	Protosiphon	Coelosphaerium
Ankistrodesmus	Chara	Batrachospermaceae
Richteriella	Closterium	Oscillatoria
Pleurodiscus	Xanthophyceae	Unknown Sample (uni-cellular)
Genicularia	Ophiocytium	Eurycercus
Mastagloia	Pinularia	
Synura	Nitzschia	
Gyrosigma	Amphiprora	
Cyclotella	Stephanodiscus	
Melosira	Euglena	
Amphora	Spirulina	
Frustulia	Unknown Sample (olive colored) (red-pink colored)	
Asterionela	Pelomyxa	
Synedra	Thecamoeba	
Ostracod	Paramecium	
Unknown Sample (Protozoa)	Spirotrichida	
Thuricola	Vorticella	
Trichocerca	Secernentea	

Table 6. a. Specimens common between two lakes.

Lakes I and III	Lakes I and IV	Lakes III and IV
Ceriodaphnia	Zygnema	Ceratium
	Dinobryon	Anabaena
	Amoebaea	Unknown Sample (insect sample)
	Chlorophyceae	

b. Specimens common among all three lakes.

Hydrodictyon	Cyclops	Chrysophyceae
Limnocalanus	Daphnia	Unknown Sample (bright blue ribbon)
Diaptomus	Keratella	
Oedogonium		

SUMMARY

This report offers additions and comparisons to previous studies. No lists of aquatic life had been compiled since 1983. Lists of biota were completed as accurately as possible for each lake. Twenty-three new genera of specimens were identified in Lake I, twenty-three in Lake III, and eighteen in Lake IV. Chemical data were also collected and formatted into a table, displaying a chronology of physical and chemical characteristics of Lakes I, III, and IV. Furthermore, a brief history of the evolution of the study area was compiled and included in the report.

Several deficiencies are present within this study. Identification of the biota are not known with great certainty, and the identification of specimens was limited to a small portion of each slide. This limited amount of specimens examined increased the possibility of overlooking certain organisms. Furthermore, dissolved oxygen tests were made in the lab. As a result of the samples being placed in a cooler, dissolved oxygen tests were made at a temperature somewhat lower than that of the three lakes. Since oxygen dissolves more readily at lower water temperatures, the results of the study for dissolved oxygen may have some degree of error.

This study did not test for light penetration, nor were the current depths of the lakes determined. Observations have been made concerning each lake, but no current, accurate sketches of the shapes of the lakes and contours of the lake bottoms have been made. The next project in the on-going study of the three strip mine lakes should include these characteristics.

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APPENDIX I

Access Roads

There is a trail on the west shore of Lake III. This pathway roughly follows the contour of the lake and cuts through some of the forest area. There is a small clearing in the trail at the northwest tip of Lake IV. The path continues by cutting between the southern shore of Lake III and the northern shore of Lake IV. Then the trail cuts through a forested area and comes to an opening. This clearing, moderately populated by trees, faces the back of the house observed on the northeast shore of Lake IV.

The pathway continues in a southeast direction and ends at a third opening. This open space is void of trees and offers an option of three or four trails to follow. The pathway directly opposite, or southeast, leads to the tip of the northeastern-most arm of Lake I. Another pathway, located approximately fifty yards west of the first, leads to the two northwest arms of Lake I.

Most of these trails are no longer wide enough for safe access by an automobile. The trails are approximately three to four feet wide and would better serve an off-road vehicle (either a motor-bike or a personal all terrain vehicle).

APPENDIX II

Use of Study Area

In 1972, Mr. and Mrs. Robert Davis owned the land that Michual Coe had studied. Both are now deceased, but the land was left to their three daughters: Ms. Melanie Davis, Mrs. Susan Kahn, and Mrs. Valeria Tulley. It is their desire that the land be used as a natural wildlife area. The three heirs of the property also wish for the land to be respectfully used and fished by people in the neighboring communities, as well as for students of St. Meinrad College to continue studies and research on the land.

APPENDIX III

Chemical Analyses

In 1972 and 1975, water samples were sent to Calgon Corporation of Evansville. Chemical tests were run and the results were returned to St. Meinrad College. Between 1975 and 1980, the Calgon Corporation moved out of Evansville. As a result of this, water samples were sent to Calgon Corporation of Pittsburgh in 1981. However, by 1983, St. Meinrad College had obtained the equipment to run chemical tests within its own laboratory. As a result, Breidenbach (1983) tested for specific chemical characteristics himself (Table 1). Chemical characteristics were also determined by using the same Hach Corporation instruments in 1996.