State Water Survey Division

WATER QUALITY SECTION
AT
PEORIA, ILLINOIS

**Illinois Department of
Energy and Natural Resources**

SWS Contract Report 313

DIAGNOSTIC-FEASIBILITY STUDY OF LAKE LE-AQUA-NA

by

V. Kothandaraman and Ralph L. Evans

**Prepared for the
Illinois Department of Conservation**

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Kothandaraman, V.
DIAGNOSTIC - FEASIBILITY
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INTRODUCTION

The Water Quality Section of the Illinois State Water Survey undertook a detailed and systematic diagnostic-feasibility study of Lake Le-Aqua-Na commencing January 1, 1981. The major objective of the project was to develop an integrated protection/management plan for Lake Le-Aqua-Na and its watershed.

The diagnostic study was designed to delineate the existing lake conditions, to examine the causes of degradation, if any, and to identify and quantify the sources of nutrients and any pollutants flowing into the lake. On the basis of the findings of the diagnostic study, water quality goals were established for the lake. Alternative management techniques were then evaluated in relation to the established goals.

The diagnostic-feasibility study was funded through the Illinois Environmental Protection Agency by the U.S. Environmental Protection Agency with non-federal cost sharing by the Illinois Department of Conservation, all under the provisions of Section 314 of Public Law 95-217.

Lake Le-Aqua-Na is located in Stephenson County. It is a 39.5-acre lake with a maximum depth of 25 feet. The lake was formed in 1956 by the impoundment of Waddams Creek. This publicly owned lake and the surrounding park are managed by the Illinois Department of Conservation for outdoor recreational activities. These include bank fishing, boat fishing, ice fishing in season, boating, canoeing, camping, picnicking, hiking, and winter sports. The location map for the lake, indicating state, county, and municipal boundaries, is shown in figure 1. Other relevant general information is included in table 1.

Lake Le-Aqua-Na State Park, in which the lake is located, is open year-round except for a brief period during the winter thaw, which usually occurs in late March or early April. It is open to the general public from 8:00 a.m. to 6:00 p.m. During the summer months free interpretive programs are offered, such as nature walks, movies, and lectures by guest speakers. The park has 160 gravel campsites, 60 primitive campsites, and extensive foot and bridle trails.

Acknowledgments

This investigation, partially funded by the Illinois Department of Conservation and U.S. Environmental Protection Agency through the Illinois Environmental Protection Agency, was conducted under the general supervision and guidance of Stanley A. Changnon, Jr., Chief of the Illinois State Water Survey.

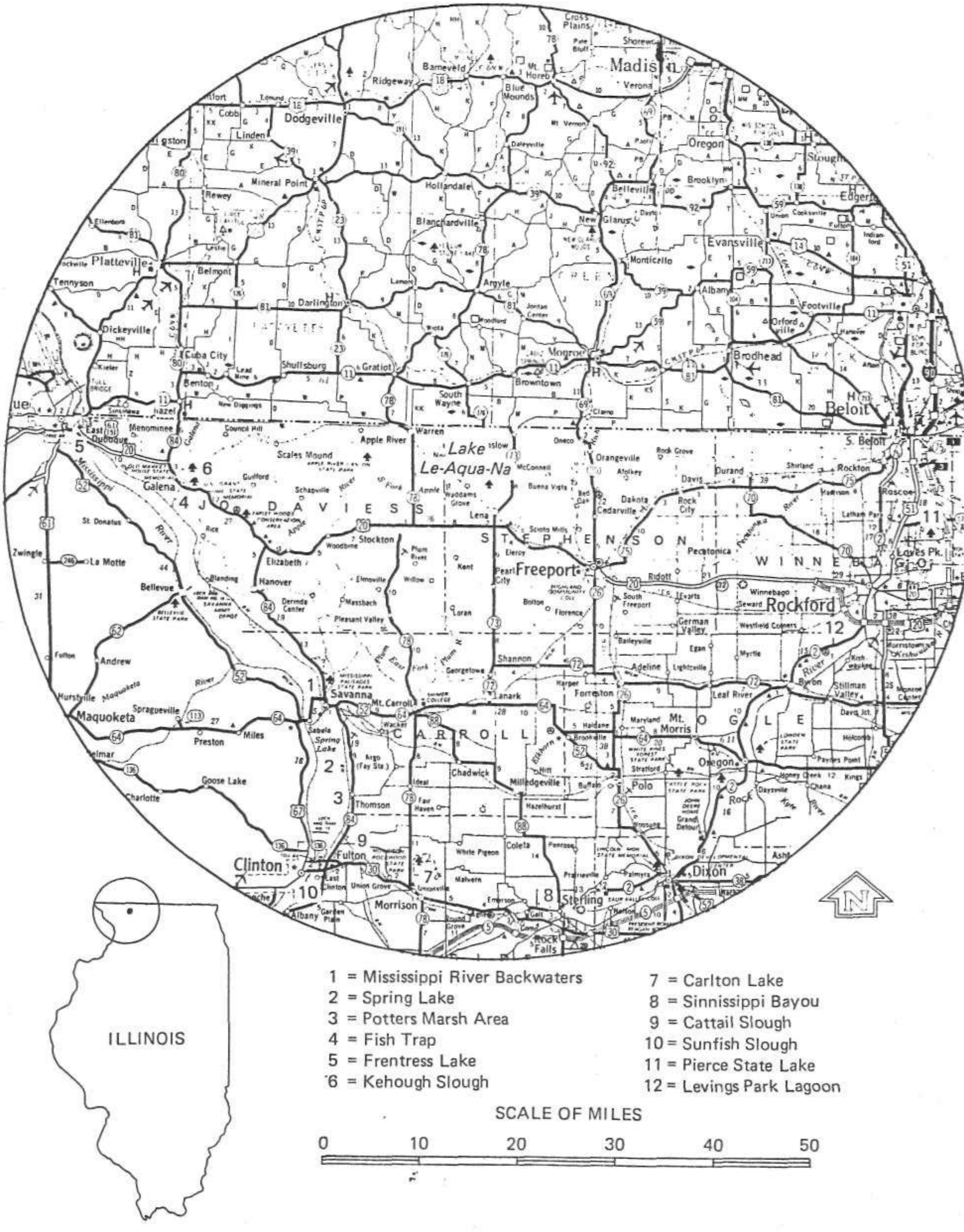

Figure 1. Location map, Lake Le-Aqua-Na

Table 1. General Information Pertaining to Lake Le-Aqua-Na

Lake name	Le-Aqua-Na
State	Illinois
County	Stephenson; T28N., R6E., Section 17
Nearest municipality	Lena, Illinois
Latitude	42°-25'-09"
Longitude	89°-49'-54"
USEPA region	V
IEPA major basin name and code	Mississippi River, 07
IEPA minor basin name and code	Rock River, 09
Major tributary	Main branch of Waddams Creek
Receiving water body	Rock River via Waddams Creek and Pecatonica River
Water quality standards	General standards promulgated by the Illinois Pollution Control Board and applicable to waters designated for aquatic life

Several Water Survey staff members contributed to this investigation. David Hullinger, Dana Shackleford, and Brent Gregory performed chemical analyses; Thomas Hill identified benthic organisms; Davis Beuscher performed bacterial analyses and algal identification and enumeration; Thomas Butts carried out the *in-situ* sediment oxygen demand tests; and Gene Brooks installed stage gages, developed stage-discharge rating curves, and determined daily flow rates. Bill Bogner managed the field work for the bathymetric survey and developed sedimentation data. Maureen Kwolek, under the direction of Ming T. Lee, determined the watershed slope classification and the gross soil erosion from the watershed, using the Universal Soil Loss Equation. Several others participated in field sample and data collection efforts. Linda Johnson typed the original manuscript; Lynn Weiss and Kathleen Brown typed the camera copy; Gail Taylor edited the manuscript; and the graphic arts staff, under the supervision of John W. Brother, Jr., prepared the illustrations.

The excellent cooperation, assistance, and courtesy extended by Jeff Hensal and his staff of Lake Le-Aqua-Na State Park are appreciated very much. Gary McCandless of the Illinois Department of Conservation was very helpful during this investigation.

The assistance of Donna Sefton and John Little, both of the Illinois Environmental Protection Agency, is gratefully acknowledged. Donna Sefton's critical review of the draft report is appreciated. Analyses of trace metals and organochemicals in sediments, elutriated samples, and fish flesh samples were done by the IEPA laboratories.

Steven Chick, District Soil Conservationist, Stephenson County, provided valuable information, including information on parameter values for the Universal Soil Loss Equation and on cropping practices in the watershed.

STUDY AREA

Lake Le-Aqua-Na

Lake Le-Aqua-Na lies within the state park of the same name and is located in Stephenson County. It is situated 6 miles south of the Illinois-Wisconsin state line and 3 miles north of Lena, Illinois. The lake was formed in 1956 by the impoundment of Waddams Creek. It currently has a water surface area of 39.5 acres with a maximum depth of 25 feet. Other pertinent morphometric details regarding the lake are included in table 2.

The impoundment was created only for recreational purposes, with no other designated uses. It is stocked and managed by the Fisheries Division of the Department of Conservation for warm water fish such as largemouth bass, bluegill, red ear sunfish, and catfish. Public access to the lake exists, and a ramp and docks for private and rental boats are provided on the north shore. Boats are limited to those that are propelled manually and by electric-powered motors. Swimming is prohibited. Bathymetric maps of the lake for 1956 and 1981 are shown in figure 2.

Geological and Soil Characteristics of the Drainage Basin

The landscape of Lake Le-Aqua-Na State Park was shaped partially by glacial ice, running water, and wind. This area is composed of undulating hills of the stage from late youth to early maturity. Illinoian drift is thin and is not known to be underlain by older till. The major uplands and valleys are shaped by the form of the bedrock surface (Leighton et al., 1948).

The area is one of moderate relief. The highest elevation is approximately 1160 feet above sea level and the lowest point is about 820 feet above sea level.

Lake Le-Aqua-Na State Park is located within the Rock River Hill Country of the Till Plains Section of the Central Lowland Province. The park is underlain by limestones and dolomites of Ordovician age which are covered by glacial drift and loess. There are occasional outcrops. Also present is Ordovician-age shale of the Maquoketa formation.

Table 2. Morphometric Details regarding Lake Le-Aqua-Na

Surface area, acres	39.5 (16.0 ha)
Volume, acre-feet	487.2 (0.61 x $10^6 m^3$)
Mean depth, feet	11.6 (3.54 m)
Maximum depth, feet	25.0 (7.62 m)
Length of shoreline, miles	1.4 (2.25 km)
Average retention time, years	0.186
Total original capacity loss, percent	15.8
Annual capacity loss, percent	0.6
Watershed area, acres	2348.1 (9.5 km^2)

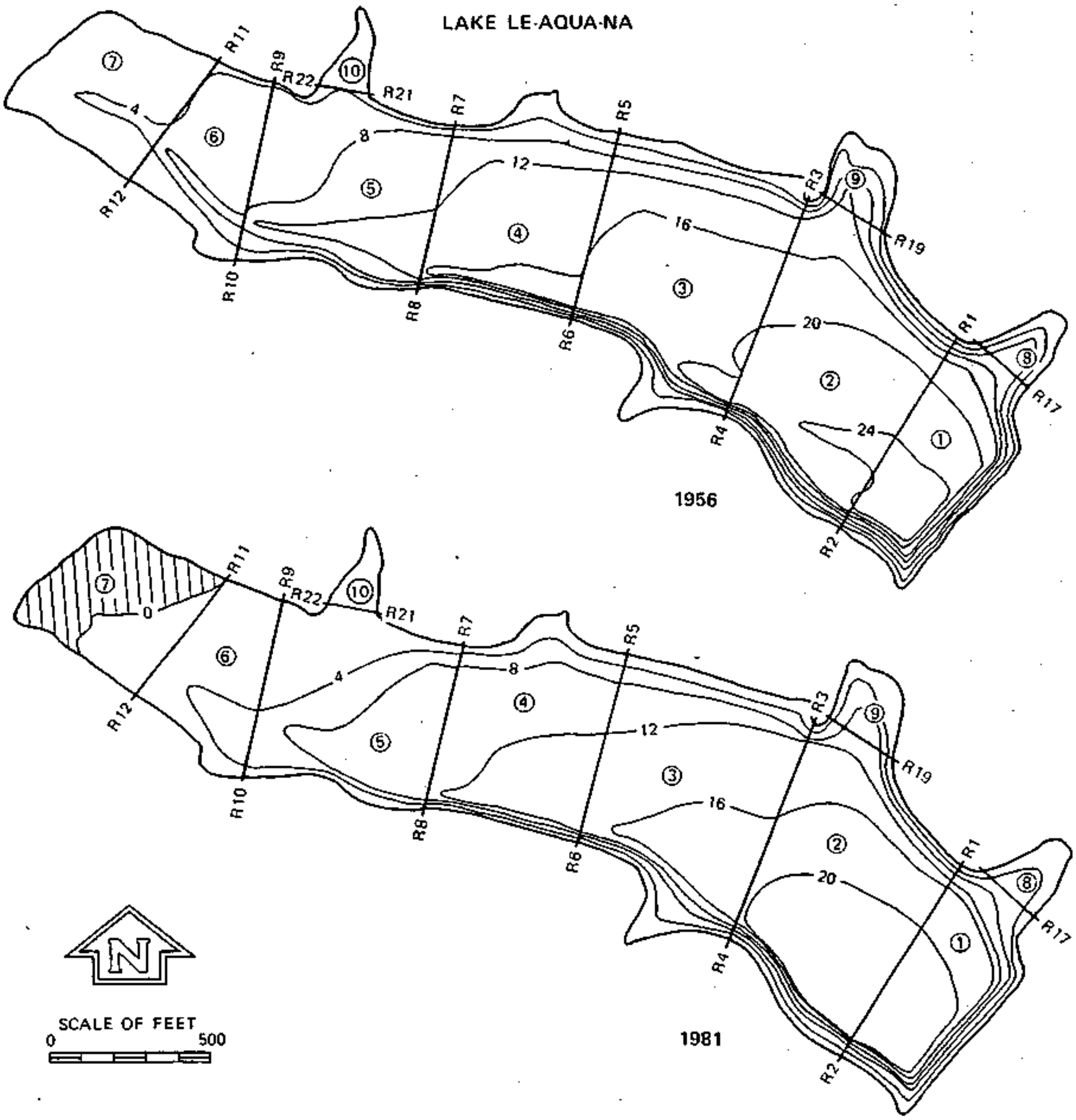

Figure 2. Bathymetric maps of Lake Le-Aqua-Na (contour intervals in feet)

The area was subjected to one major period of glaciation, the Illinoian stage. Most of the glacial deposits are considered to be related to the Green Bay Lobe of the Illinoian glacial stage (Ray et al., 1976).

The Pleistocene deposits in this area are less than 50 feet thick with a loess cover of 10- to 15-inch thickness. These deposits belong to the Winslow Till Member of the Glasford Formation (Illinoian stage, Monican substage).

The present soils were derived mainly from outwash material carried by the glacier's meltwater and deposited on floodplains. Winds picked up the fine silt-sized particles called loess and deposited this material in the uplands.

The main soil type in this area is silt loam. This soil is developed on various thicknesses of loess underlying till and bedrock of dolomite, limestone, or shale, hence giving rise to many variations in the A, B, and C horizons. These soils belong to many different series, but four general area association classifications can be made (Ray et al., 1976):

1) Tama-Downs-Muscatine. Dark and moderately dark, mostly well-drained to somewhat poorly-drained, developed entirely in loess.
2) Flagg-Pecatonica. Light, mostly well-drained loam and sandy loam drift, developed in thin or no loess and drift.
3) Dubuque-Dunbarton-Palsgrove. Light, well-drained, mainly loess over limestone.
4) Eleroy-Derinda-Keltner. Light and dark, mostly moderately well-drained loess over shale.

A detailed soil map, showing the specific type of soils, average slope of the area, and estimated erosion conditions within the area, is included as figure 3. The soil symbols designate mapping units that are based on these three characteristics.

For the three-part symbols in figure 3 (for example, 233C2), the first number (233) indicates the soil name, the capital letter (C) indicates the slope range, and the third part (2) is a number that indicates the degree of erosion.

A detailed legend for soil names can be found elsewhere (Ray et al., 1976).

The slope symbols (capital letters) have the following definitions:

Slope symbol	*Slope description*	*Slope range (%)*
A	Nearly level	0-2
B	Gently sloping	2-4
C	Moderately sloping	4-7
D	Strongly sloping	7-12
E	Very strongly sloping	12-18
F	Steep	18-30

The erosion symbols (numbers) have the following definitions:

Erosion symbol	*Erosion description*	*Inches of original soil surface remaining*
None	None to slight	More than 7
2	Moderate	3 to 7
3	Severe	Less than 3, or plow layer is largely subsoil material

Thus, in the example mentioned previously, 233C2 is interpreted as Birkbeck silt loam, with 4 to 7 percent slopes, and moderately eroded.

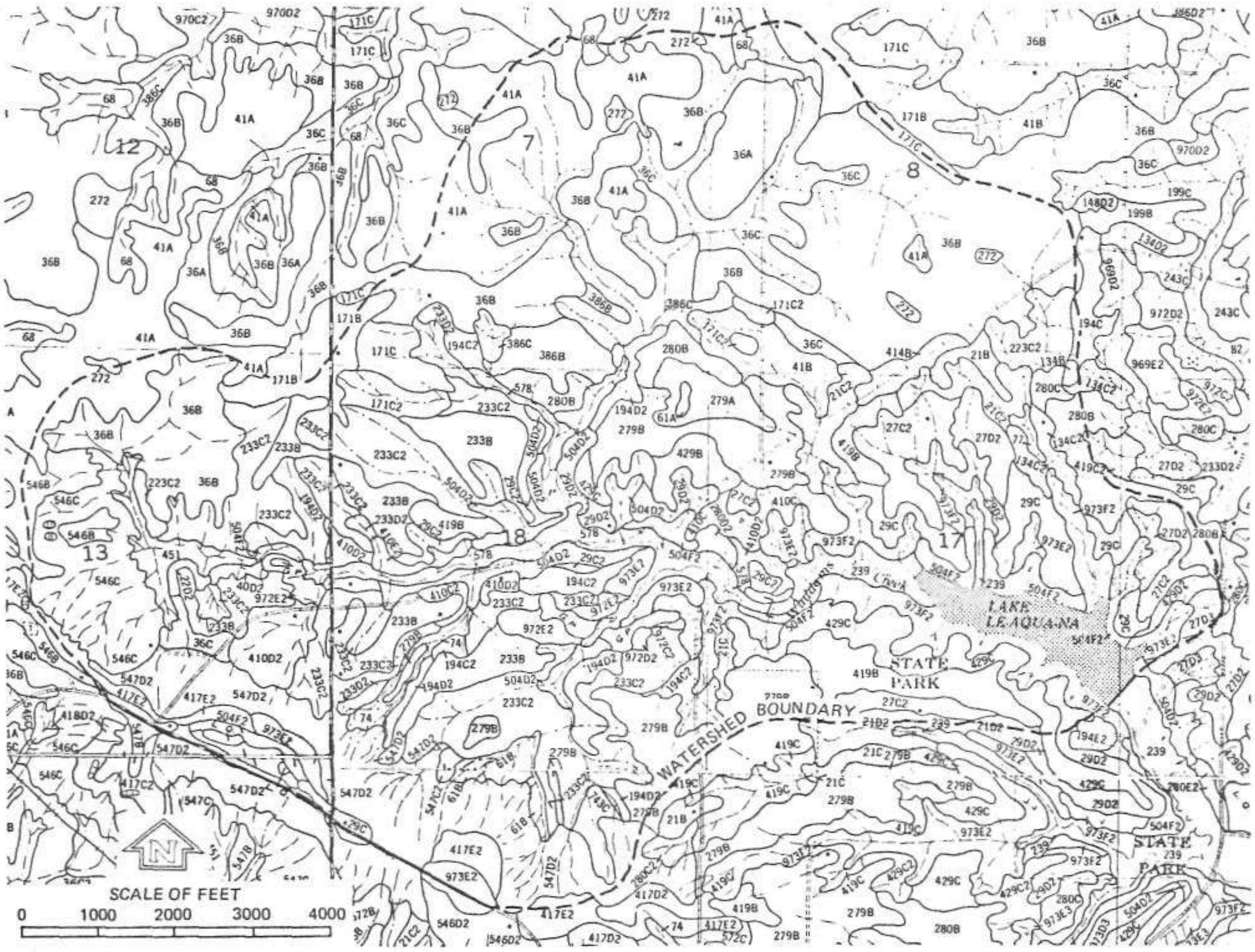

Figure 3. Soil classifications in the Lake Le-Aqua-Na watershed (after Ray et al., 1976)

Slope information was obtained from the soils map of the area. The acreages in each slope category for the six watershed sub-basins are given in table 3. The sub-basin demarcations and the land uses in the watershed are shown in figure 4.

Watershed sub-basin I has a rugged terrain with an average slope of about 10 percent. Of the six sub-basins, it has the largest acreage with slopes of 18 to 30 percent. Sub-basin II has an average slope of 8.5 percent, which places it in the moderately to steep sloping category. Sub-basins III and IV, with average slopes of 3.5 and 2.5 percent, respectively, fall into the category of gently to moderately sloping. Sub-basins V and VI both have average slopes of 5 percent and fall into the moderately sloping category.

The scope of the diagnostic-feasibility study did not include investigations pertaining to groundwater hydrology in relation to the lake basin.

Table 3. Areas in Different Slope Categories

Slope range (percent)	Sub-basin area (acres) I	II	III	IV	V	VI	Total area (acres)	Percent of total acreage
0-2	6.3	5.3	75.6	144.4	46.2	3.1	280.9	12.2
2-4	49.5	49.0	195.8	278.9	167.5	19.2	759.9	32.9
4-7	47.8	94.4	223.4	159.9	108.2	71.4	705.1	30.5
7-12	2.7	111.9	133.5	30.5	52.9	18.4	349.9	15.2
12-18	4.5	46.8	33.7	0.0	7.5	9.6	102.1	4.4
18-30	41.6	0.0	7.5	0.0	35.8	25.8	110.7	4.8

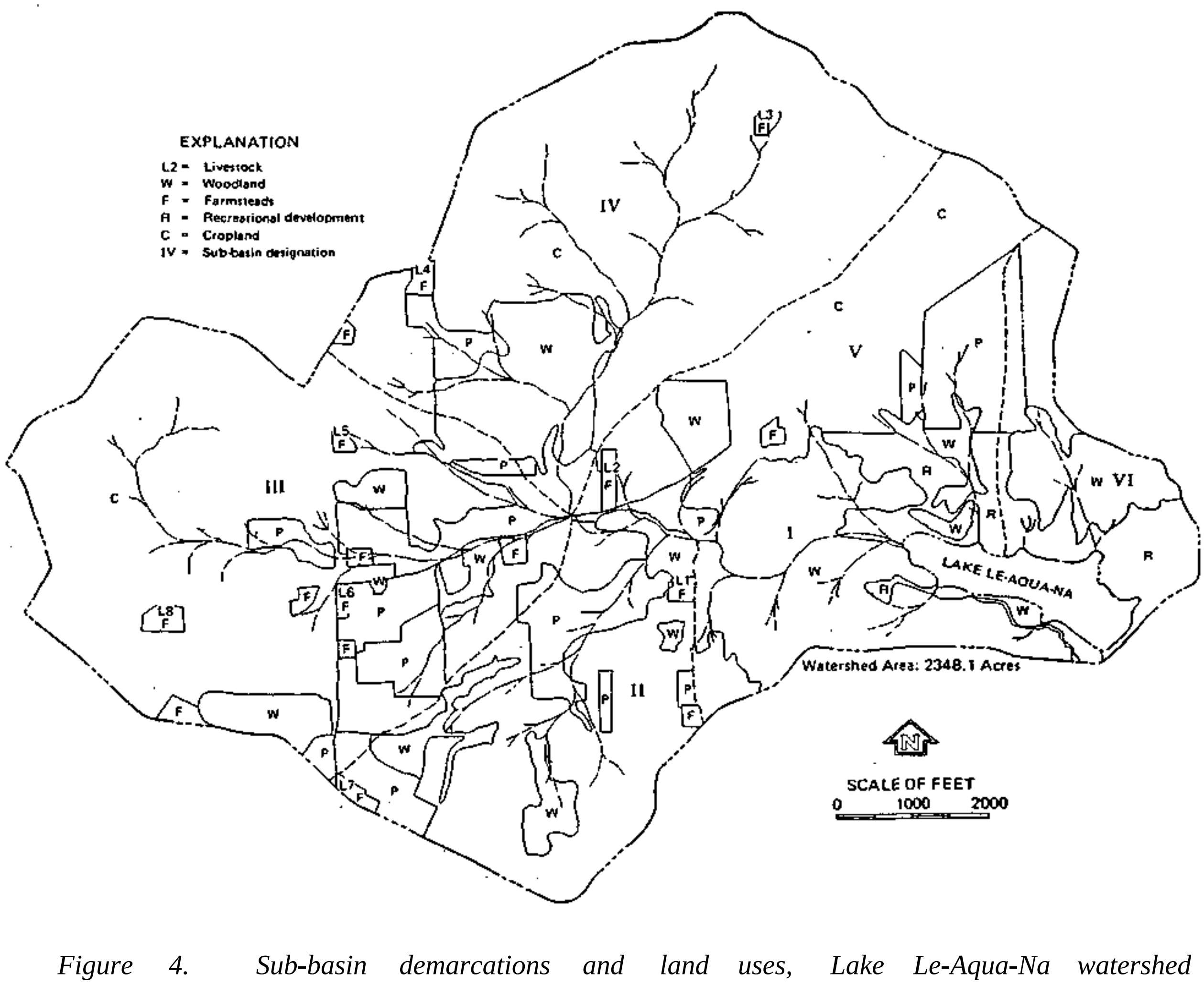

Figure 4. Sub-basin demarcations and land uses, Lake Le-Aqua-Na watershed

No definitive statements can be made concerning questions such as: Does the lake recharge aquifers through exfiltration? Does it receive groundwater discharge directly? How significant is groundwater compared to surface water in the lake's water budget? However, some qualitative assessments can be made regarding these questions. These will be dealt with later in this report in the section on inflows and outflows, when the water budget of the lake is considered.

Public Access to the Lake Area

The major population centers reasonably close to the lake area are Lena and Freeport, Illinois, which are 3 and 15 miles away, respectively. There is no public transportation available for use to and from the lake and the state park; however, an excellent blacktop road provides access to the park area from Lena.

There is a public road circling the lake, providing ready and easy access for such activities as bank fishing, nature study, and use of playground facilities. Strategic lookout points with adequate parking facilities also exist around the lake. A noteworthy feature of this lake is that it has special dock facilities that enable handicapped persons in wheelchairs to engage in fishing. A map of the lake, identifying public access points and facilities, is given in figure 5. Pertinent information on access points is tabulated in table 4.

There is a boat launching ramp on the north shore of the lake with a capacity sufficient for inland fishing boats. Although there is space for parking 10 vehicles at the ramp site, more than adequate parking facilities exist throughout the state park. There are no fees charged for the use of the park or the launch facilities.

Potential User Population

The resident population at the lake consists of the park ranger and his family. Daily and weekend visitors come to the state park from Lena (3 miles away, population 1800) and Freeport (15 miles away, population 28,000).

Lena is a prosperous small community served by two banks, and it is dependent primarily on agribusiness, small town commerce, and employment opportunities in Freeport. There is no urban blight, no chronic unemployment, and no housing shortage. Lake Le-Aqua-Na and the state park together are a resource which brings in transient visitors and the commercial opportunities provided by those visitors.

Freeport has a significant industrial base. The Microswitch Company and the. Kelly Springfield Company are the major companies providing ongoing employment. Freeport is a typical small town with a broad-based economy including manufacturing, agriculture, retail trade, health and social services, and financial services including banking, insurance, and real estate.

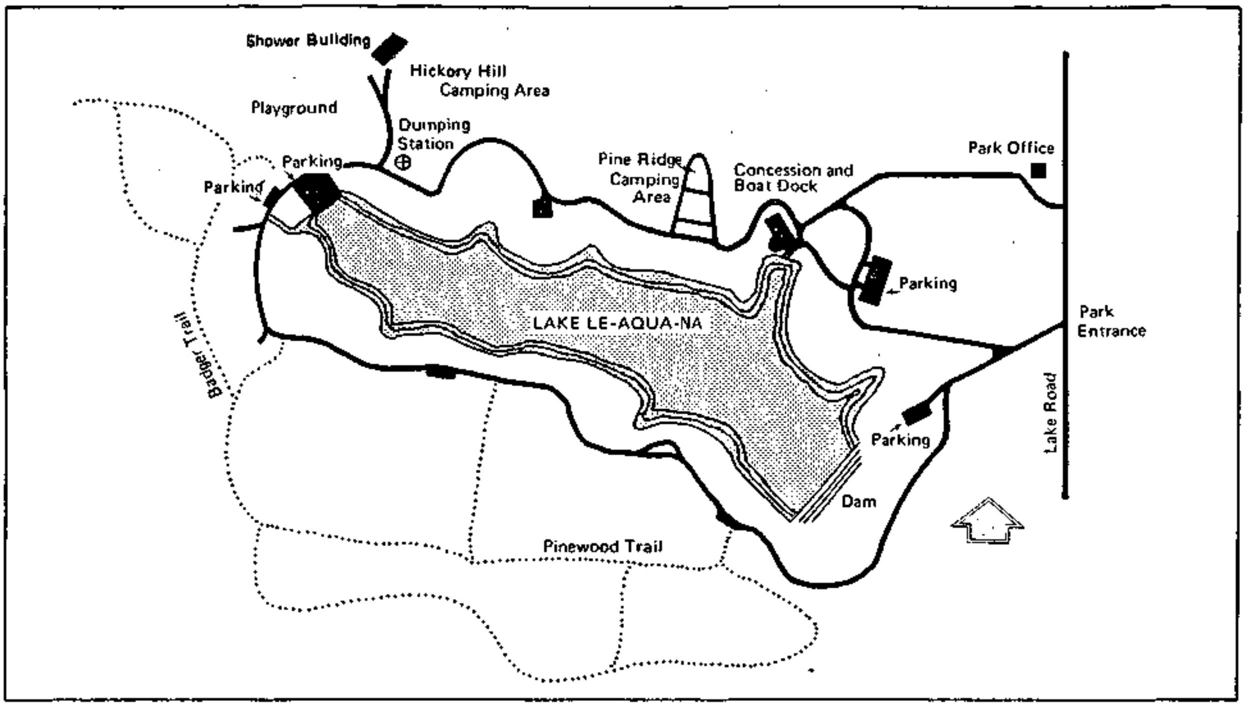

Figure 5. Public access points and facilities, Lake Le-Aqua-Na

Table 4. Public Access Points in Lake Le-Aqua-Na

Location	*Type*	*Land area (acres)*	*Lake frontage (feet)*	*Types and capacities of facilities*
Concession stand landing	Boat launch	0.5	170	Launching ramp with capacity sufficient for inland fishing boats, parking for 10 vehicles, and a concession stand
East landing	Fishing dock	0.6	50	Dock designed for handicapped persons, parking for 10 to 15 vehicles
West end of the lake	Park	5.5	400	Playground, trails, parking for about 50 vehicles
South landing	Fishing dock	0.7	250	Fishing only

Table 5. Population and Economic Data for Areas near Lake Le-Aqua-Na
(Population figures are in thousands)

County and population	*Major city within the county and its population*	*Employment sources and number of people employed*	*Pay-roll (thousands of dollars)*
Illinois			
Winnebago, 251.6	Rockford, 150.0	Farm equipment manufacturing, retail and wholesale trades, health and hospital services, transportation-trucking, public utilities, 112.0	1,523,868
Stephenson, 49.7	Freeport, 18.0	Manufacturing, retail trade, services, finance, 19.1	232,755
Jo Daviess, 23.9		Fabricated metal products, retail and wholesale trade, health and hotel services, 4.2	37,701
Carroll, 18.8		Machinery and electrical equipment manufacturing, retail and wholesale trades, health and social services, 3.5	29,092
Ogle, 46.9		Machinery manufacturing, restaurants, food stores, wholesale in durable and nondurable items, health services, 11.7	133,934
Whiteside, 66.5	Sterling, 16.3 Rock Falls, 10.6	Metal products fabrication, machinery manufacturing, retail trade in general merchandise, restaurants, wholesale trade in durable and nondurable goods, health and social services, 21.1	317,998
Lee, 36.3	Dixon, 15.7	Manufacturing of transportation equipment, lumber products, retail and wholesale trade, health and business services, 9.6	102,027
Wisconsin			
Grant, 52.5		Electric/electronic manufacturing, dairy/food products, restaurants, services, 11.6	95,148

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It is known that the park facilities attract visitors from a wide area, with past attendance topping 500,000 in one year (1976).. Table 5 gives information on a number of Illinois, Wisconsin, and Iowa counties that are relatively close to the state park. Data regarding county populations, major population centers, and pertinent economic characteristics are provided. It is interesting to note that President Reagan's birthplace, Tampico (in Whiteside County), and his boyhood hometown, Dixon (in Lee County), are within 50 miles of the park.

Lakes within a 50-Mile Radius of Lake Le-Aqua-Na

There are 12 Illinois public lakes, sloughs, bayous, and other waterbodies with surface areas of more than 20 acres within a 50-mile

Table 5. Concluded

County and population	Major city within the county and its population	Employment sources and number of people employed	Payroll (thousands of dollars)
<u>Wisconsin</u> (cont 'd)			
Lafayette, 17.5		Food and dairy products, retail and wholesale trades in durable and nondurable goods, health services, 2.2	20,447
Green, 30.7		Electric/electronic manufacturing, dairy/food products, health services, business services, computer/data processing, retail sales, 9.1	96,191
Dane, 323.4	Madison, 169.7	Manufacturing-meat products, printing/publishing, contract construction, wholesale and retail trades, health and business services, 113.9	1,303,559
Iowa, 15.4		Manufacturing - household appliances, electrical equipment, retail sales, health and hotel services, 6.2	61,781
<u>Iowa</u>			
Dubuque, 94.5	Dubuque, 62.4	Manufacturing - construction machinery, food/meat products, wholesale and retail trades, health services, membership organizations - labor/civic, 41.5	577,390
Jackson, 22.9		Manufacturing - engines, turbines, retail and wholesale trades, nursing/personal care services, 3.9	33,391
Clinton, 57.3	Clinton, 32.8	Manufacturing - food/grain products, rubber/plastics, health and business services, retail and wholesale trades, 18.9	220,646

Sources: 1980 Census of Population, Bureau of the Census (U.S. Department of Commerce); Sales and Marketing Management, 1982 Survey of Buying Power, July 26, 1982

radius of Lake Le-Aqua-Na. Also, there are 27 lakes in Wisconsin within a 50-mile radius of Lake Le-Aqua-Na. Table 6 lists these lakes and gives information on such factors as maximum depth, availability of public access, presence of a launching ramp, and recreational facilities available at these lake sites.

The locations of the Illinois lakes are indicated in the regional map (figure 1). There are too many Wisconsin lakes within a 50-mile radius to be shown with any clarity on the regional map.

All the lakes listed for Illinois except one are much larger than Lake Le-Aqua-Na. Carlton Lake, Pierce State Lake, and the Mississippi River Backwaters provide all the recreational facilities available at Lake Le-Aqua-Na. Water-oriented recreational resources available in Wisconsin, particularly in Dane County, are significant. Four lakes in Dane County

Table 6. Lakes within a Fifty-Mile Radius of Lake Le-Aqua-Na

Name of lake	Area (acres)	Max. depth (feet)	Public access	Launching ramp	Recreational facilities*
Grant County, WI					
Glen Lake	60	20	Yes	Yes	WS,HU,F,IS,B
Rice Lake	40	6	Yes		
Woodman Lake	30	10	Yes	Yes	C,WS,HU,F,IS,B
Lafayette County, WI					
Yellowstone Lake	455	8	Yes	Yes	F
Green County, WI					
Albany Millpond	102	8	Yes	Yes	F
Beckman Lake	73	12	Yes	Yes	F
Decatur Lake	151	10	Yes	Yes	F
Zanders Lake	21	8	Yes	Yes	F
Iowa County, WI					
Avoca Lake	48	10	Yes	Yes	HU,F,C
Cox Hollow Lake	96	29	Yes	Yes	C,S
Ludden Lake	70	14	Yes	Yes	F
Twin Valley Lake	145	35	Yes	Yes	C,F,S
Dane County, WI					
Belleville Millpond	93	9	Yes	Yes	S,F
Brandenburg Lake	43	6	No	No	C,HU
Fish Lake	252	62	Yes		P
Kegonsa Lake	2716	31	Yes	Yes	HU,F
Marshall Millpond	194	5	Yes		F
Marx Pond Lake	61	5	Yes		F,HU
Mendota Lake	9730	82	Yes	Yes	S,F,B,WS,IS,P,C
Monona Lake	3335	64	Yes	Yes	S,F,B,WS,IS,P,C
Mud Lake (Lower)	195	5	No		F
Mud Lake (Upper)	223	8	No		F
Rockdale Mill Pond	104	5	Yes		F
Stoughton Lake	82	5	No		
Token Creek Millpond	23	6	No		F
Waubesa Lake	2113	34	Yes	Yes	F
Lake Wingra	345	21	Yes	Yes	F
Carroll County, IL					
Mississippi River Backwaters	150		Yes	Yes	P,C,B,F,IF,SK, HI.HT
Potters Marsh Area	250				
Spring Lake	3550				
Jo Daviess County, IL					
Fish Trap Lake	285				
Frentress Lake	92				
Kehough Slough	109				
Whiteside County, IL					
Carlton Lake	77	27	Yes	Yes	P,C,F,B,HI,IS,IF
Cattail Slough	115				
Sinnissippi Bayou	70				
Sunfish Slough	178				
Winnebago County, IL					
Pierce State Lake	162	36	Yes	Yes	C,HI,IS,IF,F,B
Levings Park Lagoon	24				

*B = boating; C = camping; F = fishing; HU = hunting; IS = ice skating; P = picnicking; S = swimming; HI = hiking; WS = water skiing; IF = ice fishing; SK = skiing; HT = horse trail

Sources: Surface Water Resources of Grant, Lafayette, Green, Iowa, and Dane Counties, Wisconsin Conservation Department; Illinois Surface Water Inventory, 1972, Illinois Department of Conservation are larger than 2000 acres and ten are larger than 100 acres. There are six lakes larger than Lake Le-Aqua-Na in counties adjoining the Illinois-Wisconsin state border. All the Wisconsin lakes listed in the table except five have public access and excellent recreational amenities.

Historical Lake Uses and Conditions at Lake Le-Aqua-Na

The historical data on park attendance are shown in table 7. The figures shown in the table are for total park usage. Information is not available on the number of users for different recreational categories.

The data in table 7 indicate that there was a general trend of increasing park attendance commencing in 1972 and peaking in 1976. It is possible that subsequent reductions in attendance were caused in part by the gasoline shortages and rapidly increasing gasoline prices after the 1973 Arab oil embargo. Decreases in the amount of long-distance travel may have cut down on the number of people stopping at the park.

Also, the lake experienced a massive winter fish kill during the winter of 1976-1977, due to oxygen depletion in the lake under ice cover. The rest of the fish population was totally eradicated through the use of rotenone on March 24, 1977, and the lake was subsequently restocked. The lack of fishing opportunities in the lake was probably the primary reason for the drop in park attendance to 219,612 visitors in 1977 from a previous year's record attendance of 532,761. Since 1977, the park attendance seems to have stabilized at around 300,000 visitors per year.

In its first year (1956-1957) the lake experienced algal blooms with blue-greens as the dominant species, dense filamentous algal growth, and submerged aquatic vegetation in the shallow upper part of the lake. Since its creation, the lake has routinely been subjected to applications of algicides and herbicides for controlling algae and submerged macrophytes. Profuse algal growth and macrophytes of weed proportions interfere with boating, fishing, and the general aesthetic enjoyment of the lake and its environs.

Table 7. Historical Data on Park Attendance

Year	*No. of visitors*
1981	301,587
1980	296,251
1979	324,664
1978	362,310
1977	219,612
1976	532,761
1975	295,811
1974	352,462
1973	268,177
1972	201,687

Uncontrolled sediment transport from the agricultural land parcels within the watershed has resulted in the sedimentation of the upper end of the lake. Aerial photographs of the lake taken in 1970 and 1979 vividly indicate the reduction in the areal extent of the lake, primarily due to siltation, within just one decade.

Another inherent problem for man-made lakes in central and northern Illinois is the total depletion of oxygen in the hypolimnetic zone during summer months. Observations of the lake waters for dissolved oxygen and temperature made on August 14, 1958, indicated that there was practically no oxygen in the lake at depths 9 feet from the surface and below, even though the thermocline was found to exist at depths 12 to 15 feet below the surface. Such conditions severely restrict the fish habitat during summer months and alter the character and species makeup of the benthic macroinvertebrates in the profundal region of the lake.

With the progressive degradation of the lake water quality conditions, sports fisheries will be significantly affected. That segment of the park visitors most affected by lake degradation will be the people who engage in fishing to supplement family food supplies or as a recreational activity.

The economy of Lena is dependent to a significant extent on the visitors and campers at Lake Le-Aqua-Na State Park: Retail trades such as restaurants, general stores, bait and tackle shops, and boat rental and repair shops in Lena will be adversely affected by lake degradation.

Point Source Waste Discharge

The discharge from the Lake Le-Aqua-Na State Park wastewater treatment plant is the only point source waste discharge in the lake's watershed. The treatment plant is operated only during the camping season, which lasts from May through October. Wastes generated in the shower buildings of the state park and wastes from the dump station for recreational vehicles are treated at this plant. The NPDES permit number for the treatment plant is 0054062.

The treatment plant operates on the extended aeration principle. It consists of a mixed liquor tank, a clarifier, a sand bed for drying excess sludge, and a chlorine contact chamber. The effluent produced is discharged to an unnamed creek tributary to the lake. As a part of this study the effluent outfall was observed during every field trip for the period May through October 1981. There was no discharge from the wastewater treatment plant. During weekdays, evaporational losses probably exceed the inflow to the treatment plant. The following concentrations were reported for the effluent (all in mg/l): 5-day BOD — 22.9; suspended solids — 5.1; nitrogen — 17.7; and phosphorus — 10.0.

Land Uses and Nonpoint Pollutant Loadings

The watershed area for the lake is approximately 2350 acres, with agriculture as the predominant land use. Figure 6 shows the watershed basin for the lake. Cultivation of row crops and production of dairy and

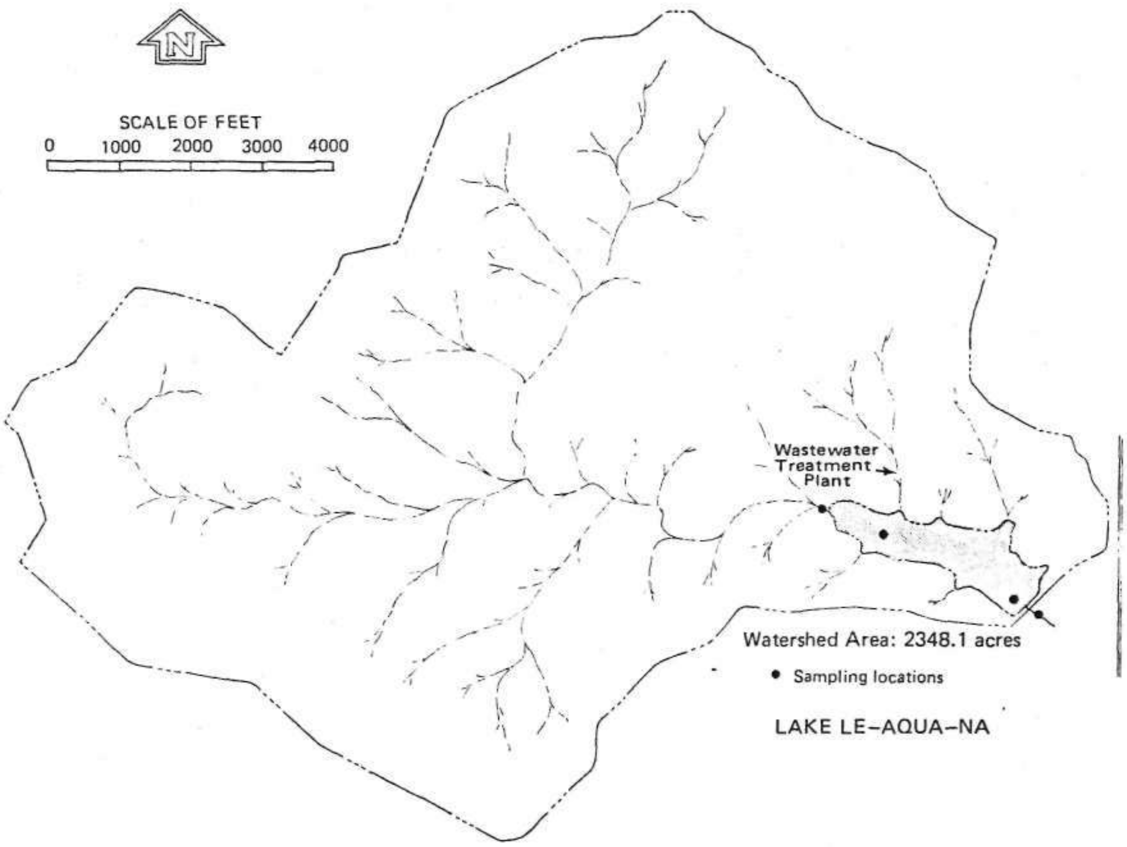


Figure 6. Watershed basin, Lake Le-Aqua-Na

beef livestock are both important in the watershed. Detailed information on the land uses in the watershed and the changes that occurred between the years 1970 and 1979 is given in table 8. The land use information was extracted from aerial photographs taken in 1970 and 1979 by the Soil Conservation Service of the U.S. Department of Agriculture. Cropland is the predominant use, accounting for about 67 percent of the total watershed. There has been no significant areal change in land use within the past 15 years. Approximately 31 percent of the watershed is state-owned and the remainder is in private ownership.

Within the state-owned portion of the watershed, there is practically no land use activity which involves land disturbance. Of the 730 acres of state-owned land, about 79.5 percent is in woodlands and grasslands, 5.5 percent is in water, and the rest is in recreational development such as playgrounds and campsites.

A land use map of the Lake Le-Aqua-Na watershed is shown in figure 4. The land uses in each of the six sub-basins, developed from 1979 aerial photographs, are shown in table 9. These land use values were used in estimating potential nonpoint pollution loadings to the lake originating from its watershed.

Table 8. Lake Le-Aqua-Na Watershed Land Uses

Type of land use	1970 Area (acres)	1970 Percent of total	1979 Area (acres)	1979 Percent of total
Cropland	1595.1	67.9	1569.8	66.9
Pasture or hayland	289.4	12.3	182.5	7.8
Woodland	373.9	15.9	415.1	17.7
Recreational development	0.0	0.0	107.4	4.6
Farmsteads	27.5	1.2	33.8	1.4
Water	46.2	2.0	39.5	1.7
Junkyard	16.0	0.7	0.0	0.0
Total	2348.1		2348.1	

Table 9. Lake Le-Aqua-Na Watershed Sub-Basin Land Uses, Acres

Land use	Sub-basin I	II	III	IV	V	VI	Total
Cropland	6.8	226.2	552.0	525.9	240.3	18.6	1569.8
Pasture or hayland	0.0	30.0	56.2	15.2	61.7	19.4	182.5
Woodland	140.5	42.8	46.4	63.9	68.1	53.4	415.1
Recreational development	5.1				46.2	56.1	107.4
Farmsteads	0.0	8.4	14.9	8.7	1.8		33.8
Total	152.4	307.4	669.5	613.7	418.1	147.5	2308.6

Of the 1570 acres of land, approximately 970 acres are in continuous corn production and the remainder are in crop rotation. Crop rotation generally practiced in the watershed is 2-1-3 (corn, corn, small grain, hay, hay, and hay) and there are practically no soybeans grown in the watershed. Primary fall chisel ploughing and double disking in spring for fertilizer and pesticide incorporation are the general tillage practices in the watershed. Strip cropping is practiced in about 240 acres and contouring in 60 acres of the agricultural lands. The farmers currently leave about 20 percent ground cover or 600 pounds of residue per acre after harvest. There are currently 22 farm owners in the watershed and ten of them are Soil and Water Conservation District Cooperators. Seven of the farms are managed by tenant farmers. The average size of the farms is about 80 acres.

Details of the locations and sizes of livestock operations are shown in figure 4 and table 10. The locations are marked on the watershed map as LlF . . .L8F denoting farmsteads with livestock location number 1, 2, etc. Table 10 gives the sizes of the operations at these locations. The operation at L3 is the only confined feedlot operation in the watershed. All the other operations utilize pastures.

Table 10. Livestock Operations in Lake Le-Aqua-Na Watershed

Location	*Type and number of livestock*
L1	50 cows, 5 heifers, 30 calves
L2	40 beef cattle, 20 dairy cows and calves
L3	140 beef cattle, 600 hogs
L4	5 beef cattle, 30 hogs
L5	19 beef cattle, 20 dairy cows and calves, 20 sheep
L6	20 cows and calves
L7	None
L8	12 beef cattle, 35 cows, 25 heifers, 10 calves

For estimating the soil loss rate from the watershed, the boundaries of land uses were first transposed on the watershed soil map. Seventy categories of soil types, slopes, and erodibility potentials were identified. The soil types and their associated land uses within each sub-watershed were then delineated with the aid of a digitizer. The soil loss rates were computed through use of the Universal Soil Loss Equation, or USLE (Wischmeier and Smith, 1965):

$$A = RKSLCP$$

In this equation, A is the average soil loss rate in tons per acre per year, R is the rainfall factor, K is the soil erodibility factor, S is the steepness factor, L is the slope length factor, C is the cropping factor, and P is the support practice factor.

The slope, slope length, and cropping factors were determined for various land uses in consultation with the Stephenson County District Conservationist. The erodibility factor of each soil type was obtained from soil description files available from the Soil Conservation Service State Office at Champaign. The R x P factor value was assigned as 135 for ' agricultural cropland and 180 for all other land uses. Based on the soil information compiled in the watershed, the soil loss rates were computed. The total soil loss for each soil type was obtained by multiplying the rate and the soil acreage. The soil losses from farmsteads with livestock were computed by taking one-third the farmstead area and an erosion rate of 35 tons/acre/yr.

The estimated soil losses for each of the six sub-watersheds are shown in table 11. In computing the soil erosion potential from cropland using the USLE, no allowance was made for the fact that some of the agricultural lands are in strip cropping and some are in crop rotation. However, the soil erosion from the cropland within the total watershed was reevaluated by the District Conservationist to account for the conservation practices already adopted in the watershed. The soil erosion from cropland was estimated as 7646 tons/year instead of 10,700.6 tons/year as shown in the table.

Table 11. Soil Losses in Lake Le-Aqua-Na Watershed
(Tons per year)

Land use	*Sub-basin*						*Total*
	I	*II*	*III*	*IV*	*V*	*VI*	
Cropland	74.4	2722.1	4200.5	2453.9	1160.4	89.3	10,700.6
Pasture or hayland		25.2	54.3	15.5	52.7	9.5	157.2
Woodland	5.6	1.8	2.0	1.4	3.9	2.5	17.2
Recreational devel.	0.8				28.8	56.6	86.2
Farmsteads		84.1	86.4	67.4	1.8		239.7
Total	80.8	2833.2	4343.2	2538.2	1247.6	157.9	11,200.9

Table 12. Pollution Load from Nonpoint Sources in
Lake Le-Aqua-Na Watershed

Land Use	*Area (hectares)*	*Percent of watershed*	*Constituent*	*Loading (kilograms x 10^3/year)*
Cropland	635.3	66.9	Susp. solids	7388.9
			Total N	10.2
			Total P	2.8
Pasture or hayland	73.9	7.8	Susp. solids	142.6
			Total N	0.6
			Total P	0.1
Woodland	168.0	17.7	Susp. solids	15.4
			Total N	0.5
			Total P	0.04
Recreational development	43.5	4.6	Susp. solids	78.2
			Total N	0.07
			Total P	0.01
Farmsteads	13.7	1.4	Susp. solids	217.4
			Total N*	24.3
			Total P*	2.3
Water	16.0	1.7	None	None

*Only the farmsteads with livestock are considered

The total amount of soil loss in the watershed was estimated as 8146 tons/year. Excluding the lake area, the mean soil erosion rate for the watershed is estimated as 3.53 tons/acre/yr.

The estimated nutrient loads emanating from the nonpoint sources within the watershed along with the sediment load for the entire watershed are shown in table 12. Nutrient export rates for nitrogen and phosphorus (in kilograms per hectare per year) were estimated as follows:

	Nitrogen	*Phosphorus*
Cropland	16.09	4.46
Pasture and hayland	8.65	1.5
Recreational development	2.86	0.236
Farmsteads	3110.7	300.7

All these values are the mean values for the respective land uses as indicated by Reckhow et al. (1980), except the values for recreational development. Nutrient export rates applicable to low density residential areas were used for estimating the nutrient export from recreational areas.

LIMNOLOGICAL ASSESSMENT OF THE LAKE

Materials and Methods

In order to assess the current conditions of the lake, certain physical, chemical, and biological characteristics of the lake were monitored during the 1981 calendar year. The lake was monitored on a once-a-month basis during January through April and again from October through December, and it was visited on a biweekly schedule during the intervening summer months. A total of 17 visits were made during the year. During each of these visits water samples were collected from Waddams Creek upstream and downstream of the lake for chemical and biological characterization. The locations of the lake and tributary monitoring stations are shown in figure 6.

In-situ observations for temperature, dissolved oxygen, and secchi disc readings were made at the deep and shallow stations in the lake. An oxygen meter, Yellow Spring Instrument Company model 54, with a 50-foot probe was standardized in lake surface water in which dissolved oxygen content was determined by the modified Winkler method as outlined by the American Public Health Association et al. (1976). Temperature and dissolved oxygen measurements were obtained in the water column, at 2-foot intervals for the deep station and at 1-foot intervals for the shallow station, commencing from the surface of the lake.

For measuring secchi disc transparencies, an 8-inch-diameter secchi disc with black and white quadrant markings attached to a calibrated line was used. The disc was lowered until it disappeared from view, and the depth of immersion of the disc was noted. The disc was lowered farther and then raised slowly until it reappeared. Again the depth of immersion was noted. The average of these two observations was recorded as the secchi disc readings.

Water samples for chemical analyses were obtained from the lake with a Kemmerer sampler at points 1 foot below the surface, mid-depth, and 1 foot from the bottom. Integrated water samples within a depth twice the secchi disc readings were obtained for phytoplankton identification and enumeration, and chlorophyll-a determination. A Juday sampler was used for obtaining integrated samples. Samples for coliform determination were obtained at 1 foot below the surface in pre-sterilized glass bottles. All the samples were stored on ice during transportation and kept in a refrigerator until processed, with the exception of the algae and chlorophyll-a samples. Chlorophyll-a samples were kept frozen.

Water subsamples in a volume of 380 ml were collected for algal identification and enumeration, preserved with 20 ml of formalin at the time of collection, and stored at room temperature until examined.

Determinations for pH, alkalinity, and conductivity were made at the lake site soon after sample collections. Laboratory analyses were performed to determine total suspended and dissolved solids, volatile suspended solids, turbidity, total and dissolved phosphorus, nitrate-nitrogen, total Kjeldahl-nitrogen, and chlorophyll-a. Streamwater samples were not examined for chlorophyll-a content. The methods and procedures involved in these determinations are given in table 13.

For algal identification and enumeration, the sample was thoroughly mixed and a l-ml aliquot was pipetted into a Sedgwick Rafter Cell. A differential interference contrast microscope equipped with a 10X or 20X eyepiece, 20X or 100X objective, and a Whipple disc was used for identification and counting purposes. Five short strips were counted. The algae

Table 13. Analytical Procedures

Turbidity	Nephelometric method, using Turner Fluoremeter, model 110; Formazin used as a standard
pH	Glass electrode method with portable Metrohm-Herisau meter (model E588)
Total solids	Residue on evaporation overnight on a steam bath at 103-105°C
Suspended solids	Dry weight of solids retained on gooch crucible with fiberglass filter
Suspended volatile solids	Loss on ignition of suspended solids at 550°C in a muffle furnace for 1 hour
Alkalinity	Potentiometric method; titration with standard sulfuric acid solution to an end point pH of 4.3
Conductivity	YSI model 33 conductivity meter
Total phosphorus	Sample was digested with sulfuric-nitric acid mixture and determined by ascorbic acid method
Total dissolved phosphorus	Sample was first filtered through 0.45 μm filter paper, digested with sulfuric acid mixture, and determined by ascorbic acid method
Ammonia-N	Phenate method
Nitrate-N	Chromotropic method
Nitrite-N	Diazotization method
Kjeldahl-N	Digestion and distillation followed by endophenol-hypochlorite colorimetric determination

were identified as to species and were classified into five main groups: blue-greens, greens, diatoms, flagellates, and others. For enumeration, blue-green algae were counted by trichomes. Green algae were counted by individual cells except for Actinastrum, Coelastrum and Pediastrum, which were recorded by each colony observed. Scenedesmus was counted by each cell packet. Diatoms were counted as one organism regardless of their grouping connections. For flagellates, a colony of Dinobryon or a single cell of Ceratium was recorded as a unit. Dimensions of the individual species of algae were determined using a widefield Filar Micrometer eyepiece after calibrating it with a Leitz stage micrometer. The dimensions and shapes of various organisms found in the water samples are tabulated in table 14.

Lake and stream bacterial samples were examined for total coliform, fecal coliform, and fecal streptococci. Standard Methods procedures (American Public Health Association et al.,1976) using 0.45μm filters were used in the bacterial determinations.

A macrophyte survey of the lake was made in July from a boat with the services of a scuba diver. Samples of submerged vegetation were obtained with roots intact. The macrophyte beds were probed thoroughly by the scuba diver, and representative samples of the various types of vegetation found in the lake were obtained and placed in plastic bags with lake water, which were then sealed. These samples were then examined with stereo microscope, and identified. The areal extent of the submerged vegetation was noted on the lake map.

Benthic samples for macroinvertebrate examination were obtained at monthly intervals during June through September. The bottom muds were also examined for percent moisture and volatile fraction. Benthic samples were obtained at both the deep and shallow stations in the lake.

Three grabs with an Ekman dredge (6 x 6 inches) were taken at each station for macroinvertebrate analyses. The samples were washed in a 30-mesh screen bucket and the residue was placed in quart jars and preserved in 95 percent ethyl alcohol. In the laboratory, the samples were washed again and the organisms were picked from the bottom detritus. They were identified, counted, and preserved in 70 percent ethyl alcohol.

Water consistency (percent water) of the sediment samples was determined by first decanting the supernate from the stored sample and thoroughly mixing it. Loss of weight from the wet samples at 103°C overnight on a steam bath expressed as percent of original weight was taken as a measure of the consistency of the sediment sample. The fixed and volatile fractions were determined according to Standard Methods (APHA, 1976).

In-situ sediment oxygen demand (SOD) rate determinations were made at the deep and shallow stations of the lake on two different occasions. One determination was made in July when anoxic conditions existed in the deep station, and the second was- in October after the fall circulation period, known as "fall turnover."

In-situ measurement of sediment oxygen demand rates consists essentially of confining a known volume of water over a given bottom area.

Table 14. Sizes and Shapes of Algae Used in Determining Biomass Computations

	Name of algae	Shape	Size (µm)
Blue-green	*Anabaena circinalis*	Spherical	10x80 filamentous
	Anabaena spiroides	Spherical	10x100 filamentous
	Aphanizomenon flos-aquae	Cylindrical	4.5x90 filamentous
	Oscillatoria putrida	Cylindrical	11x40 filamentous
	Oscillatoria chlorina	Cylindrical	9x67.5 filamentous
	Schizothrix calcicola	Cylindrical	1.5x60 filamentous
Green	*Actinastrum hantzchii*	Spherical	42 diam.
	Chlamydomonas reinhardi	Spherical	12 diam.
	Chlorella ellipsoidea	Spherical	8x9.5
	Chlorella pyrenoidosa	Spherical	6
	Coelastrum microporum	Spherical	24
	Crucigenia rectangularis	Colony flat, rectangular	4.5d x 24w x 241
	Micractinium pusillium	Colony triang.	5x25
	Mougeotia scelaris	Cylindrical	28x35
	Oocystis borgei	Spherical-	22
	Pediastrum duplex	Cylindrical	3x150
	Scenedesmus carinatus	Flat, rectang.	3x12x18
	Scenedesmus dimorphus	Flat, rectang.	5x19
	Ulothrix variabilis	Cylindrical	5x10
Diatoms	*Cyclotella michiganiana*	Cylindrical	3x12
	Cymbella affinis	Cylindrical	12x60
	Diploneis smithii	Cylindrical	15x8x1
	Fragilaria crotonensis	Rectangular	30x60
	Melosira granulata	Cylindrical	12x60
	Melosira varians	Cylindrical	12x60
	Navicula odiosa	Cylindrical	3x15
	Navicula gastrum	Cylindrical	12x45
	Navicula zanoni	Cylindrical	12x45
	Nitzschia palea	Cylindrical	6x45
	Synedra acus	Cylindrical	4.5x200
	Synedra nana	Cylindrical	2x20
	Synedra ulna	Cylindrical	4.5x200
Flagellates	*Ceratium hirundinella*	Triangular	48x48x200
	Dinobryon sertularia	Cylindrical	30x60
	Euglena gracilis	Cylindrical	6x45
	Euglena viridis	Cylindrical	17x50
	Trachelomonas erebea	Spherical	18
Other	*Peridinium cinctum*	Cylindrical	50x60
	Staurastrum paradoxum	Cylindrical	39x274

For this investigation, a small box-type sampler 12 x 7 x 6 inches in size, made of 3/16-inch welded steel plate, was used. The dissolved oxygen (DO) drop within the confined waters was monitored with a galvanic cell oxygen probe equipped with a stirrer. The stirrer-probe combination was implanted internally in the sampler. The details regarding the sampler, field procedures, and SOD rate evaluation techniques have been given by Butts and Evans (1979).

Core samples in duplicate from two different sites in the upper end (shallow part) of the lake were obtained in April. The regular shallow station and a location 200 feet upstream were the sites chosen for obtaining core samples. Each of these cores, four in all, was divided into three equal parts. Portions of each of these subsamples were used for particle size distribution analyses and for determinations of heavy metals and trace organics concentrations.

The sieve-pipet method as outlined by Guy, U.S. Geological Survey (1977), was used for particle size distribution analyses. Each sample was placed on a 0.062-mm sieve and the fine particles were washed from the sample using a stream of deionized water. One liter of the washed sample was used for the sieve-pipet analyses. A dispersing agent, containing 137.5 grams/liter of sodium metaphosphate and 7.95 grams/liter of sodium carbonate, was added to the cylinder containing the washed sample at a dosage rate of 2.5 ml/1. Corrections for dissolved solids were also made.

At the same time core samples were obtained, Ekman dredge samples were also obtained from the same two sites in the shallow part of the lake for elutriation tests. Elutriation tests were performed on the sediment samples according to the procedure set forth by the U.S. Army Corps of Engineers (Brannon, 1978). The sediment-lake water mixture was kept agitated for 30 minutes using an air diffuser with the compressed air passing through a deionized water trap.

Sediment core samples, elutriated samples, and fish flesh samples were examined for heavy metals and trace organics by the IEPA laboratories. Standard Methods procedures (APHA, 1976) were used in these determinations.

Stage gages were installed for measuring the depth of flows in the streams upstream and downstream of the lake. Daily stage readings were recorded with the help of state park officials. Actual stream flow measurements were made using a current meter to establish stage-discharge relationships for different discharge levels. Rating curves were developed for each location of the stage gages. From the daily stage readings and the rating curves, daily flow volumes were estimated and used in developing hydraulic and nutrient budgets.

An automatic recording rain gage was installed in the watershed and was in operation from March 1 to December 31, 1981. Rainwater samples collected in the rain gage were examined periodically for nitrogen and phosphorus content.

On a few occasions, following heavy precipitation in the watershed, water samples were collected from tributaries with the help of park officials. These samples were analyzed for suspended sediments and various forms of nitrogen and phosphorus.

Water Quality Characteristics

Physical Characteristics

Temperature and Dissolved Oxygen. Lakes in the temperate zone generally undergo seasonal variations in temperature through the water column. These variations, with their accompanying phenomena, are perhaps the most influential controlling factors within the lakes.

The temperature of a deep lake in the temperate zone is about 4°C during early spring. As the air temperatures rise, the upper layers of water warm up and mix with the lower layers by wind action. By late spring, the differences in thermal resistance cause the mixing to cease, and the lake approaches the thermal stratification of the summer season. Closely following the temperature variation in water is the physical phenomenon of increasing density with decreasing temperature up to a certain point. These two interrelated forces are capable of creating strata of water of vastly differing characteristics within the lake.

During thermal stratification the upper layer (the epilimnion) is isolated from the lower layer of water (the hypolimnion) by a temperature gradient (the thermocline). Temperatures in the epilimnion and hypolimnion are essentially uniform. The thermocline will typically have a sharp temperature drop per unit depth from the upper to the lower margin. When the thermal stratification is established, the lake enters the summer stagnation period, so named because the hypolimnion becomes stagnated.

With cooler air temperatures during the fall season, the temperature of the epilimnion decreases. This decrease in temperature continues until the epilimnion is the same temperature as the upper margin of the thermocline. Successive cooling through the thermocline to the hypolimnion results in a uniform temperature through the water column. The lake then enters the fall circulation period (fall turnover) and is again subjected to a complete mixing by the wind.

Declining air temperatures and the formation of an ice cover during the winter produce a slight inverse thermal stratification. The water column is essentially uniform in temperature at about 3 to 4°C, but slightly colder temperatures of 0 to 2°C prevail just below the ice. With the advent of spring and gradually rising air temperatures, the ice begins to disappear, and the temperature of the surface water rises. The lake again becomes uniform in temperature, and the spring circulation occurs.

The most important phase of the thermal regime from the standpoint of eutrophication is the summer stagnation period. The hypolimnion, by virtue of its stagnation, traps sediment materials such as decaying plant and animal matter, thus decreasing the availability of nutrients during the critical growing season. In a eutrophic lake, the hypolimnion becomes anaerobic or devoid of oxygen because of the increased content of highly oxidizable material and because of its isolation from the atmosphere. In the absence of oxygen, the conditions for chemical reduction become favorable and more nutrients are released from the bottom sediments Co the overlying waters.

However, during the fall circulation period, the lake water becomes mixed, and the nutrient-rich hypolimnetic waters are redistributed. The nutrients which remained trapped during the stagnation period become available during the following growing season. Therefore, a continual supply of plant nutrients from the drainage basin is not mandatory for sustained plant production. Fruh (1967) and Fillos and Swanson (1975) state that after an initial stimulus, the recycling of nutrients within a lake might be sufficient to sustain highly productive conditions for several years.

Isothermal plots for the deep station in Lake Le-Aqua-Na are shown in figure 7. The vertical temperature profiles for the deep station on selected dates are shown in figure 8. From figure 7 it is seen that the summer stratification begins to set in during the latter half of April and intensifies progressively during the summer months. The maximum water temperature of 28.1°C was observed on July 8, 1981. The lake experienced the maximum temperature differential of 16.8°C between the surface and bottom waters on the same date. Thereafter, the intensity of stratification began to decrease. The lake was found to be uniform in temperature after the fall turnover on October 7, 1981.

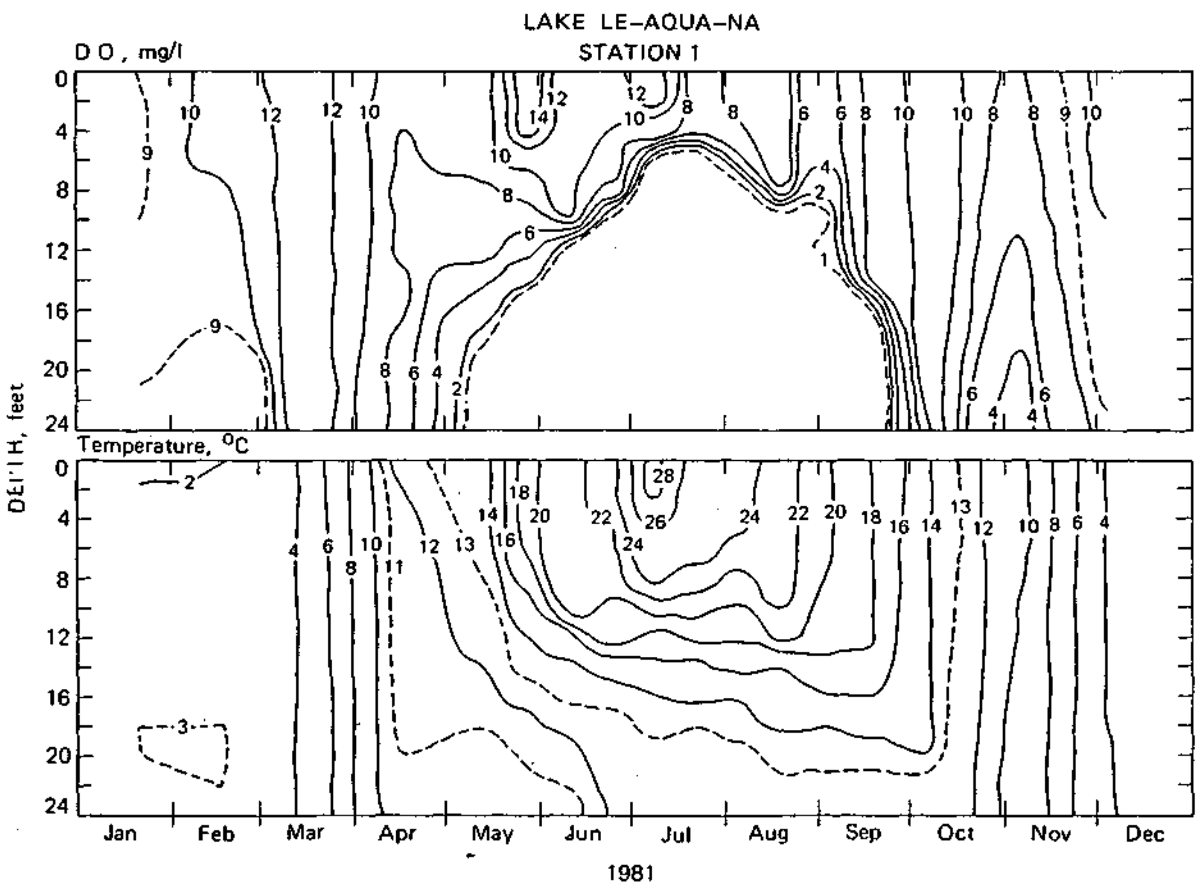


Figure 7. Isothermal and iso-dissolved oxygen plots for the deep station

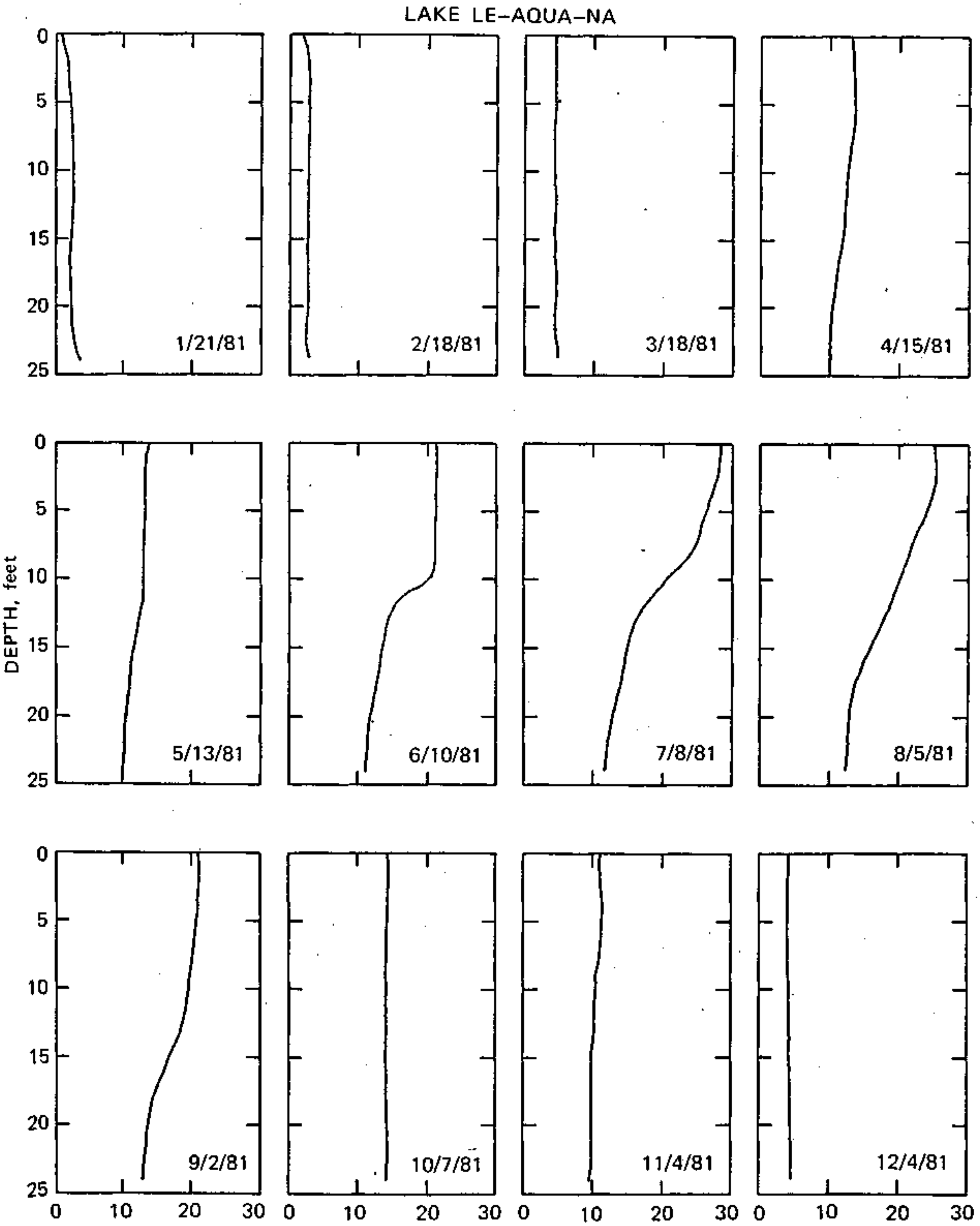


Figure 8. Temperature profiles at the deep station on selected dates

start

Lake stability has long been used by limnologists as an arbitrary measurement of the intensity of stratification in any body of water (Symons, 1969). Stability is calculated in work or energy units. It is defined as the work that must be done to lift the entire weight of a body of water the vertical distance between the center of gravity when the body is in a given state of stratification, and the center of gravity when the water body is isothermal. The greatest stability is generally reached just prior to maximum heat content in the summer. Detailed procedures for computing the stability factor for lakes using periodic lake vertical temperature profiles are discussed by Symons (1969).

The temporal variations in the stability factor for the lake are shown in figure 9. The stability factor reached a maximum value of 7.75×10^6 foot-pounds (2.92 kilowatt-hours) on July 8, 1981. Values for the months January to April and October to December 1981 were either zero, or negligible. In comparison, stability values for Lake Catherine, located in the northeastern part of Illinois, reached a maximum of 44.98×10^6 foot-pounds (16.96 kilowatt-hours) on June 27, 1977. Lake Catherine is nearly four times as large as Lake Le-Aqua-Na in areal extent.

It is common knowledge that the impoundment of water alters its physical, chemical, and biological characteristics. The literature is replete with detailed reports on the effects of impoundments on various water quality parameters. The physical changes in the configuration of the water mass following impoundment reduce reaeration rates to a small fraction of those of free-flowing streams. Where the depth of impoundment is considerable, the thermal stratification acts as an effective barrier for the wind-induced mixing of the hypolimnetic zone. The oxygen transfer to the deep waters is essentially confined to the molecular diffusion transport mechanism.

During the period of summer stagnation and increasing water temperatures, the bacterial decomposition of the bottom organic sediments exerts a high rate of oxygen demand on the overlying waters. When this rate of oxygen demand exceeds the oxygen replenishment by molecular diffusion, anaerobic conditions begin to prevail in the zones adjacent to the lake bottom. Hypolimnetic zones of man-made impoundments were also found to be anaerobic within a year of their formation (Kothandaraman and Evans, 1975).

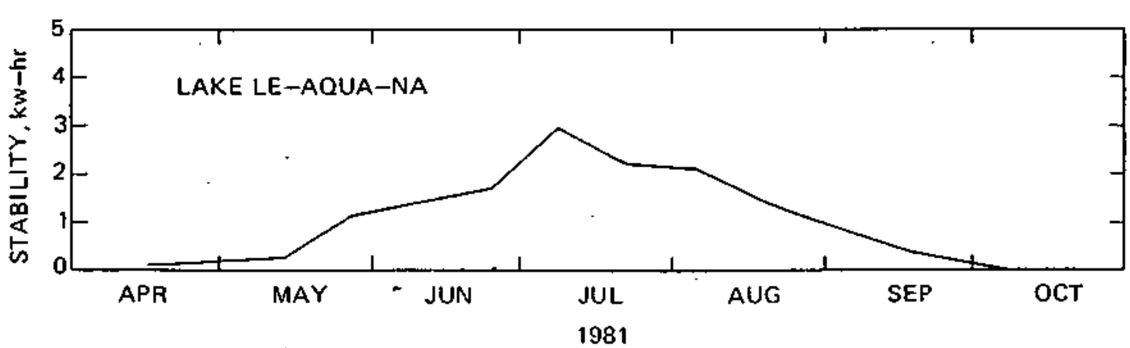


Figure 9. Temporal variations in lake stability

The isopleths of dissolved oxygen for Lake Le-Aqua-Na are shown in figure 7. Selected vertical DO profiles for the deep station are shown in figure 10. Dissolved oxygen depletion began to occur during the early part of May. As the summer thermal stagnation intensified, the anoxic zone of hypolimnetic waters increased progressively, reaching a maximum during mid-July. The extent of this anaerobic zone started diminishing thereafter, and the DO concentration became uniform in the water column in late September. As is apparent from figure 7, the progression of this anoxic zone coincided with the progression of the thermal stratification in the lake.

During the period of peak stratification, the lake was totally anoxic at depths 6 feet from the surface and below. About 250 acre-feet or approximately 51 percent of the water volume of the lake was anoxic, severely restricting its habitat for desirable fish food organisms and fish. During summer months, adequate oxygen levels did not generally exist at depths below 8 feet from the surface.

The temporal variations in dissolved oxygen and temperature for the surface, mid-depth, and near bottom sampling points of the deep station in the lake are shown in figure 11. Also, the figure includes the variations in percent DO saturation at the surface of the lake. The figure clearly demonstrates that supersaturation conditions due to algal photosynthesis existed at the surface during May, June, and July. Near bottom waters became anoxic in May and remained so until mid-September. Anoxic conditions prevailed at mid-depth during June, July, and August.

Isothermal and iso-dissolved oxygen plots for the shallow station, which had a maximum depth of 6 feet, are shown in figure 12. A weak thermal gradient persisted at the upper end of the lake during July. However, severe oxygen depletion was observed at this station during June and July.

Secchi Disc Transparencies. Secchi disc visibility is a measure of the lake water transparency or its ability to allow light transmission. Even though the secchi disc transparency is" not an actual quantitative indication of light transmission, it serves as an index and a means of comparing similar bodies of water or the same body of water at different times. Since changes in water color and turbidity in a deep lake are generally caused by aquatic flora and fauna, transparency is often related to this entity.

The mean and range of values observed for secchi disc readings at the deep station are given in table 15 along with the summary of observations for other physical and chemical water quality parameters. The temporal variations in secchi disc observations are shown in figure 13. The mean secchi disc reading was 59 inches. A maximum value of 192 inches was observed in February when the lake had ice cover. The minimum of 6 inches occurred in September immediately after a heavy rainfall, indicating a significant sediment influx. About 5.25 inches of rainfall was recorded over a period of 7 days in late August, with 3.15 inches occurring in one 24-hour period. Secchi disc readings during June, July, and August were in the range of 30 to 36 inches.

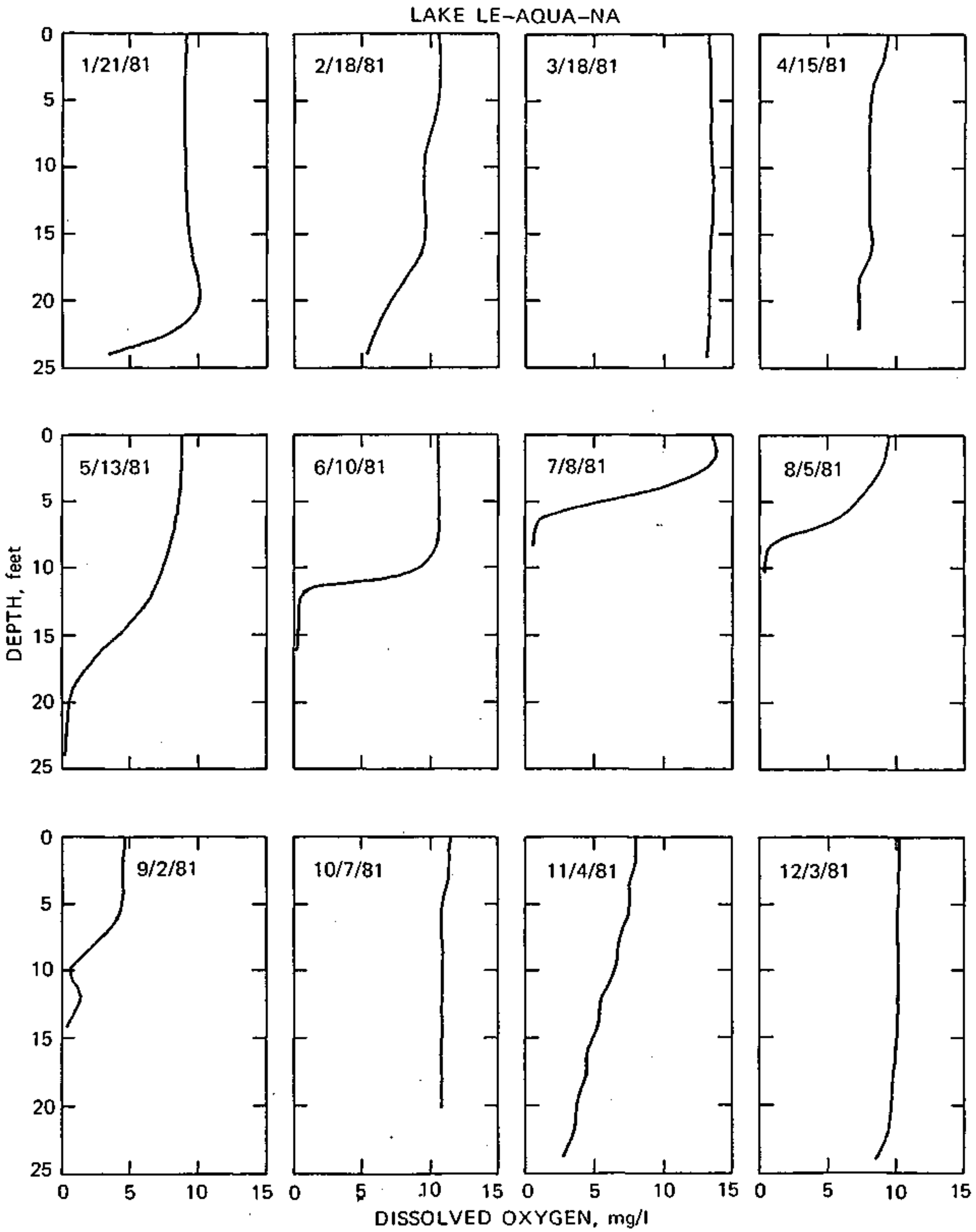


Figure 10. Dissolved oxygen profiles for the deep station on selected dates

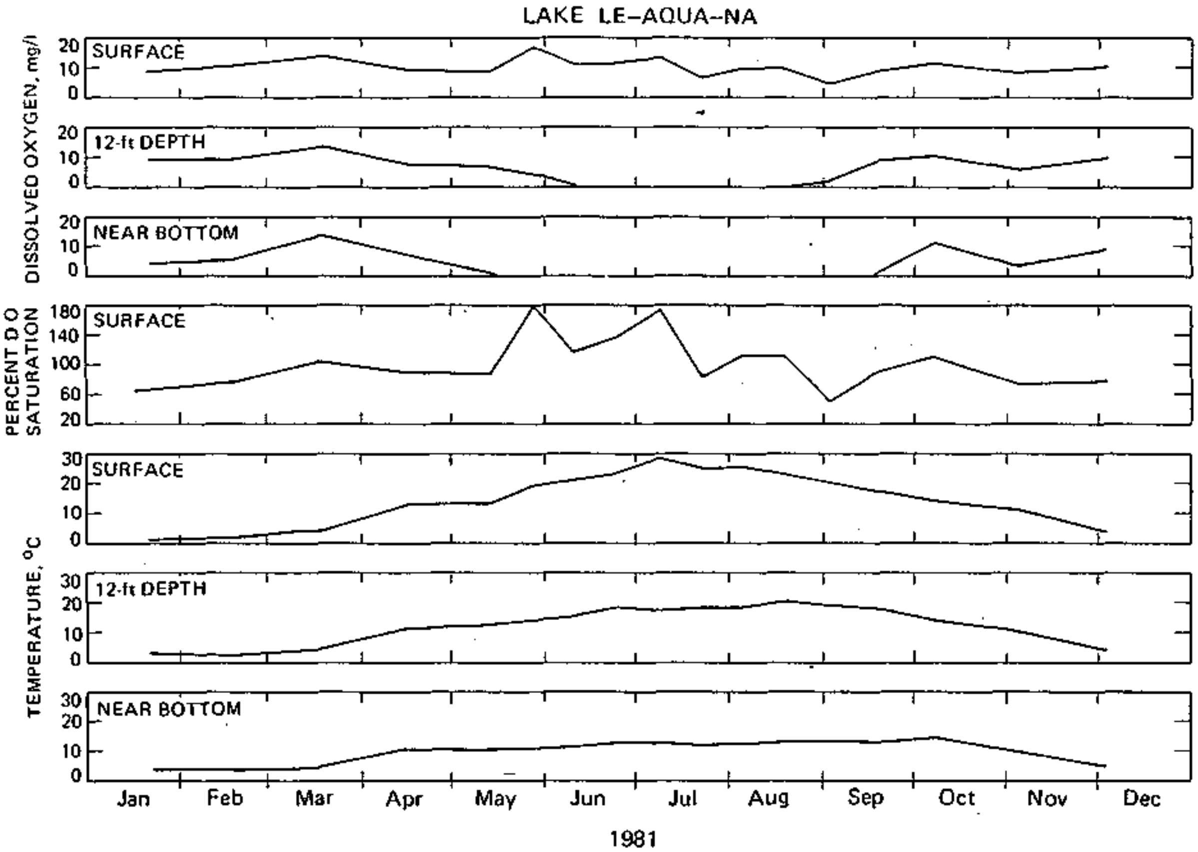


Figure 11. Temporal variations in DO, percent DO saturation, and temperature in the lake

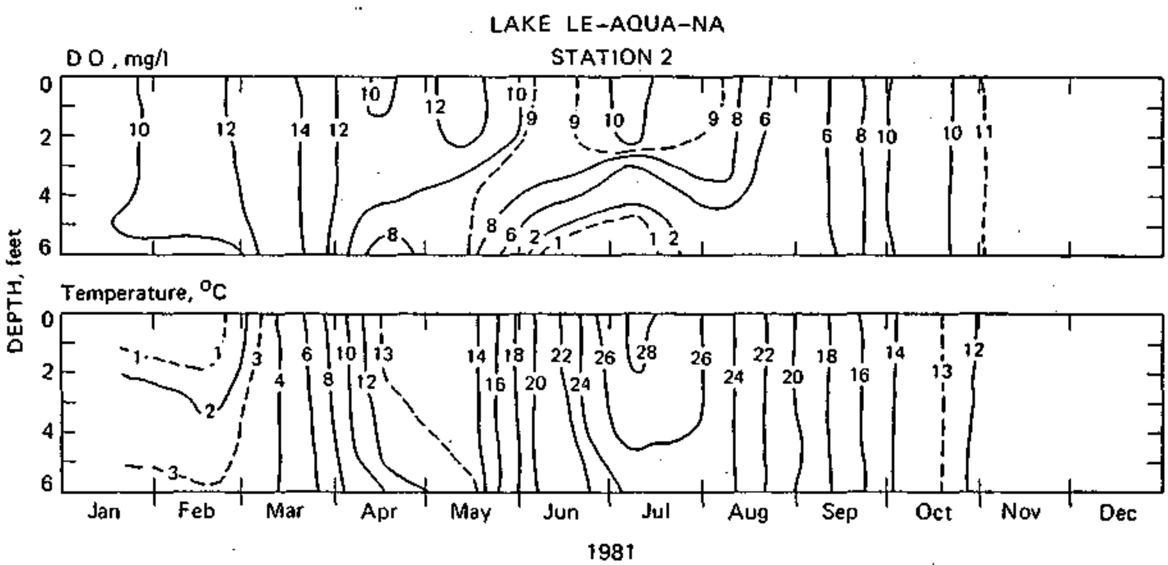


Figure 12. Isothermal and iso-dissolved oxygen plots for the shallow station

Table 15. Lake Le-Aqua-Na Water Quality Characteristics

Parameter	Near surface Mean	Near surface Range	Mid-depth Mean	Mid-depth Range	Near bottom Mean	Near bottom Range
Secchi readings (inches)	59	6-192				
Turbidity (NTU)	5.2	0.7- 5.8	5.6	0.30-8.1	17.0	1.8-40.7
pH (dimensionless)		7.6-10.0		7.7-9.2		7.4-8.5
Alkalinity	188	120-250	214	160-290	251	205-305
Conductivity (umho/cm)	314	152-370	343	285-421	379	290-450
Total phosphate-P	0.15	0.05-0.45	0.22	0.06-0.51	0.60	0.09-1.44
Dissolved phosphate-P	0.09	0.02-0.29	0.15	0.02-0.42	0.41	0.07-0.99
Total ammonia-N	0.34	0.04-1.00	0.63	0.06-1.71	2.42	0.22-6.60
Dissolved ammonia-N	0.23	0.02-0.65	0.55	0.05-1.60	2.13	0.17-5.68
Nitrate-N	0.73	0.02-1.87	0.78	0.04-1.88	0.66	0.05-2.05
Kjeldahl-N	1.26	0.41-1.90	1.49	0.68-2.48	3.48	0.62-8.46
Dissolved solids	276	140-362	303	232-368	318	262-354
Total suspended solids	9.2	0-38	9.2	0-19	28.1	0-170
Volatile susp. solids	6.5	0-15	6.4	0-17	10.4	0-34

Note: Values in mg/l unless otherwise indicated

Turbidity. High turbidity affects the aesthetic quality of the water. Its origins are generally considered to be municipal and industrial wastes; clastic materials derived from the drainage basin; soil erosion resulting from agricultural practices and urban and highway developments; sediments in lakes stirred by wind, waves, and high-speed boating activities in shallow lakes; and detrital remains of algae and aquatic and terrestrial plants and animals. However, in the case of Lake Le-Aqua-Na, some of these causative agents are absent, including industrial wastes, urban development, and high-speed boating activities.

Temporal variations of turbidity in surface, mid-depth, and near bottom sampling points of the deep station are shown in figures 13, 14, and 15, respectively. These values are summarized in table 15. The turbidity of surface and raid-depth samples had relatively low mean values of 5.2 and 5.6 NTU, respectively. However, values of over 30 NTU were observed on September 2, 1981. Lake turbidity at that time was nearly six times as high as the normal values. This was caused by a significant influx of suspended sediments into the lake after the heavy rainfall referred to earlier. Wet antecedent conditions prior to the heavy downpours created conditions conducive to soil erosion and sediment transport from the watershed. Turbidity of. the near bottom water samples was relatively higher, due partly to the settling of particulate matter from the surface.

Chemical Characteristics

pH and Alkalinity. It is generally considered that pH values above 8.0 in natural waters are produced by a photosynthetic rate that demands more carbon dioxide than the quantities furnished by respiration and decomposition (Mackenthun, 1969). Photosynthesis by aquatic plants

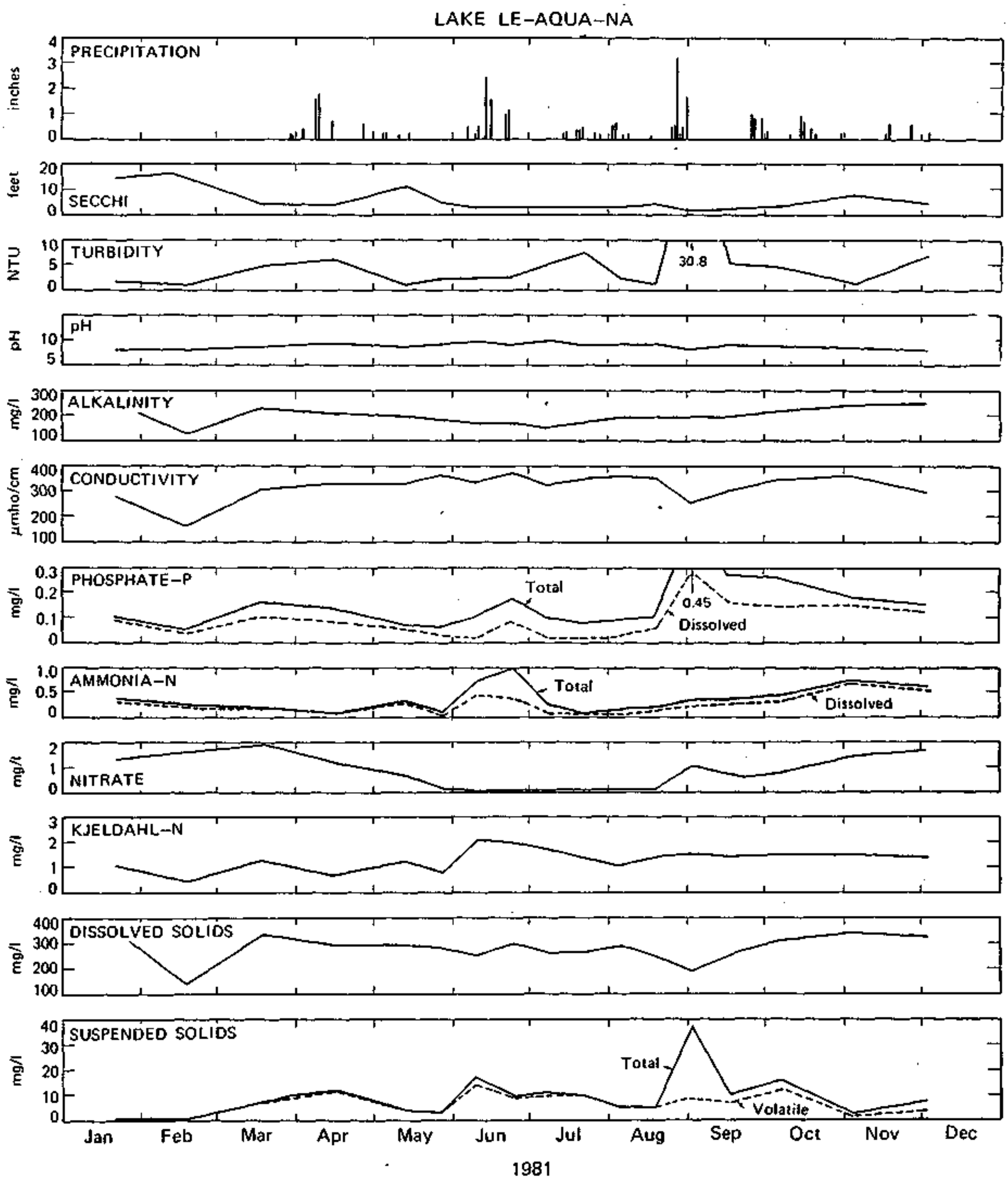


Figure 13. Temporal variations in near surface water quality characteristics at the deep station

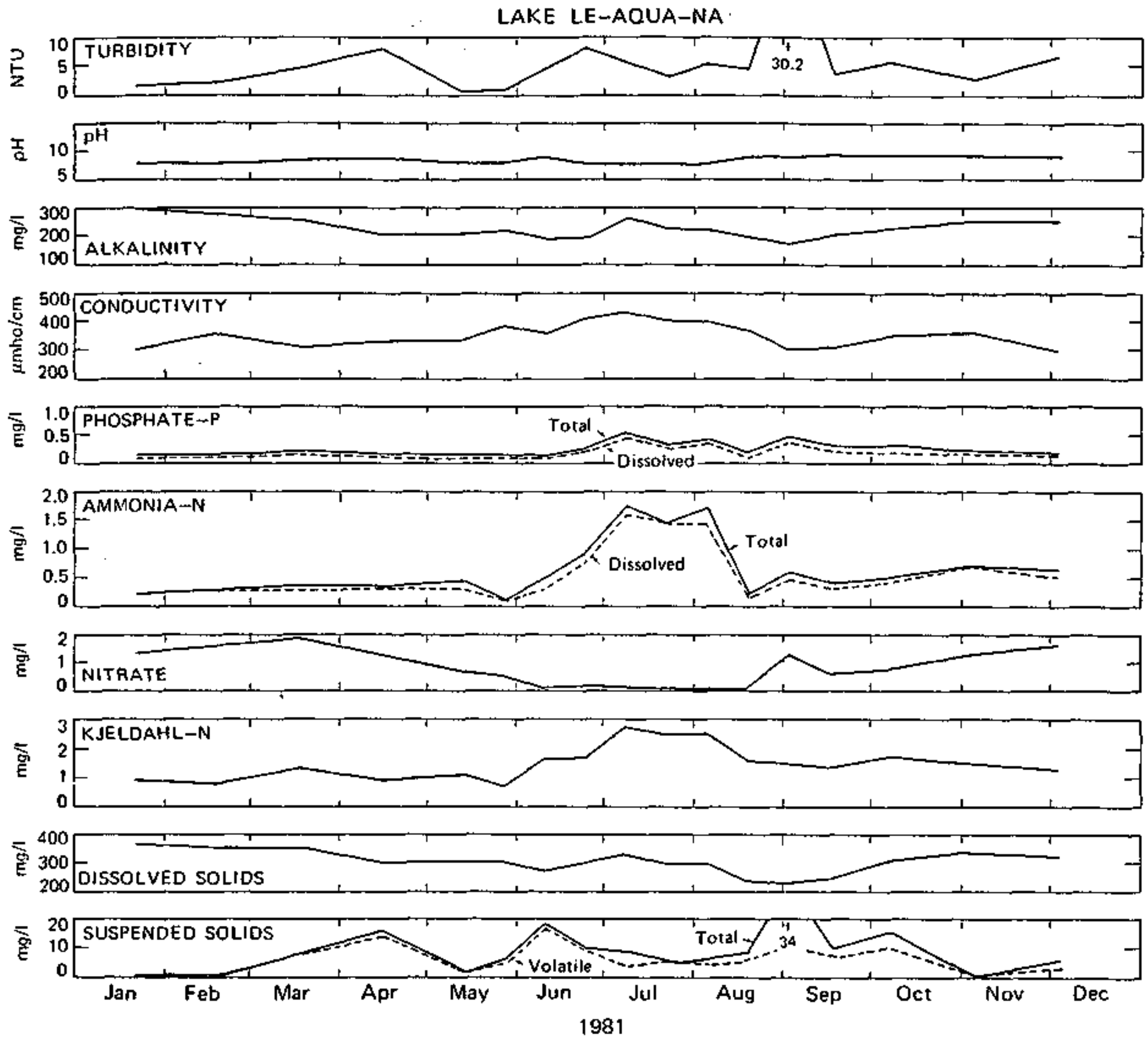


Figure 14. Temporal variations in mid-depth water quality characteristics at the deep station

utilizes carbon dioxide, removing it from bicarbonate, when no free carbon dioxide exists in the water medium. Decomposition and respiration tend to reduce pH and increase bicarbonates.

The alkalinity of a water is its capacity to accept protons and is generally imparted by bicarbonate, carbonate, and hydroxide components. The species makeup of alkalinity is a function of pH and mineral composition. The carbonate equilibrium, in which carbonate and bicarbonate ions and carbonic acid are in equilibrium, is the chemical system present in natural waters.

The pH and alkalinity values observed in Lake Le-Aqua-Na are typical of Illinois lakes. The range of pH values was the highest for the surface waters (7.6-10.0) and the lowest for the near bottom waters (7.4-8.5).

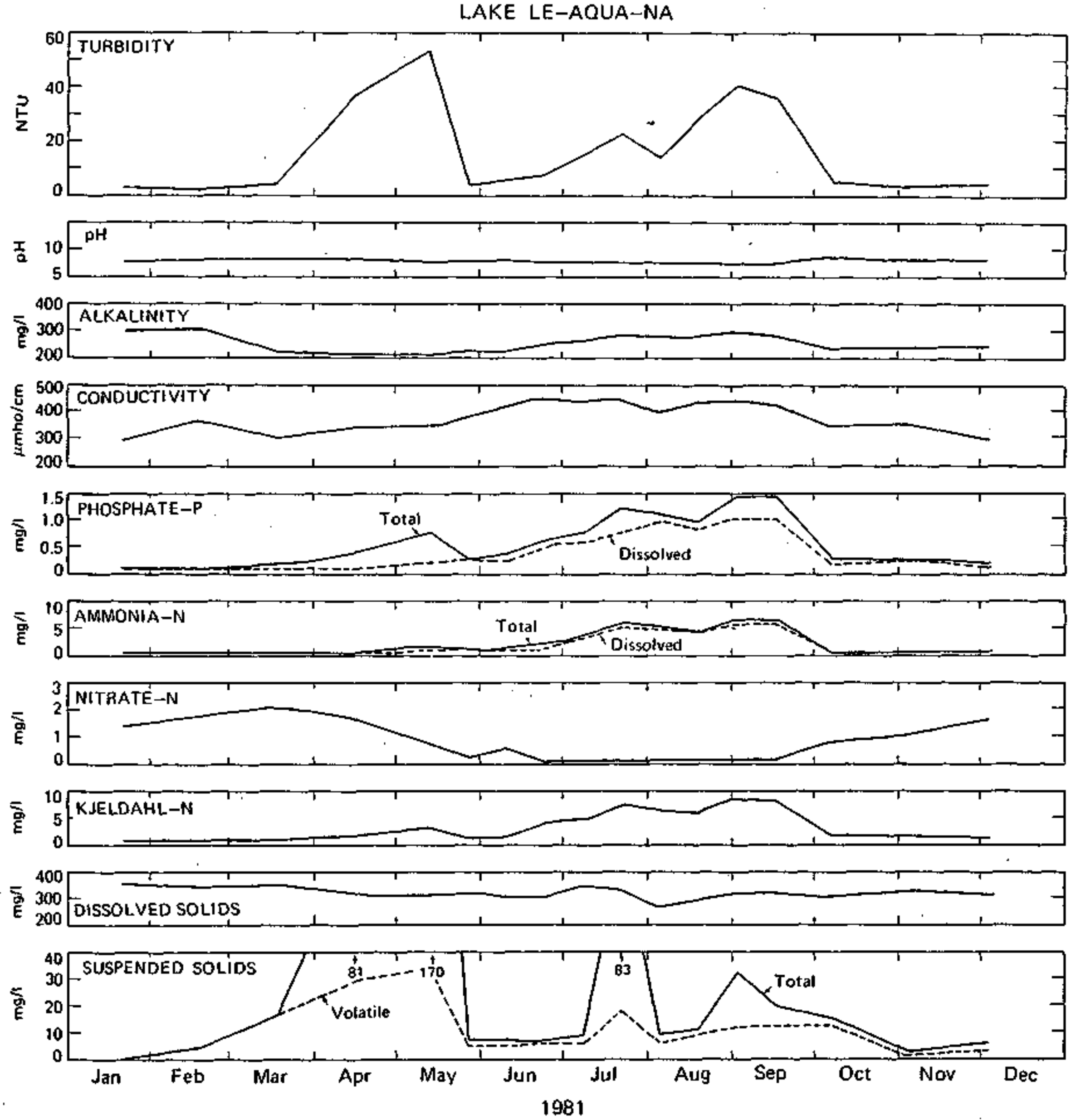


Figure 15. Temporal variations in near bottom water quality characteristics at the deep station

Also, alkalinity decreased in the surface water samples during summer months, presumably due to algal photosynthesis, and increased at the same time in the bottom water samples. Mean alkalinity values for the surface, raid-depth, and deep water samples were 188, 214, and 251 mg/l, respectively.

Conductivity. Specific conductance provides a measure of a water's capacity to convey electric current and is used as an estimate of the dissolved mineral quality of water. This property is related to the total concentration of ionized substances in water and the temperature at which the measurement is made. Specific conductance is affected by factors such as the nature of dissolved substances, their relative concentrations, and the ionic strength of the water sample. The geochemistry of the drainage basin is the major factor determining the chemical constituents in the waters. Practical applications of conductivity measurements include determination of the purity of distilled or deionized water, quick determination of the variations in dissolved mineral concentrations in water samples, and estimation of dissolved ionic matter in water samples.

The mean conductivity values for the lake water samples were 314 µmho/cm for the surface, 343 µmho/cm for the mid-depth, and 379 µmho/cm for the near bottom. The increasing trend of conductivity toward the lake bottom follows the same pattern as for alkalinity. Conductivity of bottom waters was high during the summer months, indicating the increased mineralization of organic matter under anaerobic conditions. Lower conductivity values at the surface reflect biological uptake of dissolved minerals. The temporal variations of conductivity in the lake waters are shown in figures 13, 14, and 15.

Phosphorus. Phosphorus as phosphate may occur in surface waters or groundwaters as a result of leaching from minerals or ores, natural processes of degradation, or agricultural drainage. Phosphorus is an essential nutrient for plant and animal growth and, like nitrogen, it passes through cycles of decomposition and photosynthesis.

Because phosphorus is essential to the plant growth process, it has become the focus of attention in the entire eutrophication issue. With phosphorus being singled out as probably the most limiting nutrient and the one most easily controlled by removal techniques, various facets of phosphorus chemistry and biology have been extensively studied in the natural environment. To prevent biological nuisance, the Illinois Pollution Control Board (1979) stipulates, "Phosphorus as P shall not exceed 0.05 mg/l in any reservoir or lake with a surface area of 20 acres or more or in any stream at the point where it enters any reservoir or lake."

In any river system, the two aspects of interest for phosphorus dynamics are the phosphorus concentration and phosphorus flux (concentration times flow rate) as functions of time and distance. The concentration itself indicates the possible limitation that this nutrient can place on vegetative growth in the stream. The phosphorus flux is a measure of phosphorus transport rate at any point in the river. This aspect will be dealt with subsequently in the section on the nutrient budget for the lake.

Unlike nitrate-nitrogen, phosphorus applied as fertilizer is held tightly to the soil. Most of the phosphorus carried into streams and lakes from runoff over cropland will be in the particulate form. On the other hand, the major portion of phosphate-phosphorus emitted from municipal sewer systems is in a dissolved form. This is true of phosphorus generated from anaerobic degradation of organic matter in the lake bottom. Consequently, the form of phosphorus, namely particulate or dissolved, is indicative of its source to a certain extent.

From his experience with Wisconsin lakes, Sawyer (1952) concluded that aquatic blooms are likely to develop in lakes during summer months when concentrations of inorganic nitrogen and inorganic phosphorus are in excess of 0.3 and 0.01 mg/l, respectively. These critical levels for nitrogen and phosphorus concentrations have "been accepted and widely quoted in scientific literature.

A summary of the observations for total and dissolved phosphate-phosphorus in the lake is given in table 15. Temporal variations in phosphorus content in the lake are depicted in figures 13, 14, and 15. Even the lowest observed total phosphorus value was 5 to 10 times higher than the critical value suggested by Sawyer (1952). The mean dissolved phosphorus levels in the lake varied from 0.09 mg/1 at the surface to 0.41 rag/1 near the bottom. Phosphorus level tended to increase in the lake after a heavy rainfall, and this phenomenon was most pronounced during the September 2, 1981, sampling which was preceded by a week-long heavy rainfall. The total and dissolved phosphorus levels in the lake after the spring turnover were 0.16 and 0.10 mg/1, respectively. A significant and progressive increase in phosphorus content in the deep waters of the lake was noted during the summer months (figure 15), until the onset of fall turnover. The highest total phosphorus level measured in the lake was 1.44 mg/1. This occurred in the near bottom waters on September 2, 1981.

The ratio of dissolved phosphorus to the total phosphorus in the surface water samples varied from 0.20 to 0.90 with a mean value of 0.55. The high values ranging from 0.71 to 0.90 occurred during the months November through May when primary productivity was very low. During summer months, when the primary productivity in the lake was relatively high, the ratio varied from 0.20 to 0.50 with a mean of 0.32.

The ratio of dissolved phosphorus to total phosphorus at mid-depth varied from 0.25 to 0.89 with a mean of 0.68 for the duration of the lake monitoring. Corresponding values for the deep station were 0.24 to 1.00, and 0.69. The mean values at these locations during the summer months were respectively 0.69 and 0.77. No biological uptake of dissolved phosphorus took place at these locations where anoxic conditions prevailed during summer months. The high concentrations of dissolved and total phosphorus levels at mid-depth and deep stations during summer months were the result of mineralization of organic-rich bottom sediments under anaerobic conditions.

Nitrogen. Nitrogen in natural waters is generally found in the form of nitrate, organic nitrogen, and ammonia-nitrogen. Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrates also occur in percolating groundwaters. Ammonia-nitrogen, being a constituent of the complex nitrogen cycle, results from the decomposition of nitrogenous organic matter. Ammonia-nitrogen can also result from municipal and industrial waste discharges to streams and rivers.

The concerns about nitrogen as a contaminant in water bodies are twofold. First, because of adverse physiological effects on infants and because the traditional water treatment processes have no effect on the removal of nitrate, concentrations of nitrate plus nitrite as nitrogen are limited to 10 mg/l in public water supplies. Second, a concentration in excess of 0.3 mg/l is considered sufficient to stimulate nuisance algal blooms (Sawyer, 1952). The 1PCB stipulates that ammonia-nitrogen and nitrate plus nitrite as nitrogen should not exceed 1.5 and 10.0 mg/1, respectively.

Nitrogen is one of the principal elemental constituents of amino acids, peptide, proteins, urea, and other organic matter. Various forms of nitrogen—for example, dissolved organic nitrogen and inorganic nitrogen such as ammonium, nitrate, nitrite, and elemental nitrogen—cannot be used to the same extent by different groups of aquatic plants and algae.

Vollenweider (1968) reports that in laboratory tests, the two inorganic forms of ammonia and nitrate are as a general rule used by planktonic algae to roughly the same extent. However, Wang et al. (1973) reported that during periods of maximum algal growth under laboratory conditions, ammonium-nitrogen was the source of nitrogen preferred by planktons. In the case of higher initial concentrations of ammonium salts, yields were noted to be lower than with equivalent concentrations of nitrates (Vollenweider, 1968). This was attributed to the toxic effects of ammonium salts. The use of nitrogenous organic compounds has been noted by several investigators, according to Hutchinson (1957). However, Vollenweider (1968) cautions that the direct use of organic nitrogen by planktons has not been definitely established, citing that not one of 12 amino acids tested with green algae and diatoms was a source of nitrogen when bacteria-free cultures were used. But the amino acids were completely used up after a few days when the cultures were inoculated with a mixture of bacteria isolated from water. He has opined that in view of the fact that there are always bacterial fauna active in nature, the question of the use of organic nitrogen sources is of more interest to physiology than to ecology.

The mean and range of values for ammonia, nitrate, and Kjeldahl-nitrogen in the lake are included in table 15, and the temporal variations in these parameters are shown in figures 13, 14, and 15. Mean inorganic nitrogen (total ammonia-nitrogen and nitrate-nitrogen) was always higher than the suggested critical concentration (0.3) for nitrogen. The mean values for total ammonia-nitrogen increased from 0.34 mg/1 at the surface to 2.42 mg/1 at the bottom. Nitrate-nitrogen mean values were 0.73 mg/1 at the surface, 0.78 mg/1 at mid-depth, and 0.66 mg/1 at the bottom. Kjeldahl-nitrogen mean values showed an increasing trend toward the bottom of the lake. The highest nitrate-nitrogen concentration of 1.87 mg/1 was recorded for mid-March.

Significant decreases in nitrate-nitrogen concentrations were detected throughout the lake during summer months. Ammonia and Kjeldahl-nitrogen concentrations increased severalfold at the mid-depth and the deep sampling points during the summer thermal stagnation period. This is a clear indication of the intense anaerobic decomposition of the organic debris occurring on the lake bottom.

Total Solids, Total Dissolved Solids, and Suspended Solids. Total solids, as presented here, include total dissolved solids and suspended solids. In natural waters, the dissolved solids consist mainly of carbonates, bicarbonates, sulfates, chlorides, phosphates, and nitrates of calcium, magnesium, sodium, and potassium with traces of iron, manganese, and other substances. The constituent composition of these minerals is to a large extent dependent on the geochemistry of the area contributing to the surface or groundwater resource. The amount of suspended solids found in impounded waters is small compared with the amount found in streams because solids tend to settle to the bottom in lakes. However, in shallow lakes this aspect is greatly modified by wind and wave actions and by the type and intensity of use to which these lakes are subjected.

All salts in solution change the physical and chemical nature of the water and exert an osmotic pressure. Some have physiological as well as toxic effects. However, possible synergistic or antagonistic interactions between mixed salts in solution may cause the effects of salts in combination to be different from those of salts occurring separately.

Greeson (1971) observed that high dissolved solids contents of Oneida Lake (New York) in 1967 and 1969 accompanied the high production of algae. Low dissolved solids content in 1968 accompanied lesser algal production. He concluded that these relationships indicate that the dissolved solids content is an important index of potential productivity conditions because no element, ion, or compound is likely to be a limiting factor on algal production when the dissolved solids content is high.

Dissolved solids concentrations found in Lake Le-Aqua-Na are typical of midwestern lakes. Abnormally high suspended solids concentrations were found in the lake only for the September 2, 1981, sampling trip. As indicated earlier, this was due to a week-long heavy rainfall preceding the sampling date. On this particular occasion only, the suspended sediments were predominantly inorganic in nature for the surface and mid-depth samples. Otherwise, the major portion of the suspended sediments was organic (volatile) matter, indicating that transparency was influenced primarily by algae. High suspended sediment values reported for the lake near-bottom samples may be due partly to the accidental lake bottom disturbance while sampling with a Kemmerer sampler, and partly to the settling of particulate matter from the water column. The results for solids determinations are shown in table 15 and in figures 13, 14, and 15.

Biological Characteristics

Algae. The total algal counts and the species distribution of algae found in the lake are shown in table 16. Chlorophyll-a content and algal biomass are also listed in the table. Except for the observations during May, algal counts in the lake were found to be of bloom proportions (> 500 cts/ml), with blue-green dominating. Blue-green algae create unsightly conditions in the lake by forming algal scum under quiescent lake conditions. Chlorophyll-a was found to peak on July 8, 1981, with a concentration of 93 µg/l. Algal biomass was found to be the highest on June 24, 1981, with a concentration of 99.591 mm^3/l. Relatively large numbers of flagellates were found in the water sample on that date. These organisms are much larger than the other types of algae found in the lake,

Table 16. Algal Types and Densities, Chlorophyll-a, and Biomass in Lake Le-Aqua-Na
(Algal densities in counts per milliliter)

date	*BG*	*G*	*D*	*F*	*0*	*Total*	*Chlorophyll-a (µg/l)*	*Biomass (mm^3/l)*
5/13/81			120			120	20	0.812
5/27/81	120	30	10			160	30	0.451
6/10/81	1210	300				1510	70	18.937
6/24/81	1700	180	60	10		1950	80	99.591
7/08/81	3810	390	230	70	50	4550	93	82.033
7/22/81	2680	1450			120	4250	47	62.676
8/05/81	4790	2825	170		370	8155	53	12.295
8/19/81	5310	30	190	20	770	6320	27	11.220
9/02/81	1710	170	1040	180	305	3405	27	12.018
9/17/81	150	490	3120	1775	770	6305	2	34.571

Note: BG = blue-greens; G = greens; D = diatoms; F = flagellates;
0 = others

Table 17. Relative Dominance of Algal Types
(Percent of total)

Date	*BG*	*G*	*D*	*F*	*0*
5/13/81			100.0		
5/27/81	75.0	18.8	6.3		
6/10/81	80.1	19.9			
6/24/81	87.2	9.2	3.1	0.5	
7/08/81	83.7	8.6	5.1	1.5	1.1
7/22/81	63.1	34.1			2.8
8/05/81	58.7	34.6	2.1		4.5
8/19/81	84.0	0.5	3.0	0.3	12.2
9/02/81	50.2	5.0	30.5	5.3	9.0
9/17/81	2.4	7.8	49.5	28.2	12.2

Note: BG = blue-greens; G = greens; D = diatoms; F = flagellates;
0 = others

accounting for the very large biomass. There apparently is no correlation between biomass, chlorophyll-a, and the counts of algae found in Lake Le-Aqua-Na.

The relative dominance of algal types found in the lake is shown in table 17. Except for the first (May 13) and the last (September 17) observations made for algal enumeration, blue-greens were found to be the dominant algae in the lake during the summer months. Blue-green species constituted 50.2 to 87.2 percent of the total algae found in the lake between May 27 and September 2, 1981.

Table 18. Benthic Macroinvertebrates Collected from Lake Le-Aqua-Na (Individuals per square meter)

	Shallow station			
	6/10/81	7/8/81	8/5/81	9/2/81
Ceratopogonidae (biting midge)	345	201		14
Chaoborus (phantom midge)	1,062	6,717	345	115
Chironomidae (midge)	273	359	287	976
Hirudinea (leach)				14
Sphaevium (fingernail clam)	919			
Tubificidae (sludge worm)	1,593	129	258	14
Total	4,192	7,406	890	1,133
	Deep station			
Ceratopogonidae	29	14		
Chaoborus	32,909	11,209	12,056	2,885
Chironomidae	187	316	57	43
Ischnura (damsel fly)				14
Total	33,125	11,539	12,113	2,942

Benthic Organisms. The types and densities of benthic macroinvertebrate communities in the lake sediments are given in table 18. Chaoborus was the dominant species found in both the shallow and deep stations. The overall population density was higher in the deep station than in the shallow station at all times. This is probably due to the lack of fish predation in the hypolimnetic zone of the deep station, which was anoxic. Even though the number of Chironomidae found in the lake was relatively small compared to Chaoborus, Chironomidae constituted a sizable portion of the biomass. Relatively large numbers of large-sized Chironomidae were found in the samples. The overall averages of the macroinvertebrate densities were 3405 and 14,930 counts/m^2 for the shallow and deep stations, respectively. However, the benthic population in the shallow station was more diverse than that in the deep station. The average number of taxa per sampling was 4.25 in the shallow station versus 2.75 for the deep station.

Bacterial Densities. Bacterial densities found in the lake and in Waddams Creek upstream and downstream of the impoundment are shown in table 19. Total coliform, fecal coliform, and fecal streptococcus densities are included in the table. Fecal coliform density in the lake and in Waddams Creek downstream of the lake considerably exceeded 400/100 ml on September 2 and September 17, 1981. On September 2, 1981, the incubated samples for these two stations had fecal coliform growths too numerous to count. Fecal coliform densities in Waddams Creek upstream of the lake exceeded 400/100 ml all the time.

Table 19. Bacterial Densities in Lake Le-Aqua-Na and Waddams Creek
(Counts per 100 milliliters)

Bate, 1981	*Lake, deep station TC*	*FC*	*FS*	*W. Creek, upstream TC*	*FC*	*FS*	*W. Creek, downstream TC*	*FC*	*FS*
5/13	230	50	30	690		70	210		20
5/27	120	110	10	180		50	230		0
6/10	70	40	60		1,000	350	170	160	460
6/24	120	100	140	1,100	690	490	210	170	460
7/8	250	170	100	150		270			250
7/22	170	150	40			390	340	180	200
8/5	200		260	1,300	880	300	200	180	190
8/19	460	340	60	400		400	210		150
9/2		TNC	620	1,720	1,600	760		TNC	880
9/17	920	670	250	13,000	960	490	9,480	1,260	540

Note: TC - total coliform; FC = fecal coliform; FS = fecal streptococcus; TNC = too numerous to count

Fecal coliform/fecal streptococcus ratios (FC/FS) in the lake varied from 11.00 on May 5, 1981 to 0.67 on June 10, 1981, with an average value of 3.61. According to the Clean Lakes Program Guidance Manual (USEPA, 1980a), ratios of 4.0 and greater indicate pollution derived from human wastes; 2.0-4.0 suggests a predominance of human wastes in pollution; 1.0-2.0 represents a "gray area" of uncertain interpretation; 0.7-1.0 suggests a predominance of livestock or poultry wastes in mixed pollution; and values of 0.70 or less indicate pollution derived from livestock or poultry. The FC/FS ratios were less than 1.0 in only two of eight observations made in the lake. However, none of the values for Waddams Creek upstream of the lake was less than 1.0. The FC/FS ratios for Waddams Creek ranged from 1.41 to 2.93 with a mean of 2.25, indicating the human source as the dominant factor in the bacterial contamination.

Macrophytes. Aquatic vegetation is found in most lakes and is beneficial to the natural ecosystem. It provides food and cover for aquatic organisms, provides oxygen, and stabilizes bottom sediments. However, excessive vegetation generally interferes with recreational activities, adversely affects aquatic life, and destroys asthetic values to the extent of decreasing the economic values of properties surrounding a lake. Under these circumstances, aquatic plants are often referred to as weeds.

The areal extent and types of vegetation found in Lake Le-Aqua-Na are shown in figure 16. All the macrophytes found in the lake were the submergent type. The dominant types of vegetation in the lake were elodea and coontail. The shallow upper end of the lake was dense with these two types of macrophytes, which thrived in the lake at depths of 8 feet and less. About 13.5 acres of the lake, constituting 34 percent of the lake water surface, was covered by a dense growth of macrophytes. This portion of the lake was unsuitable for fishing or boating. The shallow portion of the lake was partially treated with 30 gallons of aquathol-K on June 8, 1981, for macrophyte control.

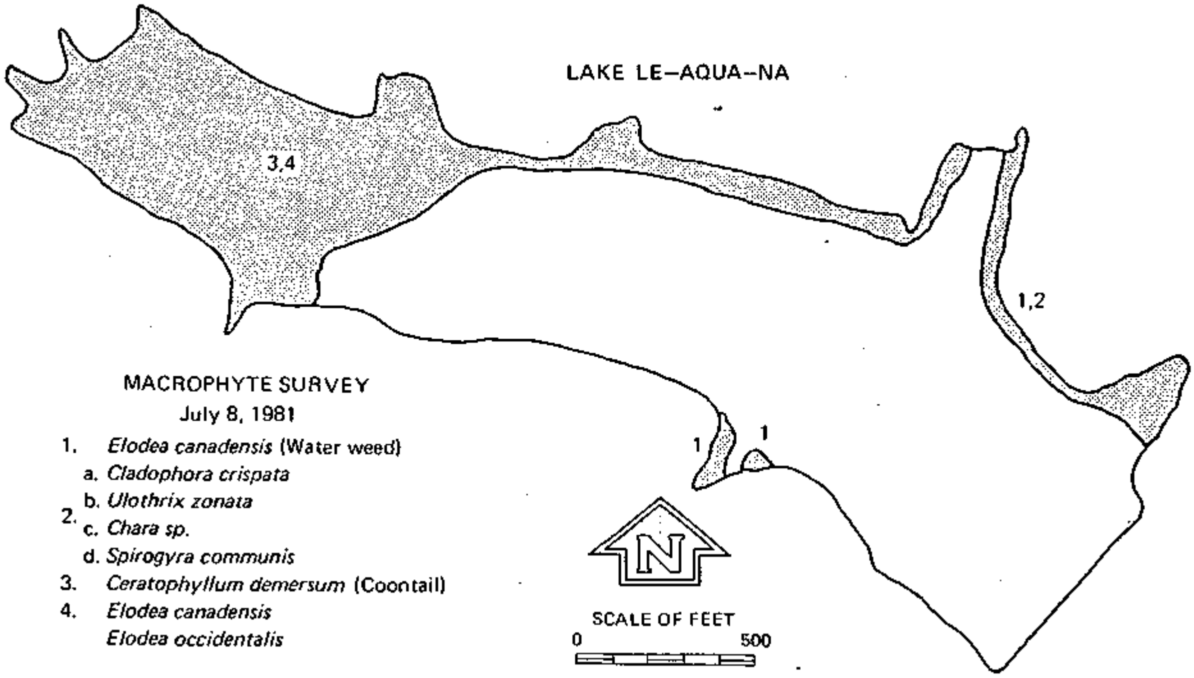


Figure 16. Types and areal extent of macrophytes

Fish Flesh Analyses

Rule 203(h) of the Water Pollution Regulations of Illinois (Illinois Pollution Control Board [IPCB], 1979) states that "any substance toxic to aquatic life shall not exceed one-tenth of the 96 hour median tolerance limit (96 hr TL_m) for native fish or essential food organisms." The primary concern in fish flesh analysis is in regard to the possibility of the bioaccumulation of toxic substances like mercury, organochlorine, and other organochemicals in fish which may prove detrimental to higher forms of life in the food chain, including humans, the ultimate consumers.

Composite fish flesh samples were analyzed for pesticides, organochemicals, and mercury. Composite samples of fish flesh were taken from five largemouth bass fish of the following sizes: 14.0", 1.63 lbs; 14.0", 1.68 lbs; 15.0", 2.10 lbs; 16.0", 2.50 lbs; and 16.5", 2.37 lbs. Concentrations of all the toxicants examined showed levels below detection limits. Chlordane, dieldrin, DDE, DDD, aldrin, lindane, heptachlor epoxide, DDT, endrin, benzene hexachloride, mirex, and hexachlorobenzene all showed concentrations <0.01 ppm. The concentration of methoxychlor was <0.05 ppm, and that of toxaphene was <0.5 ppm. PCBs were <0.1 ppm, and lipid content was 0.4 percent. Mercury content was 0.33 μg/g. The levels of pesticides and organochemicals found in the fish flesh samples are not cause for concern.

The concentrations of toxicants in fish flesh analyses were all well below the USFDA action levels for the edible filet portion of a fish. The USFDA action levels are:

	Action levels (ppm)
Heptachlor epoxide	0.3
PCBs	5.0
Chlordane	0.3
Total DDT	5.0
Dieldrin	0.3
Mercury	1.0

Historical Lake Water Quality Data

The detailed historical water quality data for Lake Le-Aqua-Na are limited, as shown in table 20. The only published data available are those gathered by IEPA. The data in table 20 pertain to the deep station, but similar data also were collected for stations in the middle and upper portions of the lake. These data are available from the USEPA STORET system.

Table 20. Historical Water Quality Data for the Deep Station

	6/25/79		*8/22/79*	
Parameter	*Surface*	*Bottom*	*Surface*	*Bottom*
Secchi disc transparency, inches	36		54	
Turbidity, JTU	2	2	3	27
pH (dimensionless)	9.5	7.9	8.2	7.5
Conductivity, umho/cm	370	460	420	350
Total alkalinity, mg/1	180	210	190	180
Nitrate-N, mg/1	0.5	0.5	0.5	0.6
Ammonia-N, mg/1	1.3	0.02	0.20	0.74
Total Kjeldahl-N, mg/1	1.7	2.2	1.4	1.7
Total phosphorus, mg/1	0.45	0.12	0.30	0.48
Total dissolved phosphorus, mg/1	0.02		0.21	0.38
Total suspended solids, mg/1	17	28	9	35
Volatile suspended solids, mg/1	13	6	8	1
Chloride, mg/1	11	12	10	9
Sulfate, mg/1	25		18	14
Total organic carbon, µg/1	9	4	7	8
Phytoplankton, counts/ml	30,620			
Dominant type	Blue-green			
Lead, total, µg/1	<10	<10		
Copper, total, µg/1	<5	<5		
Iron, total,µg/1	40	490		
Mercury, total, µg/1	0.0	0.0		
Zinc, total,µg/1	<10	<10		
Manganese, total, mg/1	0.1	1.15		
Arsenic, total, µg/1	<5	<5		
Cadmium, total, Mg/1	<2	<2		
Chromium, total, µg/1	<5	<5		

The values for the parameters reported for 1979 are within the range of values found during this investigation (see table 15). Algal counts found in 1979 were about four times higher than the maximum value for 1981. However, blue-green algae were the dominant algae in the lake. Concentrations of heavy metals in the lake waters were generally less than detection limits.

The Illinois Department of Conservation (IDOC) has maintained a detailed chronological record (unpublished) of the lake since 1956, giving details regarding fish surveys, fish stocking, fish management activities, algal and macrophyte control, lake water quality measurements, and other matters pertaining to the lake.

The lake experienced severe algal blooms during the first year of its existence and copper sulfate was applied to the lake at the rate of 10-1/3 lbs/acre. Submerged aquatic vegetation and nuisance proportions of filamentous algae existed in the lake during 1957. Sodium arsenite was used to control macrophyte growths in 1957. Macrophyte control by chemical means has been practiced annually since the very beginning of the lake's existence with only a very few exceptions, as in 1969, 1970, and 1974.

The Illinois Department of Conservation took water depth soundings of the upper part of the lake in 1969 and again in 1974. It was estimated that the rate of loss of lake volume in the shallow end of the lake was 1 inch every 11.2 months. The rate of loss of storage capacity was estimated by measuring water depths at four transects in the shallow portion of the lake and calculating the difference in the water depths for the years 1969 and 1974. However, the transects selected during these two years did not correspond to each other, and the water levels in the lake when the soundings were taken might also have been different.

The IDOC fisheries biologists have monitored the lake periodically, determining the temperature, dissolved oxygen, pH, and alkalinity values for the lake at stations near the spillway (unpublished data). The pH and alkalinity values were found to be within the range of values observed during this investigation. The lake experienced severe oxygen depletion not only during summer months but also during winter months as early as in 1958. The historical data pertaining to the depth at which the dissolved oxygen was found to be about 1.0 mg/l, the pH, the alkalinity, and the maximum depth are listed in table 21. It should be noted that the lake was practically anoxic at depths 9 feet and below during August 1958 when the lake was not quite three years old. Also, during January 1977 there was no oxygen in the lake at depths below three feet.

Sediment Characteristics

Sedimentation in the Lake

Most midwestern streams transport a considerable amount of soil particles, especially during storm events. These sediments in transport are fine-sized material, generally smaller than 60 μm, and consist mainly of silt and clay. When streams discharge into impoundments, about 90

Table 21. Historical Data Regarding Dissolved Oxygen, Alkalinity, and Maximum Depth

Date	Depth at which DO of 1.0 mg/l was observed (feet)	pH	Alkalinity (mg/l)	Maximum depth (feet)
Aug. 14, 1958	9.0	8.4		22.0
Aug. 31, 1961	8.0			24.0
Feb. 24, 1964	16.0	7.6		21.0
Feb. 8, 1965	7.0	6.9		23.0
Jan. 26, 1966	*	7.8	240**	27.0
Mar. 1, 1967	22.0	7.2		25.0
Mar. 4, 1968	22.0	7.2		24.0
Jul. 28, 1969	12.0	7.6		23.0
Feb. 28, 1970	*	7.4		23.0
Feb. 10, 1971	18.0	6.7		23.0
Aug. 31, 1972	9.0	8.2		23.0
Jul. 31, 1973	15.0	7.6		23.0
Aug. 22, 1974	8.0			23.0
Dec. 7, 1976	20.0	7.5		20.0
Jan. 21, 1977	3.0			20.0

*Dissolved oxygen concentrations greater than 3.0 mg/l were observed throughout the water column
**0nly alkalinity data available for this period

percent of the sediment conveyed by stream waters is trapped in the impoundment. It is reported that the median rate of loss of reservoir volume due to sediment is 0.6 percent per year in Illinois (Roseboom et al., 1978). The highest and lowest sedimentation rates measured by the State Water Survey in 101 reservoirs are 5.67 and 0.15 percent per year, respectively.. In Illinois, the soil delivery to reservoirs from erosion varies from 1.3 to 2.3 tons per acre per year (Roseboom et al., 1978). Sediments, in addition to causing a loss of storage capacity, are instrumental in nutrient recycling, and are potential sources of contaminants such as heavy metals and organic pesticides.

Ten transects, shown in figure 2, were established and demarcated by permanent concrete survey monuments. Soundings for water depth and sediment thickness were made from a boat using a taut line along the transect sections at selected intervals. A spud bar was used to ascertain the depth of the original lake bottom. Figure 17 shows the cross sections of the lake at selected transects. The original lake bottom is shown by a dotted line and the present lake bottom by a solid line. The difference in elevation between the two lines is the extent of sediment accumulation in the lake since its inception.

On the basis of the sediment survey, it was determined that the storage capacity of the lake has been reduced from an original volume of 578.7 acre-feet to 487.2 acre-feet. This represents a loss in water

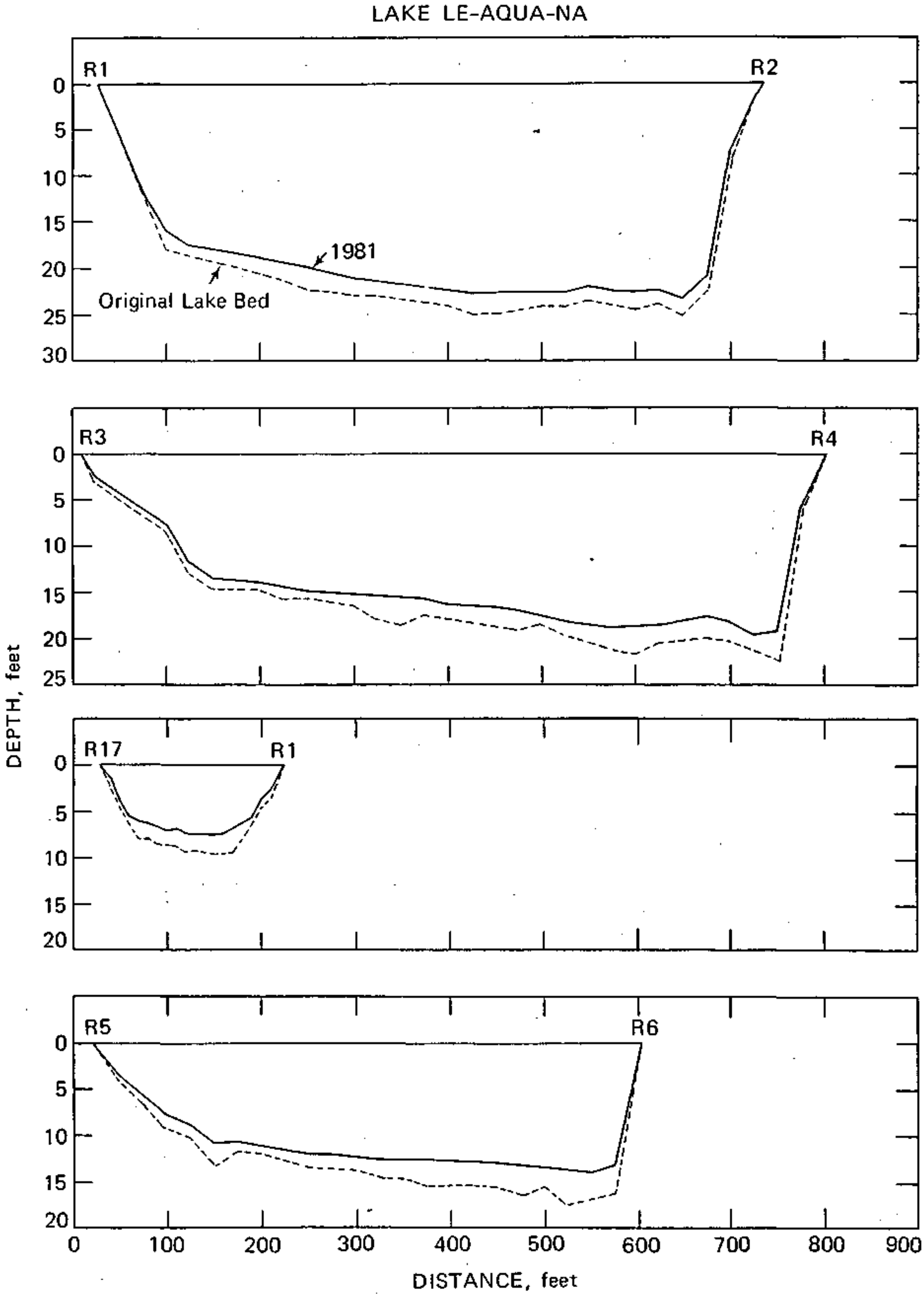


Figure 17. Reservoir cross sections at selected transects

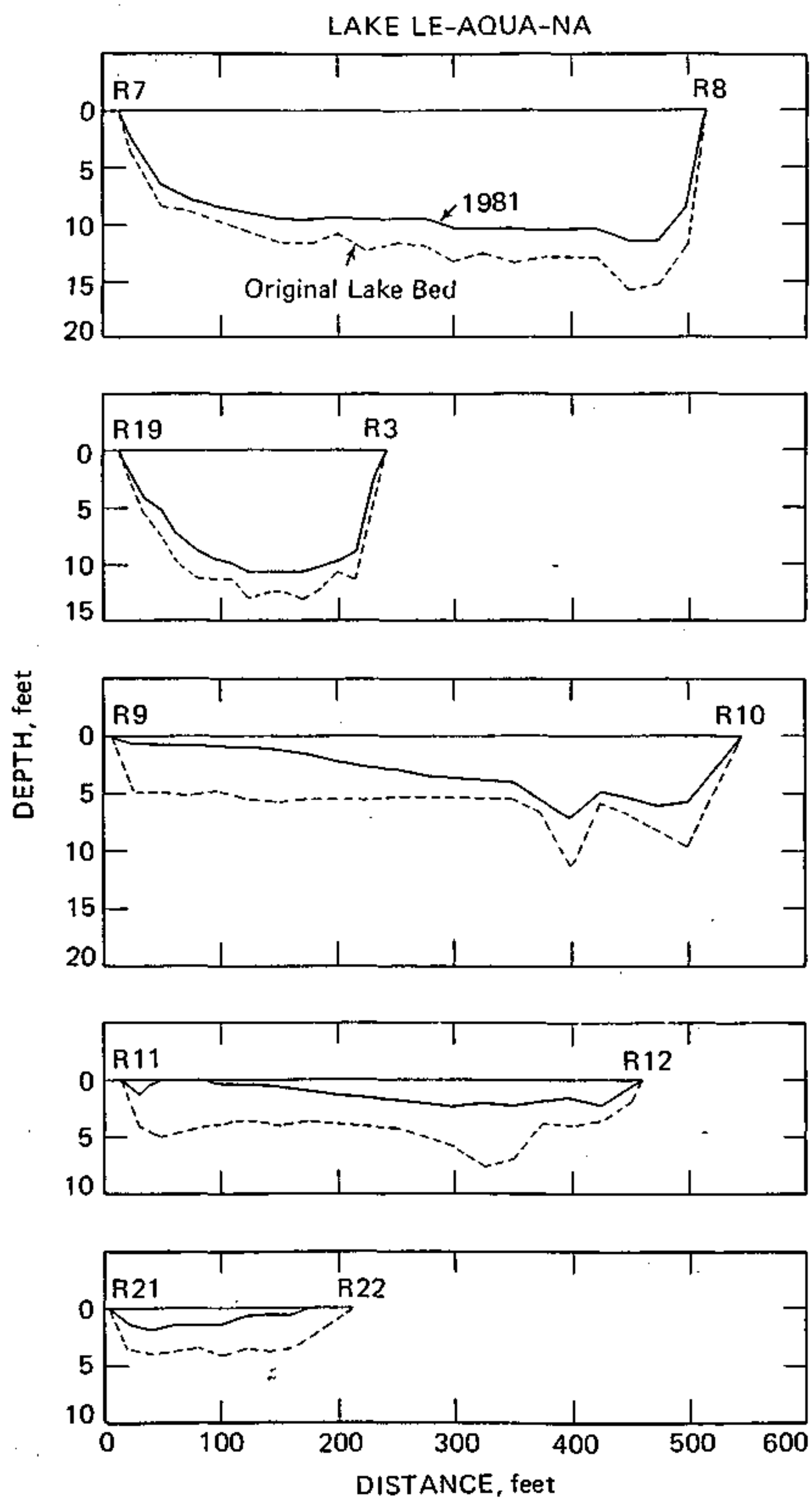


Figure 17. Concluded

storage of 15.8 percent in 25 years, or 0.63 percent per year. This rate of loss of capacity is the median rate observed in 101 Illinois lakes and reservoirs. The upper end of the lake and the original channel section within the impoundment show the greatest degree of siltation. If the density of the lake sediment is assumed to be 45 pounds per cubic foot, the estimated soil loss on the watershed is 1.53 tons per acre per year. This is within the range of values observed in other lakes in Illinois. A summary of the sediment survey is given in table 22.

With the aid of Brune's Curve (Brune, 1953), the trap efficiency of Lake Le-Aqua-Na was estimated as 92 percent, based on an average capacity-inflow ratio of 0.19. The estimated soil loss from the watershed is 3.53 tons/acre/year. The average annual sedimentation in the lake was estimated as 1.53 tons/acre. The sediment delivery ratio to the lake from the watershed amounts to 47.1 percent.

Surficial Sediments

Sediment Oxygen Demand Rates. Results of *in-situ* measurements of sediment oxygen demand rates are shown in table 23. Measurements were made in the shallow and deep stations, once during the period of thermal stratification and again after the fall turnover. In addition to the ambient water temperatures and observed sediment demand rates at the ambient water temperature levels, rates of sediment oxygen demand at 20 and 25°C were computed and are shown in this table for comparative purposes. The following equation was used:

$$SOD_T = SOD_{20}\ (1.047^{T-20})$$

where

SOD_T = sediment oxygen demand at any temperature, T°C

SOD_{20} = sediment oxygen demand at 20°C

Data on benthic organisms, algae, and sediment consistency obtained concomitantly with SOD measurements are shown in table 24.

The sediment oxygen demand rates observed in Lake Le-Aqua-Na are not excessive compared to the values observed for other lakes in Illinois. These values are in the lower end of the spectrum of values ranging from 1.66 g/m^2/day in Lake Eureka to 25.68 g/m^2/day in Pistakee Bay, determined by the Water Quality Section of the Illinois State Water Survey.

Sediment Consistency. Results of analyses of Ekman dredge samples for moisture content and volatile fractions are given in table 25. The sediments at the deep station were fluffier and capable of holding more water than the sediments obtained from the shallow station. Also the volatile fraction of the sediments was higher at the deep station than at the shallow station. On an average, shallow station samples were 44 percent dry solids (56 percent moisture content) with 7 percent volatile solids (93 percent fixed solids). Deep station samples were 31 percent dry solids (69 percent moisture content) with 10 percent volatile solids (90 percent fixed solids).

Table 22. Summary of Sedimentation Data,
Lake Le-Aqua-Na

Age		
	Years	
Built December 1955		
Survey 1981	25	
Watershed	*Sq mi*	*Acres*
Total area	3.67	2348.1
Area excluding lake	3.61	2308.6
Reservoir		
	Acres	
Surface area at spillway level	39.5	
Storage capacity at spillway level	*Acre-feet*	*Mil gal*
1955	578.7	189
1981	487.2	159
Capacity per square mile of drainage area*	*Acre-feet*	
1955	158	
1981	133	
Sedimentation	*Acre-feet*	
1955-1981	91.5	
Average annual accumulation of sediment**		
	Acre-feet from entire watershed	
1955-1981	3.66	
	Acre-feet per square mile	
1955-1981	1.00	
	Cubic feet per acre	
1955-1981	68.0	
	*Tons per acre****	
1955-1981	1.53	
Depletion of original storage	*Percent of original storage*	*Percent per year*
1955-1981	15.8	0.63

* Includes area of lake
** Excludes area of lake
*** Assumes unit weight of 45 pounds/cu ft

Dry solids in Lake Eureka and Canton Lake, which are also man-made lakes, were reported to vary from 26.0 to 53.7 percent (Roseboom et al., 1979). Volatile solids fractions ranged from 6.0 to 10.0 percent. The values observed for Lake Le-Aqua-Na appear to be typical of other man-made lakes in Illinois.

Table 23. *In-situ* Sediment Oxygen Demand Rates

Location	Date	Water depth(ft)	Ambient temperature, T(°C)	SOD (g/m^2 /day) At T°C	At 25°C	At 20°C
Shallow sta.	7/22/81	7.0	24.3	1.94	2.01	1.59
Shallow sta.	10/27/81	6.0	7.7	0.46	1.01	0.81
Deep sta.	7/22/81	24.0	12.0	1.43	2.60	2.07
Deep sta.	10/21/81	23.5	10.4	1.21	2.36	1.88

Table 24. Physical and Biological Data for SOD Measurement Dates

Location	Date	Benthic organisms (cts/m^2)	Algae (cts/ml)	Sediments % dry	% volatile
Shallow sta.	7/22/81	1,440	4840	42.0	7.8
Shallow sta.	10/27/81	4,760	450	45.5	7.7
Deep sta.	7/22/81	6,120	3770	34.2	11.1
Deep sta.	10/21/81	27,670	470	33.7	10.4

Table 25. Consistency of Surficial Sediments

Date	Shallow station % dry	% volatile	Deep station % dry	% volatile
6/10/81	38.8	6.8	30.8	9.8
7/08/81	43.0	6.4	31.3	9.1
8/05/81	49.1	6.5	30.0	10.8
9/02/81	45.7	7.9	32.5	11.2

Elutriation Tests. Results of analyses of the elutriation tests are shown in table 26 for metals concentrations and in table 27 for organochemicals. Metals concentrations found in the elutriated samples are well below the USEPA water quality criteria (USEPA, 1976) except in the case of manganese. High manganese concentrations are typical of bottom waters of Illinois impoundments. Barium, boron, cadmium, chromium, copper, iron, nickel, silver, zinc, and lead were all found to be below the IPCB's stipulated limits. As shown in table 27, concentrations of organochemicals in the elutriated samples were below detection limits and well below the concentrations stipulated by the Illinois Pollution Control Board (1979) as general standards for aquatic life and for agricultural and other uses.

Table 26. Concentrations of Metals in Elutriated Samples

Parameter	*Shallow station* Sample 1	*Shallow station* Sample 2	*200 feet upstream of shallow station* Sample 1	*200 feet upstream of shallow station* Sample 2
Calcium	35	35	28	28
Magnesium	23	23	17	17
Sodium	5.8	6.1	6.3	14.0
Potassium	5.7	5.8	4.9	5.1
Manganese	1.7	1.7	1.3	1.3
Total Kjeldahl-N	5.8	5.7	8.0	8.2
Total phosphorus	0.16	0.11	0.09	0.14
COD	68	64	45	50
Barium	120	120	97	96
Beryllium	0.5	0.5	0.5	0.5
Boron	41	42	42	43
Cadmium	3.0	3.0	3.0	3.0
Chromium	10.0	10.0	10.0	10.0
Cobalt	5.0	5.0	5.0	5.0
Copper	5.0	5.0	5.0	5.0
Iron	240	290	170	170
Nickel	5.0	5.0	5.0	5.0
Silver	3.0	3.0	3.0	3.0
Strontium	49	50	40	40
Vanadium	5.0	5.0	5.0	5.0
Zinc	49	51	46	74
Lithium	Trace	Trace	Trace	Trace
Lead	50	50	50	50

Note: Values for the first 8 parameters are in mg/l; all others are in µg/l. All analyses were performed on total samples.

Table 27. Concentrations of Organochemicals in Elutriated Samples (Concentrations in micrograms per liter)

Parameter	*Shallow station*	*200 feet upstream of shallow station*	*IPCB standards*
PCBs	0.2	0.2	
Dieldrin	<0.01	<0.01	1.0
Chlordane	<0.02	<0.02	3.0
DDT	<0.01	<0.01	50.0
Heptachlor epoxide	<0.01	<0.01	0.1
Lindane	<0.01	<0.01	4.0
Aldrin	<0.01	<0.01	1.0
Endrin	<0.01	<0.01	0.2
Heptachlor	<0.01	<0.01	0.1
Methoxychlor	<0.05	<0.05	100.0

Table 28. Particle Size Distributions in Sediment Core Samples

	Percent retained on 0.062 mm sieve	*Percent finer than 0.062 mm size (silt & clay)*	*Percent finer than 0.004 mm size (clay)*
Shallow station			
Sample 1 (27)*			
Top	4.9	95.1	15.6
Middle	25.5	74.5	16.0
Bottom	10.2	89.8	13.7
Sample 2 (15)*			
Top	2.6	97.4	19.3
Middle	6.0	94.0	15.8
Bottom	2.4	97.6	13.6
200 *feet upstream of shallow station*			
Sample 1 (22)*			
Top	2.0	98.0	22.2
Middle	1.0	99.0	14.1
Bottom	16.7	83.3	8.7
Sample 2 (24)*			
Top	1.6	98.4	17.0
Middle	0.6	99.4	23.9
Bottom	18.9	81.1	12.6

*Length of core sample in inches

Core Sediments

Particle Size Distributions. Results of particle size analyses are shown in table 28. Numbers within parentheses after the sample number designations indicate the length in inches of core samples obtained from the lake. Approximately 92 percent of the core sediments are composed of silt and clay, with clay constituting 16 percent of the total. Materials retained on a 0.062-mm sieve constituted 8 percent of the total.

Chemical Characteristics. Concentrations of heavy metals (arsenic, cadmium, copper, iron, lead, manganese, mercury, and zinc) found in top, middle, and bottom portions of the core samples obtained from the lake are shown in table 29. A detailed discussion of the chemical characteristics of these metals, their physiological effects on living organisms, and their sources and occurrences in the environment is given by Kelly and Hite (1979).

Kelly and Hite (1979) also report the concentrations of metals found in surficial sediments in 63 Illinois lakes monitored by the IEPA. These concentrations are shown in table 30. The concentrations of metals found in the core samples from Lake Le-Aqua-Na were generally less than the mean values found by the IEPA for Illinois lakes, and were well within the range indicated by that agency.

Table 29. Concentrations of Metals and Nutrients in Sediment Core Samples (Concentrations in milligrams per kilogram)

	Shallow station						*200 feet upstream of shallow station*					
	*Sample 1 (27)**			*Sample 2 (15)**			*Sample 1 (22)**			*Sample 2 (24)**		
	Top	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
Arsenic	6.9	4.7	4.2	5.6	10.0	6.0	6.0	14.0	10.0	6.2	25.0	36.0
Cadmium	1.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.2
Chromium	15.0	13.0	14.0	17.0	15.0	14.0	18.0	19.0	14.0	18.0	16.0	16.0
Copper	11.0	11.0	11.0	17.0	15.0	11.0	17.0	16.0	12.0	17.0	15.0	17.0
Iron	12,000	11,000	12,000	17,000	13,000	12,000	19,000	17,000	13,000	20,000	16,000	15,000
Lead	12.0	11.0	11.0	13.0	17.0	15.0	15.0	17.0	13.0	19.0	16.0	18.0
Manganese	520	630	740	620	490	550	580	510	540	620	570	550
Mercury	0.03	0.03	0.04	0.05	0.05	0.03	0.04	0.04	0.03	0.05	0.04	0.04
Zinc	52.0	46.0	51.0	73.0	56.0	45.0	75.0	75.0	55.0	79.0	73.0	69.0
Total Kjeldahl-N	1380.0	1050.0	1690.0	2400.0	1640.0	956.0	2400.0	3000.0	1790.0	2500.0	2060.0	2050.0
Total phos.	410.0	333.0	392.0	624.0	455.0	307.0	675.0	578.0	401.0	699.0	551.0	794.0
COD	80,000	25,000	42,000	62,000	40,000	18,000	56,000	53,000	70,000	59,000	53,000	64,000
Volatile solids (percent)	4.9	4.4	5.5	8.3	5.7	3.8	7.8	7.4	6.5	8.2	6.9	8.5

*Length of core sample in inches

Table 30. Concentrations of Metals in Surficial Sediments in 63 Illinois Lakes (Concentrations in milligrams per kilogram)

	Mean value	*Range of values*
Arsenic	12.0	0.5 — 110.0
Cadmium	0.98	0.50 — 4.00
Chromium	21.6	1.0 — 75
Copper	42	3 — 560
Iron	28,600	5,700 — 44,700
Lead	57	3 — 250
Manganese	1,300	170 — 14,000
Mercury	0.10	0.0 — 2.40
Zinc	113	11 — 750

Source: Kelly and Hite (1979)

The arsenic value of sample 2 taken 200 feet upstream of the shallow station was found to be higher than the values found for other samples (table 29). This falls within the "elevated" category of the classification of Illinois lakes given by Kelly and Hite (1979). However, this is not a cause for concern in the case of lake sediment removal because the final arsenic concentration is likely to be less when this lake sediment is mixed with other sediments with low arsenic levels in the lake basin (Donna Sefton, IEPA, personal communication). Except for a single observation for arsenic (36.0 mg/kg) all the values reported in table 29 for all the parameters fall within the "normal" category of Kelly and Hite's classification. Values for total Kjeldahl-nitrogen, total phosphorus, chemical oxygen demand (COD), and percent volatile solids in Le-Aqua-Na lake sediments also were found to be in the normal range for Illinois lakes.

Table 31. Concentrations of Trace Organics in Sediment Core Samples
(Concentrations in micrograms per kilogram)

Parameter	*Shallow station (27)** *Top*	*Middle*	*Bottom*	*200 feet upstream of shallow station (22)** *Top*	*Middle*	*Bottom*
PCBs	<10	<10	<10	<10	<10	<10
Dieldrin	<1	<1	<1	2.1	<1	<1
Chlordane	3.0	3.2	<1	2.7	<1	<1
DDT	<1	<1	<1	<1	<1	<1
Heptachlor epoxide	1.1	<1	<1	<1	<1	<1
Lindane	<1	<1	<1	<1	<1	<1
Aldrin	<1	<1	<1	<1	<1	<1
Endrin	<1	<1	<1	<1	<1	<1
Heptachlor	<1	<1	<1	<1	<1	<1
Methoxychlor	<5	<5	<5	<5	<1	<5

*Length of core sample in inches

Concentrations of trace organics found in the sediment core samples are shown in table 31. The concentrations of all the parameters examined were below detection limits except for chlordane in three analyses and heptachlor epoxide in one analysis. Kelly and Hite (1979) have reported that of 266 samples from 63 lakes, heptachlor epoxide was detected in 25 percent of the samples. Observed values ranged from 1.1 to 13.0 μg/kg. Specific values for chlordane were not reported in their report.

Inflows and Outflows

A water budget for the lake was developed taking into account Waddams Creek inflow into the lake, outflow from the lake, direct precipitation falling on the lake, and lake evaporation.

The general expression for the hydraulic budget of a lake is:

$$\Delta S = P + I + U - E - O$$

where

- ΔS = change in storage
- P = precipitation on lake surface
- I = inflow from surface stream
- U = subsurface inflow through the lake bottom
- E = evaporation
- O = outflow through surface outlet

Streamflows and precipitation values for Lake Le-Aqua-Na were obtained from actual field determinations', and evaporation losses were calculated on the basis of values suggested by Roberts and Stall (1967). Table 32 gives the monthly 1981 observed rainfall in the watershed, and the estimated evaporation losses.

Table 32. Precipitation and Estimated Evaporation in Lake Le-Aqua-Na Watershed, 1981

Month, 1981	*Precipitation (inches)*	*Evaporation (inches)*
March	0.25	1.75
April	5.35	2.80
May	0.45	4.10
June	6.90	4.60
July	2.00	5.60
August	7.90	4.40
September	2.40	3.10
October	2.70	2.10
November	1.65	0.89
December	0.25	0.34

Table 33. Monthly Water Budgets for Lake Le-Aqua-Na

	Inflow (cfs)		*Outflow (cfs)*		
Month, 1981	*Waddams Creek*	*Precipitation*	*Waddams Creek*	*Evaporation*	*Inflow minus outflow*
March	1.00	0.01	1.00	6.09	-0.08
April	5.70	0.30	5.95	0.15	-0.10
May	0.31	0.02	0.86	0.21	-0.74
June	1.01	0.38	2.54	0.25	-1.40
July	0.35	0.11	0.52	0.30	-0.36
August	7.70	0.42	17.06	0.24	-9.18
September	3.26	0.13	4.85	0.17	-1.63
October	4.00	0.14	4.52	0.11	-0.49
November	2.40	0.09	2.98	0.05	-0.54
December	2.30	0.01	2.25	0.02	+0.04

Monthly water budgets for the lake during 1981 are shown in table 33. All the values are expressed in cubic feet per second. Waddams Creek inflow into the lake and the outflow from the impoundment are the monthly average of flow values obtained from daily single observations of stage gages. Precipitation and evaporation values in inches for the respective months were converted to flow rates in cubic feet per second using a lake surface area of 39.5 acres. The last column in table 33 is presented as inflow minus outflow. The month to month change in lake storage was insignificant.

The water budget table does not include information for the months of January and February 1981. Inflow and outflow would have been negligible, if existent at all, because these streams and lakes are frozen in winter. It is seen from the table that outflow from the lake exceeds surface water inflow. The difference is attributed to the groundwater inflow, and the magnitude is indicated in column 5 of table 33. Groundwater flow into the lake during spring, summer, and fall will average about 0.90 cfs. This was developed by taking the average of the values for the months of May through November and excluding the value for August. The very high value of -9.18 in the last column of table 33 for the month of August was due to tributary flows from ungaged ephemeral creeks after heavy rainfalls.

The estimated total inflows and outflows for the year 1981 were respectively 1760 and 2620 acre-feet. The difference of 860 acre-feet between the measured outflow from the lake and the measured inflow into the lake constitute the combined effects of groundwater inflow and the inflow from the ungaged, ephemeral streams tributary to the' lake. On the basis of an average groundwater inflow rate of 0.90 cfs, the total groundwater inflow into the lake for the period of investigation is calculated as 535 acre-feet. The inflow from ungaged tributaries is estimated as 325 acre-feet. Discharge in ungaged creeks tributary to the lake occurred for very short periods, essentially on two occasions during this investigation.

The hydraulic retention time of the lake is 101 days when considering the measured inflows only, and 68 days when considering the total inflow, which includes the discharges from the ungaged rivulets and groundwater inflow.

Nutrient Budget

Although nitrogen and phosphorus are not the only nutrients required for algal growth, they are generally considered to be the two main nutrients involved in the lake eutrophication process. Despite the controversy over the role of carbon as a limiting nutrient, a vast majority of researchers regard phosphorus as the most frequently limiting nutrient in lakes.

Several factors have complicated attempts to quantify the relationship between lake trophic status and measured concentrations of nutrients in lake waters. For example, measured inorganic nutrient concentrations do not denote nutrient availability, but merely represent what is left over by the lake production process. A certain fraction of the nutrients (particularly phosphorus) become refractory while passing through successive biological cycles. In addition, numerous morphometric and chemical factors affect the availability of nutrients in lakes. Factors such as mean depth, basin shape, and detention time affect the amount of nutrients a lake can absorb without nuisance conditions. Nutrient budget calculations represent the first step in quantifying the dependence of lake water quality on the nutrient supply. It is often essential to quantify nutrients from various sources from the viewpoint of management and eutrophication control.

A potential source of nitrogen and phosphorus for lakes is the watershed drainage, which can include agricultural runoff, urban runoff, swamp and forest runoff, domestic and industrial waste discharges, septic tank discharges from lakeshore developments, precipitation on the lake surface, dry fallout (i.e., leaves, dust, seeds, and pollen), groundwater influxes, nitrogen fixation, sediment recycling, and aquatic bird and animal wastes. Potential sinks can include outlet losses, fish catches, aquatic plant removal, denitrification, groundwater recharge, and sediment losses.

The sources of nutrients considered for Lake Le-Aqua-Na were tributary inputs from both gaged and ungaged streams, direct precipitation on the lake surface, internal nutrient recycling from bottom sediments under anaerobic conditions, and the point source waste discharge from the state park wastewater treatment facility. The discharge of nutrients from the lake through Waddams Creek was the only sink readily quantifiable.

The flow weighted-average method of computing nutrient transport by the tributary was used in estimating the phosphorus and nitrogen loads delivered by Waddams Creek. A summary of water quality characteristics observed for Waddams Creek during 1981 is shown in table 34. The mean and range of values for 17 individual observations for turbidity and various fractions of nitrogen, phosphorus, and solids content are shown in the table. Each individual observation for nitrogen and phosphorus concentrations in the tributary sample was used with the mean flow values for the period represented by that sample in computing the nutrient transport for the given period. The total amount of any specific nutrient transported by the creek is then given by the expression:

$$T = 5.394 \sum_{i=1}^{17} q_i \, c_i \, n_i$$

where

T = total amount of nutrient (nitrogen or phosphorus) in pounds
q_i = average daily flow in cfs for the period represented by the ith sample
c_i = concentration of nutrient in mg/l
n_i = number of days in the period represented by the ith sample

Table 34. Waddams Creek Inflow and Outflow Water Quality Characteristics

	Inflow		*Outflow*	
Parameter	*Mean*	*Range*	*Mean*	*Range*
Turbidity	4.0	0.3-14.5	5.2	0.3-29.5
Total phosphate-P	0.16	0.06-0.46	0.18	0.07-0.60
Dissolved phosphate-P	0.12	0.05-0.31	0.11	0.03-0.45
Total ammonia-N	0.42	0.03-4.5	0.45	0.10-1.98
Dissolved ammonia-N	0.12	0.00-0.25	0.35	0.09-1.66
Nitrate-N	3.50	0.11-5.48	0.87	0.08-4.36
Total Kjeldahl-N	0.7.7	0.33-1.72	1.28	0.16-3.81
Dissolved solids	407	276-462	301	192-462
Total suspended solids	7.4	0-28	7.9	0-32
Volatile suspended solids	3.8	0-9	5.6	0-18

Note: Values in mg/1 except for turbidity (NTU)

Table 35. Nutrient Budget for Lake Le-Aqua-Na

Source	*Inorganic nitrogen*	*Dissolved phosphorus*	*Total phosphorus*
Waddams Creek	20,586 (9,336)	641 (291)	779 (353)
Waddams Creek and ephemeral creeks during storm events	6,445 (2,923)	1,160 (526)	2,900 (1,315)
Precipitation	606 (275)	3-(1.4)	5 (2.3)
Internal regeneration	34,700 (15,737)	290 (132)	290 (132)
Wastewater treatment plant	0	0	0
Gross loading	62,337 (28,271)	2,094 (950)	3,974 (1,802)
Outflow	10,061 (4,563)	1,348 (611)	1,435 (651)
Net loading	52,276 (23,708)	751 (341)	2,539 (1,151)

Note: Values are expressed as pounds per year; numbers in parentheses represent the nutrient budget in kilograms per year

The total amounts of inorganic nitrogen, dissolved phosphorus, and total phosphorus transported by Waddams Creek to the lake during 1981 are shown in table 35.

Nutrient loading from the ungaged streams was estimated using the data developed in the water budget and the analyses of water samples collected after a major rainstorm on June 13-15, 1981, when nearly 4.0 inches of rain fell.

The water quality characteristics of samples collected before, during, and after the storm event are shown in table 36. Of the total of 860 acre-feet of ungaged waterflow into the lake, 535 acre-feet is estimated to be groundwater flow and the remainder from the ungaged streams. Using average values of 3.3 and 7.3 mg/l, respectively, for total phosphorus and total inorganic nitrogen for storm-related discharges, nutrient loads transported into the lake by ephemeral waterways were computed. These values are shown in table 35. Dissolved phosphorus is assumed to be 40 percent of the total phosphorus.

The nitrogen and phosphorus concentrations measured in rainwater samples collected within the state park are shown in table 37. Nutrient input from a total of 29.85 inches of rainfall on the lake surface was computed using the averages of the observed values shown in table 35.

As indicated earlier, the flow from the treatment plant was nothing more than a trickle. Hence the impact of the point source waste discharge is insignificant.

For assessing the internal regeneration of nutrients from lake bottom sediments, reliance was placed on values reported in the literature. Vollenweider (1968) estimated sediment nutrient release rates of 1.2 and 0.01 g/m^2/day for ammonia and phosphorus, respectively, under anaerobic conditions. Fillos and Swanson (1975) reported phosphorus release rates of

Table 36. Water Quality Characteristics of Samples Collected before, during, and after Storm Event of June 13-15, 1981

Location	*Date of sample collection*	*Suspended solids (mg/l)*	*Turbidity (NTU)*	*Total phosphate-P (mg/l)*	*Total ammonia-N (mg/l)*	*Nitrate-N (mg/l)*
Waddams Creek at Ford	6/10/81	7	1.4	0.12	0.16	3.07
Waddams Creek at Pinhook	6/13/81	192	33.2			
Waddams Creek at Ford	6/13/81	140	35.9	1.21	0.41	17.70
Waddams Creek at Five Points	6/13/81	60				
Waddams Creek at Ford	6/15/81	9960	2085.0	11.76	3.09	3.05
Concession stand close to creek	6/15/81	4490	1797.0			
Pike Pond	6/15/81	6540	1932.0			
Waddams Creek at Ford	6/24/81	9	5.2	0.17	0.59	1.02

Table 37. Rainwater Characteristics

Date of collection	*Total phosphate-P (mg/l)*	*Ammonia-N (mg/l)*	*Nitrate-N (mg/l)*
4/29/81	0.02	2.00	0.68
5/07/81	0.01	2.35	0.34
5/27/81	0.02	1.03	0.43

1.2 and 26.0 mg/m^2/day under aerobic and anaerobic conditions, respectively, for the Lake Warner, Massachusetts, sediment samples. USEPA's Clean Lakes Program Guidance Manual (1980) suggests values of 0.5 to 5 g/m^2/year under aerobic conditions and 10 to 20 g/m^2/yr under anaerobic conditions.

During the summer stratification period, June through September, 27 acres of lake bottom remain anoxic. On the basis of the release rates suggested by Vollenweider, amounts of inorganic nitrogen and phosphorus released from the lake bottom sediments during this period were calculated. The amounts are shown in table 35. Phosphorus released from bottom sediments under anaerobic conditions was taken to be in soluble form. Gross nutrient loading, which is the sum total of the nutrient inputs from all the sources considered here, is also shown in table 35. Allowing for nutrient outflow from the impoundment, the net nutrient loadings have been found to be 148.3 g/m^2/yr for inorganic nitrogen, 2.13 g/m^2/yr for dissolved phosphorus, and 7.20 g/m^2/yr for total phosphorus. The relative importance of various sources of nutrients is tabulated in table 38. The watershed is the dominant source of phosphorus to the lake, contributing 86 percent of the dissolved phosphorus and 92.6 percent of total phosphorus.

Table 38. Relative Importance of Nutrient Sources
(Percent of total)

Sources	*Inorganic nitrogen*	*Dissolved phosphorus*	*Total phosphorus*
Waddams Creek	33.0	30.6	19.6
Waddams Creek and ephemeral creeks during storm events	10.3	55.4	73.0
Precipitation	1.0	0.1	0.1
Internal regeneration	55.7	13.8	7.3
Wastewater treatment plant	0.0	0.0	0.0

Trophic State

Eutrophication is a natural aging process that affects every body of water from the time of its formation. Many interacting factors contribute to the overall process of eutrophication, a term more widely known to mean the nutrient enrichment of waters. The eutrophication of a lake system consists of a gradual progression from one life stage to another based upon changes in the degree of nutrient input or productivity. The youngest stage of the life cycle is characterized by low concentrations of plant nutrients and little biological productivity. Lakes in this stage are called oligotrophic lakes. At a later stage in the succession, the lake becomes mesotrophic, and as the life cycle continues the lake becomes eutrophic or highly productive. The final life stage before extinction is a pond, marsh, or swamp.

As a lake ages, the degree of enrichment by nutrient materials increases. In general, the lake traps a portion of the nutrients originating in the surrounding drainage basin. In addition, precipitation, dry fallout, and in certain cases groundwater inflow are contributing sources. The shore vegetation and higher aquatic plants utilize part of the inflowing nutrients, grow abundantly, and in turn trap the sediments. The lake gradually fills in, becoming shallower by the accumulation of plants and sediments on the bottom and smaller by the invasion of shore vegetation, and eventually becomes dry land. The extinction of a lake is the result of enrichment, productivity, decay, and sedimentation.

Human activities, such as the alteration of lake drainage basins, agricultural practices, deforestation, and urban development, have hastened the nutrient addition to natural waters. When the pollutants are of a nutritional type, the enrichment of the recipient water is greatly accelerated and the rate of aging is consequently greatly increased. In this way, eutrophication resulting from human activities can significantly alter the rate of the natural process and shorten the life expectancy of the affected body of water.

Because eutrophic lakes contain an abundance of available nutrients, biological production is high and results in nuisance growths, which adversely affect human use of the water body. Plants, particularly algae, are of primary concern because they utilize dissolved inorganic nutrients from the water and thus become primary producers of new organic matter on which aquatic animal Life depends. In eutrophic lakes the phytoplankton are represented by large numbers of a few species. An overabundance of algae is generally called an algal bloom. Lackey (1949) and later Fruh (1967) arbitrarily defined an algal bloom as 500 cts/ml of raw water sample.

With the increased productivity associated with accelerated rates of eutrophication comes the filling of the lake basins with organic materials, which subsequently exert an increased oxygen demand on the overlying waters. The increased oxygen demand may result in total depletion of oxygen in the cooler bottom waters during the summer, accompanied by an increase in the products of decomposition, e.g., carbon dioxide, ammonia, hydrogen sulfide, and methane. These developing anaerobic conditions result in the replacement of desirable benthic organisms with less desirable types.

In addition to restricting fish populations, highly eutrophic lakes are undesirable aesthetically and with respect to water use. Algal blooms produce taste and odor problems and create unsightly surface scums which discourage water contact recreational activities. Accumulation of algal mats and dense weed growths is most pronounced near shore. The accumulated algal masses decay, resulting in extremely foul-smelling conditions.

Algal growth of bloom proportions (table 16), the dominance of cyanophyta in the lake (table 17), relatively high oxygen demand of the organic sediments in the bottom of the lake with the consequent depletion of oxygen in the hypolimnion, high concentrations of nitrogen and phosphorus in the lake waters, and other telltale signs point clearly to the fact that Lake Le-Aqua-Na is in an advanced stage of eutrophication. There is an abundance of macrophytes in the littoral zones and in the shallow upper portion of the lake.

A wide variety of indices of trophic conditions has been suggested in the literature. Indices have been based on secchi disc transparency, hypolimnetic oxygen depletion, nutrient concentrations, and biological parameters including species abundance and diversity. USEPA (1980) suggests in its Clean Lakes Program Guidance Manual (table 10-4) the use of four parameters as trophic indicators: secchi disc transparency, carbon, phosphorus concentrations, and concentrations of chlorophyll-a. The criteria suggested therein are reproduced here as table 39.

Table 39. Quantitative Definitions of Lake Trophic State (USEPA, 1980)

Characteristics	*Oligotrophy*	*Eutrophy*
Total phosphorus (winter), μg/l	≤10-15	>20-30
Chlorophyll-a (summer), μg/l	≤2-4	>6-10
Secchi disc depth (summer), meters	≥3-5	<1.5-2
Primary productivity		
Carbon (mg/m^2/yr)	30-100	300-3000
Carbon (μg/m^2/day)	7-25	75-700

The mean surface phosphorus concentration observed in Lake Le-Aqua-Na for the months of November to March showed a value of 150 ug/l, which is five times the upper limit value for eutrophic lakes shown in table 39. The mean summer secchi disc transparency in the lake was 3.23 feet or 1.0 meter. This is less than the lower limit suggested in the table. It must be pointed out that in the case of Lake Le-Aqua-Na, turbidity is caused not only by phytoplankton but also by inorganic particulate matter of both autochthonous and allochthonous origins. The average summer chlorophyll-a concentration in the lake was found to be 45 µg/l, which again was higher than the value indicated for eutrophic lakes.

Algal counts observed in the lake during summer months were of bloom proportions. Nitrogen-phosphorus ratio values shown for the lake surface water samples in table 40 indicate that nitrogen-phosphorus ratios were generally greater than 15, denoting a phosphorus-limiting condition in the lake. The values were less than 15 in September observations, mainly due to the influx of sediment-related phosphorus after the heavy rainfall during the last week of August 1981.

Vollenweider (1968) suggested that for lakes with mean depths of 5 meters (16.4 feet) or less, permissible loading levels of biochemically active nitrogen and phosphorus are, respectively, 1.0 and 0.07 $g/m^2/yr$. For the same average depth, loading rates greater than 2.0 $g/m^2/yr$ for nitrogen and 0.13 $g/m^2/yr$ for phosphorus are considered excessive from the point of view of eutrophication. The mean depth of Lake Le-Aqua-Na is 11.6 feet. The loading rates of total inorganic nitrogen and dissolved phosphorus for the lake were found to be 176.9 $g/m^2/yr$ (88 times the eutrophic rate) and 5.9 $g/m^2/yr$ (45 times the eutrophic rate), respectively.

Table 40. Nitrogen-Phosphorus Ratios for the Near Surface Water Samples

Date of sample collection, 1981	*Total nitrogen (mg/l)*	*Total phosphorus (mg/l)*	*N/P ratio*
1/21	2.75	0.10	28
2/18	2.23	0.05	45
3/18	3.27	0.16	20
4/15	1.84	0.13	14
5/13	2.13	0.07	30
5/27	0.90	0.06	15
6/10	2.70	0.10	27
6/24	3.94	0.17	23
7/08	1.89	0.10	19
7/22	1.37	0.08	17
8/05	1.19	0.09	13
8/19	1.59	0.10	16
9/02	2.85	0.45	6
9/17	2.25	0.27	8
10/07	2.61	0.26	10
11/04	3.45	0.18	19
12/03	3.47	0.15	23

Dillon (1975) developed an expression relating the phosphorus loading to a lake, mean depth, hydraulic flushing rate of the lake, and phosphorus retention coefficient. The expression is:

$$P = \frac{L\ (1-R)}{Z\ \rho}$$

where

P = total phosphorus, mean concentration during the winter equilibrium condition between fall and spring turnover, in µg/l

L = total phosphorus loading in mg/m^2/yr

R = phosphorus retention coefficient $(1 - \frac{\text{total export}}{\text{total loading}})$

Z = lake mean depth, in meters

p = flushing rate, number of times per year

The total phosphorus loading to the lake is 11,200 mg/m^2/yr, the phosphorus retention coefficient is 0.64, the mean depth of the lake is 3.54 meters, and the flushing rate is 5.7 times per year. Using these values in the above expression, the predicted mean winter phosphorus concentration is 355 yg/1. The measured mean phosphorus concentration was 330 yg/1.

BIOLOGICAL RESOURCES AND ECOLOGICAL RELATIONSHIPS

Lake Fauna

Lake Le-Aqua-Na has a large watershed relative to the lake size. The ratio of the watershed area to the lake water area is about 59:1. Since agriculture is the dominant land use, the lake receives significant amounts of eroded top soil, fertilizer, and other nutrients. In addition to the influx of excess nutrients from the watershed, there is probably a significant amount of internal recycling of nitrogen, phosphorus, and other micronutrients within the lake. The lake is extremely fertile. It is reported that the insect life within the lake is rich and varied. Also it is reported that an abundance of frogs, snails, crayfish, and leeches provide an excellent food supply for fish. However, in the profundal region of the lake, Chironomidae, which are pollution-tolerant organisms, were found to be the dominant macroinvertebrate. Diversity in the benthic macroinvertebrate population is modest.

Various fish management techniques have been applied to the lake over the years, including partial and complete fish kill-offs. The recent history of the current fish population began in 1972, when the lake drawdown coupled with the complete eradication of fish was performed. The lake was then restocked with largemouth bass (*Micropterus salmoides*), red ear sunfish (*Lepomis microlophus.*) , bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*).

In the spring of 1973, antimycin was applied to the lake to reduce bluegill and green sunfish populations. During the spring of 1975 the treatment was repeated. These proved to be successful in keeping the bluegill population under control. Smallmouth bass (Micropterus dolomieni) was introduced in 1973. In 1974, about 2000 catfish were cage-reared and released into the lake.

As mentioned previously, the lake experienced a massive winter fish kill during the winter of 1976-1977, due to oxygen depletion in the lake under ice cover. The rest of the fish population was totally eradicated through the use of rotenone on March 24, 1977, and the lake was subsequently restocked.

In addition to the kinds of fish mentioned above, white sucker (Catostomus commersoni), bullhead (Ictalurus natalis), minnow, and northern pike (Esox lucius) are present in the lake.

In 1981 an early spring fish census, directed primarily at northern pike and walleye collections, was taken by the Illinois Department of Conservation. The collection efforts lasted from March 19 to April 3, 1981. Two trap nets were set in the upper end of the lake for 11 days, and only one remained for the rest of the period. Forty-eight northern pike and 8 walleye were collected. Other fish collected at this time included warmouth sunfish, bluegill, golden shiner, channel catfish, bullhead, and largemouth bass.

A fish kill occurred in the lake during the week of June 15 and into the week of June 22. The fish kill was attributed to "insecticides" in the runoff after a heavy rainfall in the area. Bluegill and crappie were the only species affected.

The fall population check consisted of 60 minutes of afternoon and 50 minutes of late afternoon to dusk electrofishing and two seine hauls with a seine 30' x 6' x 1/4". A total of 362 largemouth bass, 593 bluegills, 88 warmouth, 5 black crappie, 4 rock bass, 3 northern pike, 2 channel catfish, 2 walleye, 9 golden shiner, and 14 brook silverside were collected.

Fish actually weighed and measured by the concessionaire at the lake site from April 11 to September 9, 1981, were 77 largemouth bass, 20 northern pike, 53 catfish, 13 bullhead, 4 walleye, and 2 smallmouth bass. The bass ranged in size from 24 to 30 inches, the catfish were 3 to 6 pounds, the walleye were 17 inches, and the smallmouth bass were 15 to 17 inches.

Terrestrial Vegetation and Animal Life

Vegetation

Wild flowers. Wild flowers are prevalent, particularly the spring ephemeral variety. Dutchman's breeches, bloodroot (Sanguinaria canadensis), spring beauty, wild ginger, Virginia bluebells, boneberry, shooting star (Dadocatheon meadia), and columbine are fairly abundant. Lady fern (Asplenium filixfoemina), blue cohash, American spikenhard, and fragile fern are also found. The rather rare spinulose wood fern occurs on slopes above Waddams Creek. The large tway blade orchid is found in a few areas.

Timber. Approximately 150 acres of the park were planted with red, jack, and Scotch pine (Pinus sylvestris). Red cedar is common in the park. The following trees are also found within the state park: white oak (Quercus alba), black oak (Q. velutina), red oak (Q. rubra), burr oak (Q. macrocarpa), shagbark hickory (Carya ovata), pignut hickory (C. glabra), black walnut (Juglans nigra), butternut (J. cinerea), sugar maple (Acer saccharium), ash cottonwood, quaking aspen (Populus tremuloides), and big-tooth aspen (P. grandidentata), black willow (Salix nigra), hop hornbeam, pin oak (Q. palustris), elm (Ulmus americana), hackberry, Osage orange (Madura pomifera), mulberry, sycamore (Platinus occidentalis), black locust (Robinia pseudoacacia), black cherry (Prunus serotina), box elder (Acer negundo), basswood (Tilia americana), sweetgum (Liquidambar styraciflua),and tulip trees (Liriodendron tulipifera).

There is a particularly significant forested tract found in the south-west portion of the park, a small area of mesic upland forest rare to northern Illinois. This tract is a second growth community with an overstory characterized by sugar maple, red oak, shagbark hickory, and ash.

Animal Life

Animals Common to the Area. The combination of various soil types, conifers, hardwoods, and food species found within the park, as well as the agricultural crops all around the park, make the park home to a surprising variety of animals. Whitetail deer (Odocoileus virginianus), red fox (Vulpes fulva), gray fox (Urocyon cinereoargenteus), fox squirrel (Sciurus niger), gray squirrel (S. carolinensis), muskrat (Ondatara nivalicia), weasel (Mustela noveboracensis), mink (Mustela vison),cottontail rabbit, raccoon (Procyon lotor), skunk (Mephitis mephitis), woodchuck (Marmota monax), eastern mole (Scalapus aquaticus), least shrew (Cryptotis parva), chipmunk (Tamius striatus), 13-lined ground squirrel (Citellus tridecemlineatus), white-footed mouse (Peromyscus leucopus), deer mouse (Peromyscus moniculatus), opossum (Didelphis marsupiolis), and badger (Taxidea taxus) are found in the park.

Reptiles commonly found in the area are: Dekay's snake (Storeria dekayi dekayi), eastern garter snake (Thamnophis sirtalis sirtalis), bull snake (Pituphi melanoleucus sayi), blue racer (Coluber constrictor foxi), black rat snake (Elaphe obsoleta obsoleta), eastern milk snake (Lampropeltis doliata triangulum), eastern hognose (Heterodon platurhinos), box turtle (Terrapene Carolina Carolina), fox snake (Elaphe vulpina), and prairie king snake (Lampropeltis calligaster calligaster).

The more common amphibians found in and around the lake, stream, and marsh areas are: common snapping turtle (Chelydra serpentina), northern water snake (Matrix sipedon sipedon), mudpuppy (Nectarus maculosus), spotted salamander (Ambystoma maculatum), small-mouth salamander (A. texanum), bullfrog (Rana catesbeiana),American toad (Bufo americanus), Fowler's toad (B. woodhousei fowleri), painted turtle (Chrysemys picta marginata), spring peeper (Hyla crucifer), northern lepoard frog (RT pipiens pipiens), eastern gray tree frog, and cricket frog (Acris crepitans crepitans).

Avian Life. Numerous types of birds inhabit or frequent the park area. A partial listing of bird life by general type is as follows.

Game birds: Ringneck pheasant (Phasianus colchicus), bobwhite quail (Colinus virgianus), Hungarian partridge (Perdix perdix), ruffed grouse (Bonasa umbellus), mourning dove (Zenaidura carolinensis), and woodcock.

Hawks and owls: Great horned owls (Bubo virginianus), barred owls (Strix waria), and screech owls (Otus asio), as well as red tail hawks (Bateo borealis borealis), pigeon hawks (Accipiter velox velox), and sparrow hawks (A. velox velox),can be seen through most of the year. Bald eagle (Haliaeetus leucocephalus) and osprey (Pandion haliaetus carolinensis) are seen irregularly. Broadwinged hawks (Buteo platypterus platypterus), marsh hawks (Circus hudsonius), and rough legged hawks (B. lagopus) are seen during migration.

Waterfowl: The lake attracts a fair number of migratory waterfowl. Of these, wood duck (Aix sponsa), mallard (Anas platyrhynchos), blue wing teal (A. discors discors), and godwall (A. strepera) have nested. Other birds commonly observed are widgeon (Mareca americana), bluebill (Aythya affinis), golden eye (Glaucionetta clangula), and green wing teal (A. Carolinensis).

Shore birds: Sand piper and killdeer (Charadrius vociferous vociferous) are the most common. Great blue heron (Ardea herodias herodias), green heron (Butorides virescens virescens),and bitterns (Botaurus lentignosus) are also present at times.

Song birds and miscellaneous: Cardinal (Richmondena cardinalis), purple martin (Progne subis), kingfisher (Megaceryle alcyon), bluebird(Sialia sialis), sparrow, oriole, starling, grackle (Quiscalus quiscula), woodpecker, swallow, bluejay (Ciganocitta cristata), robin (Gurdus migraterius), chickadee, finch, and several others.

FEASIBILITY OF WATER QUALITY MANAGEMENT IN LAKE LE-AQUA-NA

Objectives of a Lake Management Program

The lake is in an advanced stage of eutrophication with the consequent symptoms of hypolimnetic oxygen depletion, winter fish kills, algal blooms, dense macrophyte growth in the shallows and the littoral zones of the lake, gradual siltation of the lake, and high nutrient content both from internal and external nonpoint sources.

The desirable water quality goals for the lake are:

- Dissolved oxygen of at least 5 mg/1 throughout the lake during the critical winter and summer months
- Secchi disc transparency of not less than 4 feet during summer months
- Total phosphorus of less than 0.05 mg/1 at the time of the lake spring turnover
- Average annual suspended solids and turbidity values of less than 25 units
- Reduction of nutrient loading to the maximum practicable extent
- Reduction of soil erosion in the watershed to the maximum practicable extent

The primary objectives of the proposed lake management program will be to improve the lake water quality and minimize the influx of sediments and nutrients from the watershed. The specific objectives are:

1) Institute critical area treatment for the lake's watershed agricultural lands.
2) Adopt an effective livestock management scheme.
3) Improve fish habitat in the lake during summer and winter months by eliminating anoxic conditions in the lake.
4) Minimize internal regeneration of nutrients in the lake.
5) Improve the aesthetic quality of the lake waters and enhance recreational opportunities in the lake.
6) Control algal blooms and dense macrophyte growth in the lake which occur during the prime recreational period.
7) Enhance bank fishing in addition to open water fishing.

Pollution Control and Restoration Schemes

Two publications (Dunst et al., 1974; U.S. Environmental Protection Agency, 1973) provide excellent summaries of remedial measures which have been applied in lake rehabilitation programs, citing numerous case histories. Measures which may be effective in the restoration and enhancement of the quality of lakes can be considered under the following two major categories:

1) Limiting nutrient influx
    - Point source nutrient removal and diversion
    - Control of nonpoint sources of nutrients

2) In-lake treatment and control measures

- Dilution and dispersion
- Nutrient inactivation/precipitation
- Sediment exposure and desiccation
- Lake bottom sealing
- Chemical control of nuisance organisms.
- Biological control of nuisance organisms
- Harvesting of nuisance organisms
- Artificial destratification and hypolimnetic aeration
- Dredging
- Routing of stormflows through the lake
- Selective discharge
- Raising of the lake water level

The lake restoration techniques mentioned here have been employed either alone or in combination with one or more of the other techniques in lake restoration schemes. The U.S. Environmental Protection Agency (1973) report states:

> The approach to the rehabilitation of degraded lakes is two-fold: (1) by restricting the input of undesirable materials and (2) by providing in-lake treatment for the removal or inactivation of undesirable materials. Obviously the only means of maintaining the quality of a lake once desired conditions are achieved, is by rigidly restricting the input of undesirable materials. In some lakes reducing or eliminating the primary sources of waste loading is the only restorative measure needed to achieve the desired level of improvement. Once the source of pollution is abated, natural flushing and dilution with uncontaminated water may result in substantial improvements in the quality of the lake. However, in many lakes, particularly in hypereutrophic lakes with slow flushing rates, in-lake treatment schemes may also be required before significant improvements will be realized.

The U.S. Environmental Protection Agency's Clean Lakes Program Guidance Manual (1980) states that in-lake restoration techniques such as dredging, aeration, and nutrient inactivation are important lake restoration tools in two situations:

1) When sufficient pollutant reduction is being accomplished in the watershed to allow desired lake quality to be maintained, but recovery from the degraded condition will be slow or *will not occur simply as a result of watershed management.*

2) When material accumulated in the lake constitutes a significant source of pollutants which is independent of controllable activities in the watershed.

Limiting Nutrient Influx

Point Source Nutrient Removal and Diversion. Nutrient removal and diversion have been widely practiced as lake restoration schemes in the United States. Lake Tahoe is a striking example of a lake where advanced waste treatment for nutrient removal, removal of both nitrogen and phosphorus, and diversion of treated effluents were practiced even before any problems of eutrophication began to appear in the lake. Prior to 1963, Lake Washington near Seattle received heavy nutrient loading from 11 sewage treatment plants discharging directly into the lake. The lake deteriorated to a state of eutrophy. A series of steps were instituted by the municipality of metropolitan Seattle to divert sewage from Lake Washington. Complete diversion was achieved by 1968. Phosphorus was identified as the main element causing eutrophic conditions in the lake. With the reduction of phosphorus by about 80 percent of the initial levels, algal growth in the lakes decreased, secchi disc readings improved, and water quality improvement has been dramatic.

The lakes in the Madison, Wisconsin, area have a long history of algal problems. Initially Lake Monona, the second of the series of four lakes on the Yahara River, received the sewage from the city of Madison. As a consequence, algal growths became prolific and a regular program of treatment with copper sulfate was established in 1925. In 1928, treated effluent was diverted to the Yahara River downstream from Lake Monona. After the diversion, the amount of copper sulfate needed to prevent algal blooms decreased significantly. A change in species composition to species which did not form surface scums resulted in a still further diminished need for copper sulfate application. Shortly after the effluent was moved downstream from Lake Monona, the symptoms of eutrophication in the lower two lakes began to intensify. Finally in 1958, the treated effluent from Madison was diverted to the Yahara River downstream from all the lakes. Since diversion, the conditions of the lakes have been reported to have improved (Sonzogni et al., 1975).

The only point source waste discharge within the Lake Le-Aqua-Na watershed (the state park wastewater treatment plant) has practically no effluent discharge. Consequently, it has no impact on the lake.

Nonpoint Source Control. Nonpoint sources of pollution, which are incidental to land uses throughout the drainage basin of a lake, are a significant cause of lake degradation. Efforts to limit nutrient and sediment inputs from lands within drainage basins, for lake protection as well as rehabilitation, have followed two general lines: 1) structural and land treatment measures to intercept nutrients and sediments before they reach water bodies; and 2) regulatory approaches — particularly land use controls to restrict uses with direct or indirect pollution potential.

Since agriculture is the predominant land use in the watershed, with 67 percent of the watershed devo.ted to cropland, nonpoint sources for sediment and nutrient inputs to the lake are a significant factor in the rehabilitation scheme for the lake. Cropland is generally one of the most significant potential sources of nutrient and silt to lakes (USEPA, 1980a). Lake Le-Aqua-Na receives an excessive amount of phosphorus, most of it during two or three heavy rainfall events (table 35). Also the tributaries convey large quantities of sediments at the same time, as evidenced by the data presented in table 36.

A sediment retention basin upstream of the lake to prevent or minimize lake siltation is not an economically feasible solution for several reasons. There is no suitable site on the main stem of Waddams Creek upstream of the lake. The ephemeral streams draining directly into the lake from the north (figure 6) also carry a significant portion of the silt and nutrient loadings' to the lake (table 38) and they also do not have suitable retention basin sites. The sub-impoundment on the creek into which the wastewater treatment plant discharges (figure 6) does not appear to have retained any sediments even though the impoundment has been in existence for nearly 10 years. The primary reason for this is that the hydraulic retention time provided by the sub-impoundment is insignificant under heavy rainfall-runoff conditions when a major portion of the silt load is conveyed from the watershed. For example, the maximum measured streamflow in Waddams Creek was 210 cfs on August 28, 1981. At this rate of inflow, the lake itself would provide only 1.1 days of retention time. A sediment retention basin upstream of the lake which cannot provide adequate retention capacity will be of no consequence. Suspended sediment concentrations in Waddams Creek under normal flow conditions are not excessive.

It then becomes important to control sediments and nutrients at the source itself by applying proper agricultural management techniques.

Agricultural Management Practices. Agricultural management practices and control measures which can be used to bring about soil erosion control and promote infiltration, thereby reducing surface runoff, are:

- No-till planting in prior crop residues
- Conservation tillage
- Planting of winter cover crops
- Improved methods of fertilizing
- Better timing of field operations
- Contouring
- Use of graded rows
- Contour strip cropping
- Terracing
- Use of grassed waterways and outlets and control structures
- Ridge planting
- Contour listing
- Development of buffer strips between cropped areas and stream courses

Nutrients are removed from agricultural land by leaching, direct runoff, and association with sediment from erosion. The agricultural practices indicated above will reduce direct runoff and/or erosion, thus reducing nutrient transport. For controlling nutrient losses through leaching, commonly adopted farming practices are: eliminating excessive fertilization, proper timing of fertilizer application, using crop rotation, plowing green legumes under, using winter cover crops, and controlling fertilizer release or transformation.

Management practices which are best for reducing the export of pollutants may not be the best for the farming community from an economic standpoint. For example, grassed waterways and buffer strips between cropped areas and stream courses would reduce pollutant export but would also reduce the acreage in productive use for the farmer. To be effective, the control programs listed above for nonpoint source categories depend on cooperative approaches.

Three agricultural land parcels designated as 1, 2, and 3 in figure 18, with areas of 35, 80, and 35 acres, respectively, have been identified by the Stephenson County District Soil Conservationist as areas sustaining high rates of soil loss. These lands have slopes in the "gently sloping" category. These, along with another 820 acres of agricultural land, are in continuous corn production. These are the land segments within the watershed which need immediate attention to minimize the soil erosion potential.

The land areas designated as 1 and 2 need terracing, and area 3 needs strip cropping, to minimize the soil erosion potential. The cost of terracing is estimated as $400 per acre (District Soil Conservationist, personal communication), and thus the cost of terracing land parcels 1 and 2, which total 115 acres, will be $46,000. The cost share level under the Agricultural Conservation Program (ACP) of Stephenson County is 65 percent, with a cost share limit of $3500 per farm. The farmers are expected to maintain the practice for at least 10 years to be eligible for support under ACP.

Only "no till" practice is considered for subsidy under ACP practices for Stephenson County. The cost share level for this practice is 75 percent, with a maximum of $25 per acre for 40 acres. The practice is required to be employed for at least 3 years to be eligible for support by the Soil and Water Conservation District (SWCD). Strip cropping systems are supported at a 60 percent level on a $7 per acre basis. The practice life span is expected to be at least 5 years.

It is the opinion of the District Soil Conservationist that it is extremely difficult to have the farmers adopt and continue the no till practice. As the farmers in the watershed are geared to adopt minimum tillage, it will be easier and more practical, according to the District Conservationist, to educate the farmers in adopting conservation tillage practices leaving a 40 percent residue on the land. However, there is no cost sharing by the SWCD for minimum till practices. The cost of this conservation practice is estimated, as $33 per acre.

Four Alternatives and Their Effects. Four different alternatives are considered in relation to control of the pollution load emanating from the watershed's cropland. The alternatives are: 1) *status quo* (no

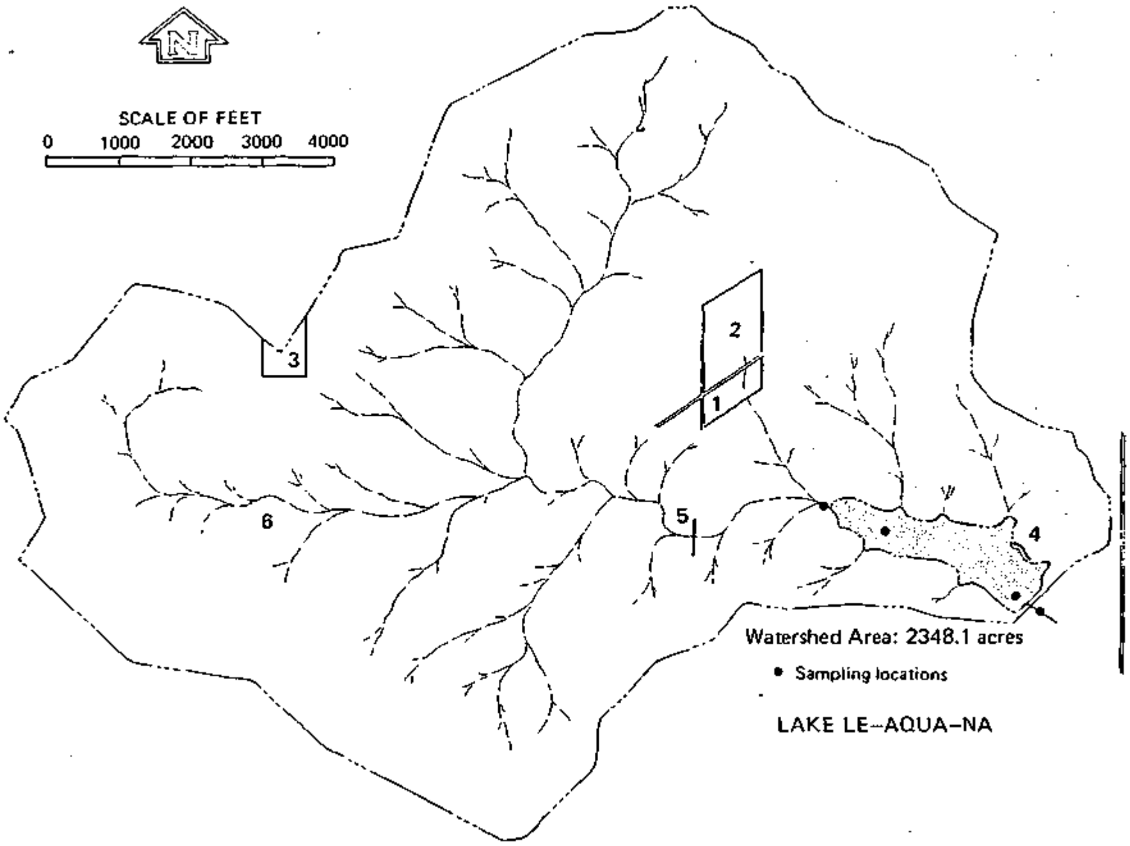


Figure 18. Identification of immediate watershed improvement needs

Table 41. Cropland Management Options in Le-Aqua-Na Watershed

Management practice	*Soil erosion (tons/yr)*	*Sediment yield (tons/yr)*	*Percent reduction in sediment yield*	*Phosphorus loading to the lake (lbs/yr)*	*Percent reduction in phosphorus loading*	*Total cost (dollars)*	*Federal share (dollars)*	*Local share (dollars)*
Status quo/ no action	8,146	3,837	0.0	2,900	0.0	0	.0	0
BMP-100 percent implementation	4,937	2,326	39.4	1,758	39.4	78,420	7,245	71,175
BMP-75 percent implementation	5,739	2,703	29.6	2,036	29.6	70,418	7,245	63,173
BMP-50 percent implementation	6,541	3,082	19.7	2,324	19.7	62,415	7,245	55,170

action); 2) 100 percent implementation of the most practicable Best Management Practice (BMP) option (minimum tillage with a 40 percent residue); 3) 75 percent implementation of the most practicable BMP option; and 4) 50 percent implementation of the most practicable BMP option. The costs, benefits, and consequences of each of these options are discussed below and the results are tabulated in table 41.

The no action alternative will result in an annual soil loss from the watershed of 8146 tons, with about 3837 tons of sediments delivered to the lake. The phosphorus loading to the lake resulting from storm events is 2900 pounds per year (table 35). If present land use trends are allowed to continue, the lake will have an estimated life of 159 years at the existing rate of loss of capacity of 0.63 percent per year. No additional expenditure of funds for conservation/restoration activities need be made.

The Best Management Practice for cropland in the watershed has been identified by the District Soil Conservationist to be: terracing of land parcels 1 and 2 and strip cropping of land parcel 3 identified in figure 18; continuing the conservation practice currently in use in 600 acres of cropland; and instituting conservation tillage practices with a 40 percent residue in 970 acres of cropland used in continuous corn production at the present time.

It is estimated that the soil erosion from the cropland will be reduced from the current rate of 7646 tons/year to 4437 tons/year when the conservation tillage practice is adopted (District Soil Conservationist, Stephenson County). The total soil erosion from the entire watershed will then be reduced from 8146 to 4937 tons/year. Using a sediment delivery ratio of 47.1 percent, the reduction in sediment delivery to the lake from the watershed will be 1511 tons/year. The proportionate reduction in phosphorus loading to the lake will be 1142 pounds/year. The expected life of the lake will increase to 262 years.

The total cost of treatment of the three land parcels, and of adoption of conservation tillage, will be $78,420. Federal and local cost share figures are shown in table 41. It must be pointed out that there is no cost sharing by SWCD for the conservation tillage proposed to be implemented, and the cost share per farm is limited to $3500.

The third alternative will be similar to the second alternative except that conservation tillage will be instituted in at least 75 percent of the acreage in continuous corn. Conservation treatment for the three land parcels identified in figure 18 will have to be carried out. The soil erosion potential from the watershed will be reduced to 5739 tons/year with sediment yield to the lake amounting to 2703 tons/year. The useful life expectancy of the lake will be 236 years.

The fourth alternative will be similar to the one above except that at least 50 percent of the acreage in continuous corn will be in conservation tillage in addition to the conservation treatment for the three land parcels. The soil erosion potential from the watershed will be reduced to 6541 tons/year with sediment yield to the lake amounting to 3082 tons/year. Phosphorus loading to the lake will be approximately 2324 pounds per year due to major storm events. Total costs and federal and local cost share figures for all the alternatives considered are shown in table 41.

Even though Lake Le-Aqua-Na Watershed is not a high priority area for conservation purposes, the Soil Conservation Service of the USDA is willing to cooperate in the implementation of the Best Management Practice for the watershed. SCS is very willing to coordinate their activities with SWCD. Cooperation of the farmers in the watershed was found by the District Soil

Conservationist to be less than average. Only 10 of 22 land holders are cooperators with the SWCD. There is a need to initiate an information/education program in the watershed. The purpose of such an endeavor would be to inform farmers of the effects of their farming practices, and to acquaint farmers with Best Management Practices as well as with sources of technical and financial assistance that are available.

It is difficult to predict the effect of sediment and phosphorus reductions resulting from the various alternatives considered above on lake water quality characteristics such as turbidity, secchi disc transparency, and algal growth. Eutrophic conditions in the lake are independent of the impact of the watershed on the lake, as evidenced by the fact that the lake showed a high degree of biological productivity during its first year of existence. Turbidity and suspended solids observed in the lake under normal streamflow conditions were below the water quality goals of 25 units.

It is estimated that alternatives 1, 2, 3, and 4 considered above will result in total phosphorus loading rates of 8.23, 5.0, 5.8, and 6.6 gm/m^2/year, respectively, as a result of major rainfall events. These rates are in turn estimated to contribute to lake mean phosphorus concentrations of 109, 66, 77, and 88 μg/l, respectively, in the lake during winter months. This implies that even with the 100 percent implementation of the Best Management Practice in the watershed (alternative 2), the contribution of phosphorus to the lake from the watershed alone will result in a mean phosphorus concentration of 66 μg/l, which is higher than the desirable level of 50 ug/1. Internal regeneration of phosphorus will also tend to increase the mean lake phosphorus level.

Prevention of Bank Erosion. Critical segments of stream banks within the state portion of the watershed have been strengthened by gabions to prevent bank erosion. Bank erosion needs to be controlled in Waddams Creek beyond the state property boundary. A small segment of about 250 feet of lake shoreline on the northeastern side of the lake near the concession stand (identified as item 4 on figure 18) needs to be stabilized to prevent bank erosion. The estimated cost for bank stabilization is $10,000.

Roadway Erosion Control Measures. There are approximately 3 miles of township roads (West Pinhook Road, North Five Corners Road, and North Cross Road) within the watershed. In addition there are 2-1/2 miles of gravel roads and paved roads encircling the lake. These roads traverse terrains steeper than 8 percent grades. Gravel roads, exposed road shoulders, and road side drainage channels are potential sources of sediment export. Gully erosion along West Pinhook Road appears to be severe. Erosion control measures along the roadways need to be considered in addition to the watershed agricultural management. Exposed shoulders and ditches should be protected by the establishment of suitable vegetative cover.

North Five Corners Road is a potential source of sediment to Waddams Creek where it crosses the main stem of the creek. A road stretch of one-tenth of a mile on either side of the creek, identified as item number 5 in figure 18, should be paved with asphalt to the specifications of

ID0T-A3 to minimize the impact of this source. The cost of paving two-tenths of a mile of this township gravel road will be $4000 (personal communication, Peoria County highway engineer). Exposed shoulders and drainage ditches have recently been seeded to provide vegetative cover and appear now to have been adequately treated.

Livestock Management. Livestock production for beef and dairy products is a significant operation in the watershed. The extent of nutrient transport from pastureland depends on such factors as the kinds and number of animals, their density on the pasture, proximity of the pasture to receiving waters, topography, and weather conditions. The privately owned tracts adjoining Waddams Creek in the watershed are used for grazing, and years of streamside grazing by cattle have depleted the streamside vegetation. The livestock appear to have trampled and denuded most of the 2 miles of privately owned watercourse, leaving the banks raw and unprotected. On several stretches the banks have collapsed.

With the cooperation of two landowners, the Department of Conservation put up 1/2-mile-long barbed wire fencing along the privately owned water course adjoining the state's jurisdiction, to establish a buffer zone between the pastureland and the stream bank. Four cattle crossing points were established with the consent of the affected landowners. The exclusion of cattle from the buffer zone was found to be very effective in sediment control.

Some commonly suggested livestock management practices are summarized as follows (Commonwealth of Virginia, State Water Control Board, 1979):

1) Maintain an adequate land-to-livestock ratio. Avoid concentrations of animals that will create holding areas rather than grazing areas.

2) Maintain a highly productive forage on the land to retard runoff, entrap animal wastes, and utilize nutrients.

3) Plan a stocking density and rotation system of grazing to prevent overgrazing and eroding of the soil.

4) Locate feeders and waterers a reasonable distance from the streams. Move feeders to new locations often enough to avoid creating erodible paths by repeated livestock trampling.

5) Provide an adequate land absorption area downslope from feeding and watering sites, preferably with a filter strip of lush forage growth between such sites and receiving streams.

6) Provide fences to prevent animals from wading in streams except at points where they may need access for drinking.

7) Where the number of animals or the characteristics of land present critical pollution problems, pipe water from a stream, farm pond, or well to watering troughs or tanks.

8) Provide summer shade, using trees or artificial shelters to lessen the need for animals to enter the watercourse for relief from heat. The same precautions used in locating feeders and waterers should be followed in locating shelters.

9) Provide for adequate winter storage for. manure to allow land spreading to be postponed until weather conditions permit expeditious incorporation into the soil.

10) Limit application of animal wastes on land to amounts that can be efficiently utilized by plants. Excess nutrients will then not be available for leaching or runoff into surface or groundwater.

As a minimum in livestock management within the Lake Le-Aqua-Na watershed, fencing along the stream banks with buffer strips of lush vegetation is necessary to prevent bank erosion and minimize the amount of sediments and nutrients from the pasture that reach Waddams Creek.

The cost of fencing the 2-mile stretch of the main stem of Waddams Creek, marked as item 6 in figure 18, would be $15,360. A rate of $12 per rod for 3-strand barbed wire fencing was used to estimate the cost (1982 ACP Practices for Stephenson County). The construction of adequate cattle crossing points would cost approximately $7500. Maintenance of the fences would be an important task which would need periodic attention. Since the Soil and Water Conservation District for Stephenson County does not have a cost share provision for livestock exclusion from stream banks, the cost of fencing along Waddams Creek will have to be met from other than federal sources.

All the livestock management practices, including the fencing of the watercourse to exclude cattle from Waddams Creek, demand wholehearted support and participation of the landowners in the watershed.

In-Lake Treatment and Control Measures

Even though not all of the in-lake treatment and control measures listed earlier are applicable to Lake Le-Aqua-Na, a brief description of these rehabilitation schemes is given here, along with a statement about their advantages and disadvantages. A few case studies of places where these techniques were employed are also cited. This information should aid in developing a rational management scheme for the lake.

<u>Dilution and Dispersion</u>. This technique has been attempted to alleviate excessive algal growth and associated problems by reducing nutrient levels within the lake. This is accomplished by the replacement of nutrient-rich waters with nutrient-poor waters and the washout of phytoplankton. For flushing to be successful, the water exchange rate must approach algal growth rates, i.e., complete water replacement every 2 to 3 weeks (USEPA, 1980b). Nutrient dilution has been attempted by two procedures: 1) pumping water out of the lake and permitting increased inflow of nutrient-poor groundwater; and 2) routing additional quantities of nutrient-poor surface waters into the lake. Domestic water supply, artesian wells, and nearby rivers are among the possible water sources.

The first procedure was used in Snake Lake in Wisconsin (Peterson et al., 1974). Nutrient levels were initially reduced significantly, and duckweed blooms were eliminated; however, leaching from nutrient-rich sediments limited the effectiveness in this particular case. The second procedure has been tried in several places. Two of the most successful experiments were at Green Lake in Washington and Buffalo Pound Lake in Canada (Dunst et al., 1974). After 5 years of flushing at a rate of 3.5 times per year or less, and after some initial dredging in Green Lake, the blue-green algal standing crop was suppressed and there was a shift in dominance with the elimination of Aphanizomenon. Sub-nuisance levels of blue-green algae were attained in Buffalo Pound Lake after 4 years.

As there are no artesians or access to nutrient-poor surface waters within the Le-Aqua-Na watershed, dilution is not a technically and economically viable solution for Lake Le-Aqua-Na.

Nutrient Inactivation/Precipitation. This technique is viewed as a method of hastening the recovery of a lake from eutrophic conditions. The purposes of this in-lake treatment are:

1) To change the form of the nutrient to make it unavailable to plants.
2) To remove the nutrient from the photic zone.
3) To prevent the release or recycling of potentially available nutrients within the lake.

In-lake nutrient inactivation techniques have been directed primarily toward phosphorus. Inactivants which have received the most attention are aluminum, iron, and calcium salts. Compounds of lanthanum, zirconium, tungsten, and titanium were found to be effective in removing phosphorus in laboratory studies, but their uses in lakes have not yet been proven.

Nutrient inactivation or precipitation can be effective only in lakes from which significant inputs of nutrients have been eliminated. This technique is used only for algal control and not for control of rooted aquatic plants. It is best suited for lakes which stratify and flush very slowly. This in-lake treatment technique has been reported to be a phenomenal success in Medical Lake, a freshwater lake in eastern Washington State, in controlling blue-green algae, improving lake transparency, and reducing the lake phosphorus concentration (USEPA, 1980b).

Since the input of phosphorus from the watershed into Lake Le-Aqua-Na is very high, and since the flushing rate is also high (5.4 times per year), phosphorus inactivation and precipitation is not a feasible solution for the lake's water quality problems.

Sediment Exposure and Desiccation. Water level manipulation has been employed as a mechanism for enhancing the quality of certain lakes and reservoirs. The exposure of lake bottom mud to the atmosphere reduces sediment oxygen demand and increases the oxidation state of the mud surface. This procedure may retard the movement of nutrients from the sediments to the overlying water when flooded once again. Sediment exposure can also curb sediment nutrient release by physically stabilizing the upper flocculent zone of the sediments. Lake drawdown has been investigated as a control measure for submerged rooted aquatic vegetation, and as a mechanism for lake deepening through sediment consolidation. In addition, this technique has been used to manage fish, to provide access to dams, docks, and shoreline stabilizing structures for needed repairs, to permit dredging using conventional earth-moving equipment, and to facilitate application of sediment covers.

Drawdown is reported to bring about at least short-term (1-2 years) control of rooted macrophytes, if there is complete dewatering of the sediments and a sufficient (1 month or more) period of cold (freezing) or heat (Cooke, 1980a). Rigorous conditions of exposure of the thallus and reproductive structures are apparently needed. Cooke states that water level drawdown is an effective technique for at least the short-term control of susceptible nuisance macrophyte species, and that it can be accomplished at relatively low cost without the introduction of chemicals or machinery. Cooke also gives a detailed list of the responses of different macrophyte species to winter and summer drawdowns. The macrophytes showed a variation in response (no changes, decreases, and increases), depending on the prevalent species in the lake.

Elodea (water weed) and Ceratophyllum (coontail) were the dominant species of macrophytes in Lake Le-Aqua-Na during 1981. The responses of these two macrophytes to drawdown were found to be non-definitive. Cooke (1980a) found in his work that these increased in a few cases, decreased in a few cases, and showed no changes in growth pattern in some cases.

Some of the important negative changes indicated by Cooke (1980a) following drawdown include establishment of resistant macrophytes, algal blooms, fish kills, changes in littoral fauna, failure to refill, decline in attractiveness to waterfowl, and unavailability of open water or access to open water for recreation.

In view of the fact that the lake drawdown is not likely to have a definitive impact on the predominant species of macrophytes found in the lake, it cannot be advocated as a sole management technique for controlling macrophytes in the lake.

Lake Bottom Sealing. Sediment covering to control macrophytes and sediment nutrient release has been widely used as an in-lake treatment technique. Covering of bottom sediments with sheeting material (plastic, rubber, etc.) or particulate material (sand, clay, fly ash, etc.) can prevent the exchange of nutrients from the sediments to the overlying waters either by forming a physical barrier or by increasing the capacity of surface sediments to hold nutrients.

The problem encountered when covering sediments with sheeting is the ballooning of the sheeting in the underlying sediments. Sand and other materials of large size tend to sink below flocculent sediments. Cooke (1980b) reports that polyethylene sheeting has not had long-term effectiveness due to macrophyte regrowth on its surface.

Cooke also discusses PVC-coated fiberglass screen, which he notes is expensive but nontoxic and appears to give long-term macrophyte control. He reports that PVC fiberglass screening (Aqua screen) of size 62 apertures/cm^2 was very effective in controlling macrophytes. Screenings with 9.9 and 39 apertures/cm^2 were either ineffective or less effective than the screens with 62 apertures/cm^2. Seed germinations and regrowth occurred on screens after significant sedimentation (2.3 years after deployment) had taken place, but autumnal removal of the screens followed by repositioning in spring seemed to correct the sedimentation problem. Cost of the screen with 62 apertures/cm^2 was $140 (1979 prices), for a roll 7 feet wide and 100 feet long. Unless the lake is drawn down, screening has to be placed directly over vegetative growth by scuba divers and anchored with metal T-bars.

In view of the extensive macrophyte growths in the lake, the high initial cost of $8640 per acre for material alone (1979 prices),and the need for skilled labor for removal and repositioning of the screens practically every year, sediment covering with screens to control macrophytes is not economically justifiable at Lake Le-Aqua-Na.

Chemical Control of Nuisance Organisms. Nuisance algal blooms, dense growth of macrophytes, and an unbalanced fish population often restrict various recreational and domestic uses of surface waters. Chemical treatment has been most widely used as a treatment method. It has the greatest utility and justification in highly eutrophic lakes in which nutrient supply cannot be effectively controlled, or in which nutrient input control measures are envisaged sometime in the future. Based on the intent, chemical controls can be divided into three categories: l)algicides, 2) herbicides, and 3) piscicides.

Copper sulfate is probably the most widely used chemical for control of blue-green algae, taste- and odor-producing algae, and some filter-clogging algae (Janik et al., 1980). Over 10,000 tons of copper sulfate are used for this purpose each year in this country at concentrations ranging from less than 0.5 to more than 10.0 mg/l (Fitzgerald, 1971). The amounts of oxygen, organic matter, and alkalinity in water determine the dosages required for effective plankton control (Fitzgerald, 1971; Mackenthun, 1969; Mulligan, 1969). For waters with alkalinity greater than 40 mg/1, copper sulfate at a rate of 1 mg/1 for the upper 2 feet of water regardless of actual depth has been widely used (Mackenthun, 1969). On an average basis, this concentration would amount to 5.4 lbs of hydrated copper sulfate per surface acre. For lakes with alkalinity less than 40 mg/1, a concentration of 0.3 mg/1 of copper sulfate would amount to 1.8 pounds per acre. The difference is due mainly to the fact that the effectiveness of copper sulfate is reduced in high alkalinity waters because of the formation of an insoluble precipitate of copper basic carbonate. Copper ions were also found to inhibit the growth of duckweed at concentration levels less than 0.1 mg/1 as Cu^{++} (Woodrow Wang, Water Quality Section, Illinois State Water Survey, personal communication, 1982).

The effectiveness of copper ions in controlling algae can be enhanced by using chelated copper sulfate. The State Water Survey (Kothandaraman et al., 1980; Kothandaraman and Evans, 1982) found that when citric acid is used as a chelating agent in the weight ratio of 1 part citric acid to 2 parts, copper sulfate, a higher concentration of the copper ion is introduced in the lake. Better distribution is achieved throughout the lake for the same quantity of copper sulfate applied alone to the lakes. Cutrine, a proprietary formulation of chelated copper sulfate, has also been employed successfully in controlling noxious algal blooms (Dunst et al., 1974).

The State Water Survey (Kothandaraman et al., 1980; Kothandaraman and Evans, 1982) followed the chelated copper sulfate application with an application of potassium permanganate after a lapse of 1 to 5 days. This was done primarily to oxidize the decaying algae after copper sulfate application and to avoid a possible depression of dissolved oxygen content in the lake due to the oxygen demand exerted by decaying algal cells. Potassium permanganate also is known to have algicidal properties (Carr, 1975; Janik et al., 1980). A dosage rate of 1.25 pounds per acre was used by the Water Survey with excellent results.

Copper sulfate has a low mammalian toxicity, is inexpensive, and is effective in controlling a wide range of planktonic algae. However, instances of fish kills have been reported soon after copper sulfate applications. These were generally traced to improper application and excessive dosage rates. The Water Survey's experience with copper sulfate application in two Illinois lakes (Kothandaraman et al., 1980; Kothandaraman and Evans, 1982) indicates that by proper control of dosages and application procedures, most of the problems could be avoided.

Copper sulfate may be applied in a variety of ways: bag dragging, dry feeding behind power boats, liquid spray, or airplane application of either dry or wet material. Application by blowing of the chemical rather than by slurry has also been employed (Mackenthun, 1969). The advantage of the blower-type machine is its ability to treat a large surface area rapidly with a light dosing of material. Use of blower-type machines is dependent upon the wind for distribution of the chemical. However, there is always some loss of copper sulfate dust that is carried by wind to the shore of the lake. Helicopters have also been used in chemical distribution. The East Bay Water Company, Oakland, California, found that a more efficient treatment could be attained with a helicopter (Mackenthun, 1969). The State Water Survey determined that chemical application in lakes where aeration is used as a lake management technique can be effected from a single point in the lake and the chemical agent dispersed throughout the lake (Kothandaraman et al., 1980; Kothandaraman and Evans, 1982). Labor involved in this type of application is very minimal.

The frequency of copper sulfate application varies from a single annual application to monthly applications during spring and summer. The continuous feed of copper sulfate to the inlet of a reservoir has also been reported (Muchmore, 1973).

The toxicity of copper sulfate to humans presents no problem at the concentration levels normally used in lakes and reservoirs. Of concern, in long-term treatment of water supplies with copper sulfate, is the potential of accumulating harmful amounts of copper in the bottom sediments (Muchmore, 1973), since the copper added as copper sulfate will end up in bottom sediments. Muchmore discusses a study of a group of Wisconsin lakes that had been routinely treated with copper sulfate. He reports that copper, in the bottom muds was considerably lower in concentration than the 9000 ppm (dry basis) found to be the level that would affect bottom-dwelling organisms. No difference in the diversity of benthal populations could be attributed to the presence of copper.

The cost per acre for chemicals and application has been reported by the Water Survey as about $2 in 1966. Dunst et al. (1974) reported that, for Mascotna Lake (1110 acres) in New Hampshire, the cost of application of copper sulfate including chemical costs amounted to about $2.60 per acre. The Southeastern Wisconsin Regional Planning Commission (1969) used the following cost figures: cost of chemicals (copper sulfate) at $1 per acre treated; a boat or barge and spraying apparatus at an initial cost of $1250; and operation and maintenance costs of $50 per day. The Water Survey incurred a materials cost of $7 per acre in 1981 for applications of chelated copper sulfate followed by potassium permanganate in Lake Eureka (Kothandaraman and Evans, 1982).

Other algicides of some use include the rosin amines, triazine derivatives, mixtures of copper sulfate and silver nitrate, quaternary ammonium compounds, organic acids, aldehydes, and ketones. Prows and McIlhenny (1973, 1974) reported after examining more than 10,000 compounds that p-chlorophenyl-2-thienyl iodonium chloride is an effective chemical for algal control. On the basis of laboratory tests and limited field evaluations, the authors concluded that the compound is safe to applicators, fish, and other higher aquatic plants and animals; that it has a fairly rapid degradation pattern under open atmospheric conditions with a half-life of 1 to 2 days; and that it exhibits a high degree of specificity to nuisance algae, particularly *Anabaena*, *Microcystis*, *Aphanizomenon*, and *Oscillatoria*. It must be pointed out that none of these algicides has been used as extensively as copper sulfate.

Chelated copper sulfate application followed by potassium permanganate is an economically viable technique in controlling blue-green algae and duckweed in Lake Le-Aqua-Na and thereby improving the lake transparency and the general lake aesthetic conditions. Past experience of the State Water Survey in Illinois lakes indicates that four applications during the months of June through September will be adequate. At an average cost of $320 per chemical treatment, the total annual cost of chemical application to control blue-green algae will be $1280.

Use of chemicals is also a common and effective method of control of nuisance weed growths. Chemicals offer longer lasting control than mechanical harvesting methods, involve less labor, and generally cost less. Years of research in testing chemical effectiveness, toxicity, and residues has weeded out questionable, hazardous materials. Now only a limited number of highly effective, approved products are available for weed control. Certain chemicals and application rates selectively control only target weed species. Hence, the applicator has the option of treating only specific nuisance weeds. Applications can be made in areas that cannot be reached by mechanical harvesters. Waters under piers and docks can be treated easily. A detailed list of various chemicals, dosage rates, and the macrophytes' responses to chemical treatments can be found in Fishery Bulletin No. 4 (State of Illinois, Department of Conservation, 1976).

The drawbacks of chemical control of macrophytes include:

- Different chemicals are required to control different plant species.
- Chemical application permits and monitoring programs are required.

- Restrictions are often placed on water usage after chemical applications.
- Success or failure of the treatment depends on variables such as chemical dosage, water temperature, pH factors, weather conditions, wind, water velocity, and many others.
- Toxicity and residue problems may make chemical control controversial and less acceptable environmentally.
- Decaying vegetation in the lake creates unsightly conditions in the lake. Released nutrients become readily available for recycling. Algal blooms occur subsequent to chemical treatments.

Smith (1979) reports that the cost of chemical control of macrophytes was $50-100 per acre per application according to the Department of Environmental Quality Engineering, Massachusetts (1977), and varied from $75-150 per acre according to pesticide application records of ACT, Inc. Allowing for inflation, the cost per acre is likely to be in the range of $125-225.

Out of 13.5 acres of weed bed in Lake Le-Aqua-Na, if 8 acres are treated selectively to promote bank fishing and open water fishing in the shallow portions of the lake, the cost will be about $1500 per application. The lake may need two chemical applications per year to control rooted vegetation.

Rotenone is used in fishery management for controlling undesirable fish populations in lakes.

Biological Control of Nuisance Organisms. This approach encompasses the introduction or promotion of organisms that are inimical to the target organisms. Dense growths of aquatic macrophytes were found to inhibit the growth of phytoplankton, both by direct competition for nutrients and by shading. One of the natural ways in which algal populations are kept under control is through predation by zooplankton and fish species. Effective grazing by Daphnia and related zooplankton on phytoplankton populations in a mesotrophic lake has been reported (U.S. Environmental Protection Agency, 1973). Dunst et al. (1974) reported that suitable plankton-feeding fish species are Tilapia mossambica and its allies, Hypophthalmichthys molitriz and Mugil cephalus. White amur or grass carp (Ctenopharyngodon idella val.) has been widely recognized as a plant control agent. However, it is illegal to import this fish species into Illinois.

Dunst et al. (1974) reported on the only planned in-lake treatment to control blue-green algae by the use of a virus. . Blue-green algal scums were apparently dissolved as a result of spraying cyanophages on the . surface of a lake in the U.S.S.R. Evaluation of biological controls has been limited, with much of the testing conducted in laboratories and experimental ponds. In general, biological control measures have yet to be proven in large lakes and reservoirs.

Harvesting of Nuisance Organisms. The harvesting of nuisance organisms is limited to macrophytes and some undesirable fish. Technical difficulties have precluded in-lake harvesting of algal cells. The technique has been advocated as a practical means of accelerating the nutrient outlfow from lake systems; however, this technique alone is deemed inadequate for lowering nutrient supplies in lakes receiving enrichment as a result of human activity. Carpenter and Adams (1978) reported that harvesting of water milfoil from Lake Wingra in Wisconsin would remove an amount of phosphorus equal to about 37 percent of the annual net load in the lake. Also, Wile (1978) reported that harvesting operations in Chemung Lake (in Canada) resulted in the removal of phosphorus equivalent to 47 percent of the gross loading and 92 percent of the net annual loading. These authors have reported a phosphorus removal rate of 1.4 grams of phosphorus per square meter per year.

Harvesting is as effective as herbicide treatment; is no more expensive than chemical control in the long run (Smith, 1979; USEPA, 1980a); and has several distinct advantages over herbicide treatments. Among the advantages are:

- The procedure is target specific, and the time and place of harvesting are decided by lake managers.
- The nuisance vegetation is immediately removed and with it a certain quantity of plant nutrients.
- No toxicants are introduced and hence no toxic residues remain.
- The lake can remain open during harvesting.
- The plants do not remain in the lake to decompose, utilize oxygen, and release nutrients which may stimulate algal growth.
- Harvested weeds may be used for compost, mulch, methane production, etc.
- Harvesting can be easily regulated to preserve fish habitats and recreational access, and at the same time avoid any major upset in the ecological balance.
- Regrowth after harvesting is usually delayed, and harvesting in one year tends to inhibit regrowth in subsequent years.
- Harvesting constitutes habitat removal, and with it will come a reduction in species of the shallow area of the lake, particularly animals such as snails, insects, and worms.
- The adverse impact on fish abundance is slight.
- Fish growth rates may increase, and fish may increasingly turn to algae grazers instead of snails and insects.

The cost of harvesting is greatly affected by the high initial cost of the equipment. Costs can be reduced by designing an efficient cutting-transport plan and by purchasing equipment of a size appropriate to the area to be harvested. Operating costs per acre go down as the total harvest goes up. Smith (1979) reported that harvesting costs ranged from $60 to $160 per acre, with one value of $600 per acre outside this range.

Harvesting of macrophytes in Lake Le-Aqua-Na is a technically viable and preferable alternative to herbicide treatment as currently practiced. The cost of each harvesting operation will be about $2000, which will include costs of labor, fuel and maintenance, repairs, disposal, amortization of equipment, and financing. Assuming that at least 8.0 acres of weed bed will be harvested each year, the nutrient removal will amount to 100 pounds per harvest. This is 7 percent of the net phosphorus loading to the lake. At least two harvests per year will be needed.

A weed harvester system consisting of a harvester, a shore conveyor, and a trailer for the road transportation of the harvester will cost $82,000. The useful life of the system is expected to be at least 10 years. If the system could be employed in several Department of Conservation lakes on a regional basis, the cost per acre of weed harvesting could be reduced significantly.

Artificial Destratification and Hypolimnetic Aeration. Artificial destratification and hypolimnetic aeration are processes by which the lake waters are oxygenated and circulated. This is accomplished either by mechanical water pumps or by compressed air released at the lake bottom. In the case of compressed air mixing, vertical water currents are generated as the bubbles rise to the surface. The colder and denser bottom water mixes with warmer surface water, and then sinks to a level of equal density and spreads horizontally. Oxygen is added to the water directly from the compressed air as well as by contact with the atmosphere. As the mixing process continues, complete circulation is achieved and the lake approaches uniform temperature and dissolved oxygen conditions from the surface to the bottom. The whole water mass becomes inhabitable by lake biota.

In contrast to total aeration, several types of aeration devices have been designed to oxygenate the hypolimnetic waters without disrupting thermal stratification. Typically, the aerator consists of a large diameter pipe which extends from the lake bottom to a few feet above the water surface. Water inlet ports are located near the bottom of the pipe, and outlet ports are located below the thermocline. The bottom water is airlifted up the vertical tube. The rising bubbles are vented to the atmosphere and the water is returned to the hypolimnion.

A thorough discussion on aeration/circulation as a lake restoration technique can be found in the report by Pastorok et al. (1981) prepared for the U.S. Environmental Protection Agency.

The advantages of artificial destratification in eutrophic lakes are:

- With increased oxygen levels in the hypolimnion, there is a reduction in the anaerobic release of nutrients from the bottom sediments.
- Oxidation of reduced organic and inorganic materials occurs in the water. (This is particularly advantageous when the lakes serve as a raw water source, because taste, odor, and color problems caused by iron, manganese, and/or hydrogen sulfide are eliminated or at least minimized.)
- The range of benthic populations is extended to the profundal region which was once anaerobic. (An increase in the number of fish and a shift to more favorable species can result from the greater availability of food organisms.)

- Favorable changes in algal populations occur with a decrease in undesirable blue-green species. (This is a result of the lowering of water temperature and the distribution of the algae between the euphotic and aphotic zones; however, there is no reduction in the productivity of the lake.)
- Evaporation rates are reduced in summer with the reduction in surface water temperatures.
- Artificial destratification often results in increased water clarity.
- Winter fish kills may be prevented by maintaining sufficient oxygen levels under ice.

The disadvantages of artificial destratification include:

- It causes an increased heat budget in the lake.
- Aeration may temporarily increase water turbidity due to the resuspension of bottom sediments.
- In most investigations artificial destratification resulted in a reduction in blue-green algae, but in other instances there was no observable effect on blue-green algae.
- The artificial destratification may induce foaming.
- The oxygen demand of resuspended anaerobic mud may result in a decrease in oxygen concentrations, at least temporarily, that may kill fish.
- Aeration may cause supersaturation of nitrogen gas, raising the potential danger to fish of gas bubble disease.

According to Pastorok et al. (1981), the effects of artificial circulation on phytoplankton populations have been reported to be extremely variable, not only because the way techniques are applied and the efficiency of mixing devices vary among investigations, but also because different biological communities exhibit different responses to the same kind of perturbations. These authors report that in 40 investigations where destratification was relatively complete, only 65 percent led to any significant change in algal concentrations; of these, about 30 percent resulted in more algae than before destratification. The authors provide detailed information on algal responses to artificial circulation for each of the 40 lakes discussed in their report.

Pastorok et al. (1981) report that expanded habitats following destratification are beneficial to fish populations because of increased food supply and alleviation of crowding into epilimnetic strata during the summer. They cite studies which showed increased growth rates in fish populations.

The experience of the State Water Survey in applying destratification as an in-lake treatment technique in Illinois lakes has been excellent (Kothandaraman et al., 1980; Kothandaraman and Evans, 1982). Aeration in combination with in-lake chemical treatment at periodic intervals was found to result in a dramatic shift of algal species makeup from problem-causing blue-green algae to more desirable greens and diatoms. Most of the detrimental effects of aeration cited earlier did not materialize in the Water Survey's investigations. Since warm water fisheries are the major concern in Illinois, a slight increase in the heat budget of the lake is of very minor consequence.

In view of the enormous benefits achievable by this in-lake treatment technique, destratification is not only an economically and technically feasible management tool, but an indispensable one for lakes in Illinois with maximum depths greater than 12 to 15 feet. Not only will aeration increase the fish habitat to 100 percent of the lake volume in summer months, prevent fish kills in winter, and improve the aesthetic conditions in the lake, but it is also likely to reduce the phosphorus loading to the lake from 290 pounds under anaerobic conditions to about 29 pounds under aerobic conditions in Lake Le-Aqua-Na. A reduction order of magnitude of 1 was assumed in this case. A 5- to 10-fold reduction is indicated in the literature (Fillos and Swanson, 1975; USEPA, 1980a).

An aerator system of the type developed by Quintero and Garton (1973) or a compressed air aeration system commonly available on the market is suitable for Lake Le-Aqua-Na. In the former case, the sizing of the impeller blade and motor is done in such a way that the downdraft jet penetrates to the bottom of the lake during the peak of lake stratification. In the case of compressed air aeration, an air delivery rate of 30 standard cubic feet per minute per million square feet of lake water surface is needed (Pastorok et al., 1981) to ensure adequate lake circulation. Based on the Water Survey's experience, the cost of an adequate system for Lake Le-Aqua-Na, including complete installation and testing, will be $15,000 (1982 dollars) and the monthly power cost for such a system will be in the range of $100 to $125.

Dredging. Sediment removal in freshwater lakes is usually undertaken to deepen a lake, thereby increasing its volume; to enhance fish production; to remove nutrient-rich sediment; to remove toxic or hazardous materials, if any; or to reduce the abundance of rooted aquatic plants (Peterson, 1981). Reviews of more than 60 sediment removal projects and in-depth examinations of five case histories reveal that the first three objectives are usually met through sediment removal, and that the effectiveness of dredging to control aquatic plants has not been well documented (Peterson, 1981).

Advantages of sediment removal techniques include the ability to selectively deepen parts of a lake basin, increase the lake volume, recover organically rich sediment for soil enrichment, and improve limnetic lake quality. Disadvantages include high cost, phosphorus release from sediment, increased phytoplankton productivity, noise, lake drawdown, temporary reduction in benthic fish food organisms, and the potential for release of toxic materials to the overlying water and for environmental degradation at the dredged material disposal site (Peterson, 1981). In addition, the nutrient content of the sediments may remain high at a considerable depth, thus making it impossible to reach a low nutrient level in sediment. Satisfactory disposal of the spoils may be very expensive.

However, high quality dredge material can be used for beneficial purposes and may offset the initial high cost of dredging.

Peterson's (1981) report on the restoration of Wisconsin Spring Ponds using dredging as the management technique is one of the most thoroughly documented studies concerning the ecological effects of dredging small lakes. The purpose of the dredging was to deepen the ponds to improve fish production. Incidental to the deepening was the control of aquatic macrophytes. It is reported that even though there was a temporary decrease in the benthic organisms soon after dredging, four to five years after lake restoration the average density and biomass of fishable-size fish were substantially greater than during the pre-dredging period.

Peterson (1981) also reports on the successful restoration of Lilly Lake (southeastern Wisconsin) by dredging. The main problems in Lilly Lake were severe shoaling, abundant aquatic plant growths, and winter fish kills. In addition to the whole basin dredging, 10 percent of the 97 acres of the lake was dredged to a depth of approximately 6.0 meters (20 feet). Dredging was completed in September 1979. As of 1981, water quality had remained good, macrophytes had virtually been eliminated, and local sponsors were generally pleased with the outcome.

Sediment removal can be accomplished either by hydraulic dredging or by exposing lake sediments for removal by conventional earth moving equipment. Dredging is a much more common approach to sediment removal (Peterson, 1981). Pierce (1970) describes various types of hydraulic dredging equipment and provides guidance on the engineering aspects of dredge selection. Peterson (1979) has described various grab, bucket, and clam shell dredges; hydraulic cutterhead dredges; and specialized dredges to minimize secondary water quality impacts. Sediment removal using earth moving equipment after lake level drawdown was successfully used in Sylvan Lake in Lake County, Illinois (Quade, 1981). Excavation was carried out during winter after the ground froze.

Dredging costs are difficult to determine accurately and even more difficult to compare because they vary a great deal depending on a number of factors (Peterson, 1979): 1) types and quantity of sediment removed, 2) type of dredges used, 3) nature of the operational environment, 4) geographic location, and 5) mode of disposal of the dredged material. The U.S. Environmental Protection Agency (1980a) indicates that costs of sediment removal vary widely from $0.76 to $12.00 per cubic yard.

There are no suitable lands adjoining Lake Le-Aqua-Na which could be used for disposal of dredged materials. The state-owned lands are either in recreational development or in timber. The privately owned lands are in prime agricultural use or in pastures. Hydraulic dredging with upland diked disposal, if at all possible, will involve very long pumping distances.

The feasible alternative will be lake drawdown during winter months, October through March, when the lake use is minimal except for ice fishing. The ground is frozen, and excavating the sediments using conventional road machineries is viable. Since the sediments do not contain heavy metals or hazardous chemicals, it is possible to use the excavated materials on the agricultural land where they originated, or else the excavated material will have to be disposed of on suitable landfill sites requiring truck hauling. As a minimum, the shallow upper end of the lake and the silted bay areas should be excavated, though not the entire lake basin to the original lake bottom. In that case, the lake needs to be emptied only partially. Lake drawdown could be effected by the control valve in the outlet structure, or the lake could be drained by flexible pipe syphons. Lake shore and dock improvements, fisheries management, etc., can be combined with the drawdown.

Lake segments 5, 6, 7, 8, and 10, as designated in figure 2, have undergone significant amounts of silt accumulation (table 42), and these areas will be the prime targets for silt removal. The amount of silt removal needed from these areas will be 36.4 acre-feet or about 60,000 cubic yards. The unit cost of sediment removal will be in the upper end of the range of values of $0.76 to $12.00 per cubic yard indicated by USEPA (1980a) since the anticipated silt removal volume is relatively small. Assuming a rate of $10.00 per cubic yard for sediment removal and disposal in landfill areas, the cost of sediment removal will be $600,000.

Sediment removal from the lake will result in a partial restoration of the original lake volume. Vegetative growths will be eliminated initially. Fisheries in the lake will improve, enhancing the recreational potential of the lake, which is the primary intended use for the lake. However, sediment removal will not reduce the nutrient recycling within the lake, as it is not economically feasible and probably not technically feasible to deepen the lake to reach nutrient-poor strata in the lake.

<u>Routing of Stormflows through the Lake</u>. The routing of sediment-laden flows through the lake and downstream during storm events has been suggested as a possible means of controlling sedimentation of the lake. This entails the handling of enormous quantities of Waddams Creek flow during one or two major storm events, while the flow at other times is extremely low. For example, the mean monthly flows in Waddams Creek for

Table 42. Summary of Sedimentation Data for Lake Le-Aqua-Na

*Segment**	*Volume (acre-feet)* *1956*	*1981*	*Loss of original capacity* *% of total*	*% per year*
1	97.8	89.6	8.4	0.34
2	175.6	159.1	9.4	0.38
3	134.0	117.9	12.0	0.48
4	75.6	62.2	17.7	0.71
5	61.2	42.3	30.9	1.24
6	16.9	7.2	57.4	2.30
7	9.2	2.5	72.8	2.91
8	2.8	2.2	21.0	0.84
9	3.8	4.0	17.9	0.71
10	0.8	0.3	66.7	2.67

*Refer to figure 2 for segment designations

May, June, and July 1981 were respectively 0.31, 1.01, and 0.35 cubic feet per second (cfs). The mean flow for August was 7.7 cfs, including the high flows caused by rainstorms during August 26-28, 1981. The average flow for August excluding this storm-related flow was 0.5 cfs. The measured discharges in Waddams Creek upstream and downstream of the dam were respectively 210 and 430 cfs during the August storm. Engineering structures and appurtenances to route the Waddams Creek flow during major storm events will be prohibitively expensive. In addition, the side stream discharges into the lake are also equally significant in sediment transport to the lake (table 36).

Selective Discharge. Selective discharge of anaerobic bottom waters has been employed as an in-lake management tool to improve the dissolved oxygen conditions in the hypolimnetic zones (Dunst et al., 1974). The implementation of this technique permits the release of anaerobic, nutrient-rich waters from the hypolimnion of the lake. The surface water discharge is often blocked off. The release of cooler water from the bottom generally results in elevated temperatures at that location. As a consequence the rate of chemical reaction may be greatly accelerated in bottom waters, thus placing increased demand on the oxygen resources. The degree of improvement in hypolimnetic water quality conditions is dependent on the outflows and lake volumes (Dunst et al., 1974).

The release of anaerobic, nutrient-rich waters has been reported to have caused problems in the downstream channel. Although reaeration can be provided by sufficient turbulence in the discharge, an oxygen sag may develop downstream. At Twin Valley Lake, Wisconsin, a high oxygen demand in the discharge waters coupled with increased macrophyte growths in the water course resulted in low DO levels at night. Also, gases such as hydrogen sulfide, methane, and ammonia may be released from the discharge waters, causing odor problems. The release of these gases and the downstream effects have been the focus of major criticisms of the selective discharge technique (Dunst et al., 1974).

If the selective withdrawal from the hypolimnetic zone of Lake Le-Aqua-Na is matched to the inflow to the lake (i.e., 0.31, 1.01, 0.35, and 0.5 cfs in May, June, July, and August 1981, respectively), the discharge rate will not be adequate to cause any change in the water quality conditions of the lake, particularly due to the fact that 51 percent of the lake volume is anaerobic. (The high flows in Waddams Creek during the week of August 23, 1981, were excluded in arriving at the average dry weather flow for August.) Roseboom et al. (1979) reported severe oxygen depletion in Lake Eureka during summer months, when water was withdrawn from the lake for water supply purposes at the rate of 1.5 cfs. The water intake is located at the deepest point of the lake, and water is withdrawn at a depth of 3 to 5 feet from the bottom. Lake Eureka has a surface area of 36 acres and a volume of 227 acre-feet, compared to 39.5 acres and 487. acre-feet for Lake. Le-Aqua-Na. Because of the high lake bottom sediment oxygen demand rates in Lake Le-Aqua-Na, because the water withdrawal rates cannot be maintained at adequate levels, and because of the adverse environmental impacts, selective discharge is not considered as a feasible water quality management alternative for this lake.

Raising of the Lake Water Level. Increasing the lake level by raising the dam will increase the lake volume. This will tend to provide a certain degree of dilution for the nutrients, particularly phosphorus, which has a mean concentration of 150 μg/l during winter months. This is 30 times higher than the desirable level of phosphorus concentration in the lake. The dilution provided by increased lake volume will not be sufficient to reduce the phosphorus concentration below critical levels. Moreover, increased lake volume will result in a reduced flushing rate, which will be conducive to algal blooms. With the increase in lake volume, the volume of the anoxic zone is likely to increase further. Since the loss of storage capacity has been only about 15 percent since the formation of Lake Le-Aqua-Na, and since increasing the lake volume not only would not alleviate the existing lake water quality problems but would tend to aggravate them, it is not a preferred alternative.

Management Alternatives

The primary objective of the lake management plan is to improve the water quality and the general aesthetic conditions in the lake by controlling algal blooms, dense macrophyte growth, and filamentous algal and duckweed patches. In comparison with the lake size, the watershed area is very large, making watershed management ineffectual in controlling nutrient and sediment influx. Peterson (1981) reports that "where watershed area to lake surface area ratios greatly exceed 10 to 1, significant nutrient reduction from the watershed may be impractical. Massive watershed management programs to protect small lakes could be counter-productive." This view is reinforced by USEPA's Clean Lakes Program Guidance Manual (1980a) which indicates that "with some lakes, particularly those where the drainage basin is 20 or more times the lake area, sufficient control of erosion and nutrients from the land may not be possible." In the case of Lake Le-Aqua-Na, the ratio of watershed to water surface areas is 59:1.

Also, one has to keep in mind that this lake experienced hypolimnetic oxygen depletion, algal blooms, and dense macrophyte growths from the first year of its existence. Consequently, the in-lake management techniques proposed here cannot be viewed as palliative measures but as necessary and essential management tools. The issue to be addressed here is the preservation, protection, and utilization of a valuable resource to its maximum potential. With these thoughts in mind, the following management alternatives are suggested.

In-Lake Management Alternatives

1) Aeration and destratification.
   Capital cost, $15,000; 0 and M, $100 to $125/mo.

2) Aeration and destratification in combination with chemical treatment to control algal blooms and duckweed.
   Cost: As in item 1, plus $1280 annual cost for algal control.

3) Aeration and destratification in combination with chemical treatment to control algal blooms, duckweed, and macrophytes. Cost: As in item 2, plus $3000 in annual costs for macrophyte control.

4) Aeration and destratification in combination with chemical treatment to control algal blooms and duckweed, plus mechanical harvesting and removal of macrophytes.
Cost: As in item 2, plus $4000 in annual costs for weed control.

5) Aeration and destratification, and chemical control of macrophytes. Cost: As in item 1, plus $3000 in annual costs for macrophyte control.

6) Aeration and destratification, plus harvesting and removal of macrophytes.
Cost: As in item 1, plus $4000 in annual costs for macrophyte control.

7) Lake drawdown and sediment removal in the shallow upper end of the lake and in silted bay areas.
Cost: Sediment removal $600,000.

Even if the alternative suggested in item 7 is adopted for implementation, one of the alternatives among the suggested alternatives 1 to 6 will be required as a minimum to enhance the water quality conditions in the lake.

Techniques Chosen for Lake Le-Aqua-Na

Based on technical, environmental, and economic considerations, the following in-lake management techniques were chosen for implementation in Lake Le-Aqua-Na:

- Aeration/destratification of the lake.
- Periodic applications of chelated copper sulfate followed by potassium permanganate applications, to control algae and duckweed. This in-lake chemical treatment will be carried out in conjunction with aeration.
- Harvesting of macrophytes in 8 of the 13.5 acres covered with dense macrophyte growth.
- Lake shoreline stabilization (total length of 250 feet).

The cost of the aeration system including design, fabrication, and installation with adequate protective and control systems, as well as the cost of bringing 3-phase 220-volt power to the site and underwater cable is estimated as $15,000. The operating cost for the aerator will be $100 to $125 per month. Allowing for four chemical applications per year for controlling algae and duckweed, the annual cost of this operation will be $1280. The annual cost for weed' harvesting will be $4000. The shoreline protection and stabilization cost will be $10,000. The total cost of project implementation for the first year will thus be $31,480 to $31,780, excluding the cost of monitoring the water quality conditions in the lake during and after the project implementation.

The schedule of activities for implementing the in-lake water quality management scheme is shown in table 43. No realistic schedule of activities can be developed at this time for implementing the major portions of the watershed management scheme. The landowners' cost share in implementing the watershed management recommendations will be at least $126,000. There is a need to initiate an information/education program in resource management for the landowners in the watershed.

Benefits Expected from In-Lake Management

The lake stratifies during summer months and approximately 51 percent of the lake volume becomes anoxic during the period June to August. Because of the anaerobic conditions in the hypolimnetic zone, high concentrations of products of decomposition such as ammonia, phosphorus, iron, manganese, and hydrogen sulfide are released to the overlying waters.

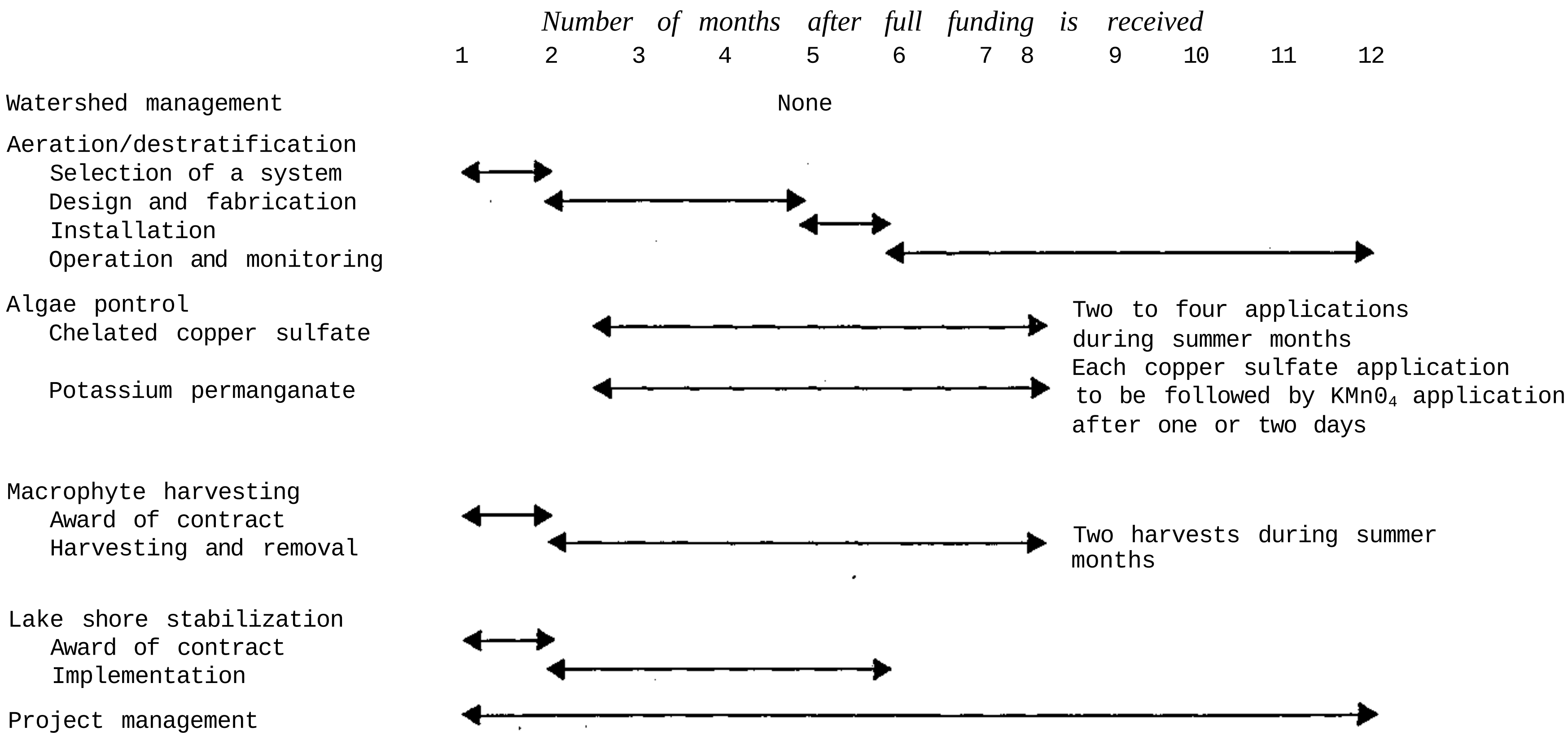
Aeration will increase the fish habitat to 100 percent of the lake volume in summer months, prevent fish kills in the winter, and improve aesthetic conditions in the lake. It is also likely to reduce the phosphorus loading from 290 pounds under anaerobic conditions to about 29 pounds under aerobic conditions. Likewise, the internal nitrogen loading would be reduced from 34,700 pounds to 3400 pounds. The harvesting and removal of macrophytes from the lake will result in a phosphorus export of 200 pounds per year from the lake.

Kothandaraman and Evans (1982) report that aeration in Lake Eureka reduced concentrations of products of decomposition such as ammonia, iron, and manganese in the hypolimnetic waters by about 95 percent. They also show that aeration in combination with chemical treatment for algal control altered the species makeup of algae in the lake from a predominance of problem-causing blue-greens to more desirable diatoms and greens. This in turn eliminated the aesthetically objectionable algal scum formation on the surface under quiescent conditions.

The overall impacts of the implementation of the in-lake management techniques are:

- An estimated reduction of total phosphorus loading to the lake by 261 pounds will occur. There will also be a concomitant reduction in nitrogen loading by 30,300 pounds. The concentration of phosphorus during spring turnover is likely to be reduced from the current level of 0.16 mg/l to 0.15 mg/l.
- The oxygen level in the hypolimnetic zone will be increased from 0.0 mg/1 to at least 5.0 mg/1 during summer months. The fish habitat will be increased from 49 percent to 100 percent of the lake volume during summer months. Winter fish kills will be avoided.
- The release of products of decomposition of the organic-rich bottom sediments such as ammonia, phosphorus, iron, manganese, hydrogen sulfide, and methane will be reduced by more than 90 percent.
- The range of benthic populations will be extended to the profundal region. An increase in species diversity in benthic macroinvertebrates can be expected.

Table 43. Schedule for In-Lake Water Quality Management Activities



- Fishing opportunities are known to improve near the aerator systems.
- Favorable changes in algal populations will occur with a decrease in undesirable blue-green species.
- Water clarity in the lake will be enhanced.
- Selective harvesting of macrophytes from the shallow portions of the lake will improve bank fishing opportunities, increase the area of boat fishing, and improve aesthetic conditions in the lake.

Engineering Specifications for Aeration Systems

Engineering specifications for two different aeration systems are given below.

Garton-Quintero Type Mechanical Destratifier. The aerator system should have the following features as a minimum:

1) Six-foot-diameter reversible flow and variable pitch impeller with appropriate accessories including stainless steel shaft, gear reduction box, electric motor, bearings, and framework, complete with working platform. The underwater U bolts and nuts used in fastening the impeller blades to the hub should be made of stainless steel.
2) The electric motor used should have a double pole switching arrangement for changing the direction of rotation of the impeller.
3) The deck should be of redwood, at least 1 inch thick. The buoyancy of the platform should be sufficient for at least three people to be supported on the platform.
4) Housing to weatherproof the motor and the gear box should be open-ended with a sloping roof.
5) The electric cable conduit leading to the motor should be taken on the bottom side of the deck and finally through the deck and into the housing.
6) One 3/8-inch eye hook with washers and nuts is to be provided for each corner of the floating platform above the water line for purposes of anchoring the device to the lake bottom.
7) The wood and iron framework should be painted with marine coat (light green or blue color) paint.

Compressed Air Aeration System. The compressor system shall consist of a heavy duty, oil-free, continuous rated air compressor of suitable horsepower, 230/460 volts, 60 Hertz, 3-phase, with silencer, pressure gages, relief valves, control valves, and other appurtenances. The compressor should be capable of delivering 50 SCFM (standard cubic feet per minute) filtered, oil-free air at 15 pounds per square inch. The compressor system should be housed in a weatherproof shelter with adequate ventilation and noise dampening features.

The air diffusion system should be designed on the basis of the lake bottom configuration to maximize the destratification and circulation in the lake.

Phase II Monitoring Program

The following monitoring program and schedule will be used in evaluating the effectiveness of the in-lake management techniques adopted for the lake.

The lake will be monitored for dissolved oxygen, temperature, and secchi disc readings at the deepest point and at the shallow end of the lake, the same as during the diagnostic/feasibility investigation. Observations for DO and temperature will be made at 2-foot intervals commencing from the surface.

Water samples for chemical analyses will be taken at the deep station (near the dam) from three different points: 1 foot below the water surface, 1 foot above the bottom, and mid-depth. Analyses will be made for pH, alkalinity, conductivity, total suspended and dissolved solids, volatile suspended solids, turbidity, total phosphorus, dissolved phosphorus, nitrate-nitrogen, and ammonia-nitrogen.

Integrated water samples (integrated to a depth of twice secchi depth) will be collected at the deep station for determining chlorophyll-a concentrations and for identifying and enumerating algal growth in the lake waters.

Sampling with an Ekman dredge at the deep and shallow stations will be conducted to identify and enumerate benthic organisms.

Physical and chemical water quality characteristics will be monitored at biweekly intervals from May to September and at monthly intervals from October to April. Phytoplankton and chlorophyll will be monitored at biweekly intervals from May to September, and benthos will be examined once a month from June to September.

Water samples obtained at the surface and at 2 feet from the surface of the deep and shallow stations of the lake will be analyzed for copper immediately before and one day after the application of chelated copper sulfate to the lake for the control of blue-green algae. Likewise samples will be collected before and after potassium permanganate application to determine manganese concentrations.

In addition, water samples from Waddams Creek and other ephemeral tributaries will be collected after rainstorm events with rainfalls in excess of 2 inches in 48 hours. These storm-related stream runoff samples will be analyzed for total suspended solids, volatile suspended solids, turbidity, total phosphate-phosphorus, total ammonia-nitrogen, and nitrate-nitrogen to monitor the effectiveness of the implementation of the watershed management scheme.

- Does the project implementation involve displacement of people, defacement of residential areas, and changes in land use patterns? Are there any adverse impacts on public land, or scenic, historic, and cultural resources?

Implementation of the in-lake water quality management scheme will not result in displacement of people, in defacement of residences, or in adverse visual impacts. There will be no reduction in the amount of open spaces and no changes in land use patterns, including agricultural land parcels. Impacts on the state park and scenic resources will be very positive as detailed earlier. As there is no land disturbing activity contemplated in the lake management plan, there will be no impact on historic or cultural resources.

- Is there likely to be a long-range increase in energy demand?

It is estimated that a 1.5-horsepower aeration system will be more than adequate for destratifying and aerating the lake. The average daily energy consumption will be 20 kilowatt-hours. The aerator will be operated throughout the year except during the periods of spring and fall turnovers. The method of applying algicides developed for Lake Eureka by Kothandaraman and Evans (1982) involves practically no energy consumption, and the method was found to be very effective in dispersing the chemicals uniformly throughout the lake. A similar method will be used in this lake.

- Will there be any changes in ambient air quality or noise levels?

The aeration system to be installed in the lake will either be noiseless or the air compressor will be housed in a soundproof structure. The ambient air quality will not be impacted by any of the treatment methods proposed for the lake.

- Are there any adverse effects of chemical treatment?

The environmental impacts of the algicide application have been discussed in detail earlier. The anticipated maximum copper concentration in the lake waters is less than 0.1 mg/l as copper. This is not toxic to the aquatic organisms in the lake. At this concentration level no adverse impact was observed either during or after copper sulfate treatment in Lake Eureka (Kothandaraman and Evans, 1982). No adverse impacts due to algicide applications are anticipated in this lake either, as the dosage rates and method of application will be similar to those used in Lake Eureka.

- Does the management plan comply with Executive Order 11988 on floodplain management? Does the management plan entail dredging, shoreline modifications, or any adverse effects on wetland resources?

Lake restoration for Lake Le-Aqua-Na does not involve any activities in floodplains and consequently does not infringe on E.O. 11988. No dredging or channel and shoreline modifications are contemplated. Wetlands and other related resources will not be adversely affected by the implementation of the restoration scheme.

• Does the project need to be done?

The lake is highly eutrophic with the attendant problems of hypolimnetic oxygen depletion during summer and winter months, periodic algal blooms, dense growth of macrophytes in the shallow portions of the lake, periodic fish kills, and other lake water quality problems. These problems greatly detract from the beneficial lake uses for recreational purposes. The state park attendance and the number of lake users have already peaked. If timely action is not taken to mitigate the aforementioned problems in the lake, the full potential of the lake as a recreational resource cannot be achieved and the lake use will decline further.

Aeration/destratification in combination with periodic algicide applications and the harvesting and removal of dense macrophyte growths would be technically feasible and environmentally acceptable for improving the lake water quality characteristics and thereby enhancing the lake uses. Dredging as a lake restoration technique, discussed in detail earlier, is not recommended, mainly because it is not an economically viable alternative at this time. Also, since the loss of lake volume since the creation of the lake is only about 16 percent, sediment removal is not warranted at this time.

COST-BENEFIT ANALYSIS

Annual Costs

Both costs and benefits of implementing the proposed lake restoration measures are estimated in terms of dollars per year. In calculating the annual capital costs, an interest rate of 12 percent is assumed. The capital costs have been taken as one-half of the actual costs to take into account the federal match. The reduced capital cost is then annualized and added to the annual recurring operation and maintenance costs.

		Annual cost, dollars
1.	Aeration/destratification system	2,080
	Operation and maintenance	1,200
		3,280
2.	Algicide application	1,280
3.	Macrophyte control	4,000
	Total annualized costs	8,560

Annual Benefits

Most of the benefits will accrue from better recreational experiences (improvement in quality of existing uses) and increases in the extent of one or more uses. The park attendance record shown in table 7 indicates that the annual attendance has not returned to the maximum value reached in

1976. This is primarily attributable to the dense macrophyte growths covering nearly one-third of the lake surface and to the aesthetically objectionable blue-green algal blooms, both predominant during summer months when the demands for recreational resources are the highest.

The Department of Conservation keeps records of the total number of visitors to the park, but does not maintain a census of users engaged in various recreational activities. The lake has the potential for attracting and meeting the needs of at least 530,000 visitors per year.

A procedure for calculating the recreational benefits in dollar values, recommended by the U.S. Water Resources Council (Federal Register, Title 18, App. 3, Subpt. K, pp. 218-221, revised as of April 1, 1982), has been used here. The recommended guidelines for assigning points for general recreation as well as the conversion of points to dollar values are given in table 44. Points for the present conditions and for the future conditions resulting from the implementation of the lake restoration measures are as follows. The activities considered in assigning points are recreational activities such as fishing, boating, camping, and picnicking.

	Points for criteria (from table 44)					
	a	b	c	d	e	Total
Present conditions	10	6	5	14	2	37
Future conditions (after restoration)	10	6	8	14	12	50

The unit day recreation values (UDVs) are obtained by using table 44 to convert points into dollar values. The UDVs corresponding to 37 and 50 points are respectively $2.22 and $2.51.

The increase in annual benefits because of improvement in the quality of recreational opportunities and increases in the number of park visitors would be:

301,587 ($2.51 - $2.22) + (530,000-301,587) ($2.51)
= $(87,460 + 573,317)
= $660,777

Thus, the net increase in anticipated annual benefits is $660,777.

Total discounted benefit
(7-1/8 percent and 10 years) = $4,614,000

314 Grant amount 50,347

$$\frac{\text{Total discounted benefit}}{\text{314 Grant amount}} = 91.6$$

Table 44. Recreation Benefit Assessment

a. Guidelines for Assigning Points for General Recreation

Criterion	Judgement factors				
(a) Recreation experience	Two general activities	Several general activities	Several general activities; one high quality value activity	Several general activities; more than one high quality value activity-^	Numerous high quality value activities; some general activities
Total points: 30 Point value:	0-4	5-10	11-16	17-23	24-30
(b) Availability of other oppoYtunities	Several within 1 hr. travel time; a few within 30 min. travel time	Several within 1 hr. travel time; none within 30 min. travel time	One or two within 1 hr. travel time; none within 45 min. travel time	None within 1 hr. travel time	None within 2 hr. travel time
Total points: 18 Point value:	0-3	4-6	7-10	11-14	15-18
(c) Carrying capacity	Minimum facility development for public health and safety	Basic facilities - to conduct activity(ies)	Adequate facilities to conduct activity without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site	Ultimate facilities to achieve intent of selected alternative
Total points: 14 Point value:	0-2	3-5	6-8 •	9-11	12-14
(d) Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good roads to site; fair access, good roads within site	Good access, high standard road to site; good access within site
Total points: 18 Point value:	0-3	4-6	7-10	11-14	15-16

Table 44. Concluded

a. Concluded

Criterion	Judgement factors				
(e) Environmental	Low esthetic factors[4] exist that significantly lower quality[5]	Average esthetic quality; factors exist that lower quality to minor degree	Above average esthetic quality; any limiting factors can be reasonably rectified	High esthetic quality; no factors exist that lower quality	Outstanding esthetic quality; no factors exist that lower quality
Total points: 20					
Point value:	0-2	3-6	7-10	11-15	16-20

b. Conversion of Points to Dollar Values

Activity categories	Point values										
	0	10	20	30	40	50	60	70	80	90	100
General recreation (Points from Part a)	1.07	1.25	1.44	1.68	1.93	2.30	2.48	2.67	2.85	3.04	3.22
General fishing and hunting (Points from Part a)	1.57	1.74	1.90	2.07	2.28	2.51	2.73	2.94	3.08	3.17	3.20
Specialized fishing and hunting	7.50	7.69	7.88	8.08	8.27	9.03	9.80	10.57	11.34	12.10	12.87
Specialized recreation other than fishing and hunting	4.29	4.65	5.00	5.36	5.72	6.44	7.15	8.58	10.01	11.44	12.87

Note: Unit day recreation values may not exceed the values provided by this table.,

1 Value should be adjusted for overuse.

2 General activities include those that are common to the region and that are usually of normal quality. This includes picnicking, camping, hiking, riding, cycling, and fishing and hunting of normal quality.

3 High quality value activities include those that are not common to the region and/or nation and that are usually of high quality.

4 Major esthetic qualities to be considered include geology and topography, water, and vegetation.

5 Factors to be considered to lower quality include, air and water pollution, pests, poor climate, and unsightly adjacent areas.

SUMMARY

Lake Le-Aqua-Na, formed in 1956 by the damming of Waddams Creek, is a 40-acre lake with a total watershed area of about 2350 acres. The lake and the surrounding park, which are publicly owned, are managed by the Department of Conservation for recreational purposes such as fishing, boating, and camping. The park system is open to the public throughout the year.

Thirty-one percent of the lake's watershed is in state ownership, and the rest is in small private holdings. Agriculture is the predominant land use in the watershed, constituting 67 percent of the total. There is no land use activity within the state-owned lands which involves land disturbance. The only point source waste discharge within the watershed, the state park wastewater treatment plant, has no measurable outflow.

The lake has exhibited very high biological productivity, requiring algicide and herbicide applications since 1956 to control algae and macrophytes. Oxygen depletion in the hypolimnion has been noted since its nascency. The lake experiences summer stratification. During the peak stratification period, the lake was found to be totally anoxic at depths below 6 feet from the surface. About 51 percent of the lake volume is anoxic. Average secchi disc transparency during the summer was found to be about 3.25 feet.

The lake water quality characteristics were found to be typical of midwestern lakes with high alkalinity, conductivity, and dissolved solids. Mean phosphorus concentration in the lake during winter months was found to be 150 ug/1. Inorganic nitrogen and total phosphorus loadings to the lake were estimated respectively as 176.9 and 5.9 $g/m^2/yr$.

The major portion of the suspended sediment was organic (volatile) matter, indicating that lake transparency was influenced primarily by algae. Waddams Creek was not found to convey unusual amounts of suspended sediment loads under normal rainfall conditions. However, the main and secondary tributaries to the lake were found to carry enormous amounts of suspended sediments and nutrients during two storm events, one occurring in June and another in August. These two storm events produced 4.4 and 6.3 inches of rainfall, respectively, in two to three days. These two storms constituted 40 percent of the total rainfall observed in the area and delivered about 73 percent of the total phosphorus loading to the lake.

The lake exhibits a high biological productivity. Algal growths of bloom proportions were encountered during summer months, with blue-greens the dominant species. Chlorophyll levels ranged from 2 to 93 ug/1 with an average value of 46 µg/l. The ratios of total nitrogen to total phosphorus in the lake indicate that phosphorus could be a limiting nutrient. However, there was an abundance of phosphorus in the lake system all the time. About 13.5 acres of the lake was covered with a dense growth of macrophytes. Coontail and elodea were the dominant vegetation found in the lake.

On the basis of a sediment survey of the lake, it was estimated that the volume of water storage has decreased 15.8 percent in 25 years, a rate of 0.63 percent per year. This is the median value of the sedimentation rates observed in 101 other Illinois lakes and reservoirs. The lake received sediments from its watershed at the rate of 1.53 tons/acre/year.

Analyses of surficial sediments, core samples, and fish flesh for trace metals and organochemicals of concern indicate that the concentrations were all well below standards stipulated by the Illinois Pollution Control Board or the detection limits for these substances.

The lake is eutrophic by all the measures and indices suggested in the literature.

Based on technical, environmental, and economic considerations, the following in-lake management techniques have been chosen for implementation in Lake Le-Aqua-Na:

- Aeration/destratification of the lake.
- Periodic applications of chelated copper sulfate followed by potassium permanganate applications. This in-lake algicide application will be carried out in conjunction with aeration.
- Harvesting and removal of macrophytes from selected areas.
- Lake shore stabilization totalling 250 feet in length.

In addition, several watershed land use management practices were found to be desirable. Implementation of these recommendations demands the wholehearted cooperation and dedication of the landowners in preserving, protecting, and enhancing the lake water quality. The desirable land use management practices are:

- Terracing and strip cropping practices in three agricultural land parcels identified as experiencing high rates of soil loss.
- Adoption of conservation tillage practices with 40 percent residue left on the land in about' 970 acres of agricultural land in continuous corn production.
- Exclusion of livestock from the main stem of Waddams Creek by fencing.

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APPENDIX

1981 Water Quality Data,
Lake Le-Aqua-Na, Stephenson County, Illinois

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 OS.O 089 49 44.0 4
L LE-AQUA-HA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL	DATE		81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21
	INITIAL	TIME-DEPTH-BOTTOM		1100 0000	1100 0001	1100 0002	1100 0004	1100 0006	1100 0008	1100 0010	1100 0012
00010	WATER	TEMP	CENT	1.0		2.3	2.8	2.8	2.8	2.8	2.8
00011	WATER	TEMP	FAHN	33.8		36.1	37.0	37.0	37.0	37.0	37.0
00020	AIR	TEMP	CENT		1.0-						
00035	WIND	VELOCITY	MPH		0.0						
00045	PRECIP	TOT DAY	IN		0.00						
00076	TURC	TRBIDMTR	HACH FTU		1.6						1.3
00077	TRANSP	SECCHI	INCHES		54						
00094	CNDUCTVY	FIELD	MICROMHO		270						285
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.0		8.9	8.9	8.9	8.9	9.0	9.1
0030V	DO	SATUR	PERCENT	63.4		64.5	65.9	65.9	65.9	66.7	67.4
00400	PH		SU		7.80						7.85
00410	T ALK	CAC03	MG/L		244						290
00515	RESIDUE	DISS-105	C MG/L		362						368
00530	RESIDUE	TOT NFLT	MG/L		0						0
00535	RESIDUE	VOL NFLT	MG/L		0						0
00608	NH3+NH4-	N DISS	M3/L		0.330						0.170
00610	NH3+NH4-	N TOTAL	MG/L		0.390						0.170
00619	UN-IONZD	NH3-NH3	MG/L								0.002
00620	N03-N	TOTAL	MG/L		1.290						1.290
00625	TOT KJEL	N	MG/L		1.070						0.860
00665	FHOS-TOT		MG/L P		0.100						0.110
00666	PHOS-DIS		MG/L P		0.090						0.080
72025	DEPTH OF	POND	FEET		25.00						

	INITIAL	DATE		81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/02/18	81/02/18
	INITIAL	TIME-OEPTH-BOTTOM		1100 0014	1100 0016	1100 0018	1100 0020	1100 0022	1100 0024	1030 0000	1030 0001
00010	WATER	TEMP	CENT	2.8	2.8	3.0	3.0	3.1	3.9	2.0	
00011	WATER	TEMP	FAHN	37.0	37.0	37.4	37.4	37.6	39.0	35.6	
00020	AIR	TEMP	CENT								10.0
00045	PRECIP	TOT DAY	IN								0.00
00076	TURB	TRBIDMTR	HACH FTU						2.6		0.7
00077	TRANSP	SECCHI	INCHES								192
00094	CHDUCTVY	FIELD	MICROMHO						292		152
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.1	9.4	9.7	10.0	8.4	3.4	10.7	
00301	DO	SATUR	PERCENT	67.4	69.6	71.9	74.1	62.2	26.0	77.5	
00400	PH		SU						7.80		7.60
00410	T ALK	CAC03	MG/L						294		120
00515	RESIDUE	DISS-105	C MG/L						354		140
00530	RESIDUE	TOT NFLT	MG/L						0		0
00535	RESIDUE	VOL NFLT	MG/L						0		0
00608	NH3+NH4-	N DISS	MG/L						0.190		0.210
00610	NH3+NH4-	N TOTAL	MG/L						0.230		0.240
00619	UN-IONZD	NH3-NH3	MG/L						0.002		
00620	N03-N	TOTAL	MG/L						1.360		

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AM8NT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/02/18	81/02/18
INITIAL TIME-DEPTH-BOTTOM	1100 0014	1100 0016	1100 0018	1100 0020	1100 0022	1100 0024	1030 0000	1030 0001
00625 TOT KJEL N MG/L						0.770		0.410
00665 PHOS-TOT MG/L P						0.090		0.050
00666 PHOS-DIS MG/L P						0.080		0.040
72025 DEPTH OF POND FEET								25.00

INITIAL DATE	81/02/18	81/02/18	81/02/18	81/02/18	81/02/18	81/02/18	81/02/18	81/02/18
INITIAL TIME-DEPTH-BOTTOM	1030 0002	1030 0004	1030 0006	1030 0008	1030 0010	1030 0012	1030 0014	1030 0016
00010 WATER TEMP CENT	2.8	2.9	2.9	2.9	2.8	2.8	2.8	2 7
00011 WATER TEMP FAHN	37.0	37.2	37.2	37.2	37.0	37.0	37.0	36.9
00076 TURB TRBIDMTR HACH FTU						1.8		
00094 CNDUCTVY FIELD MICROMHO						345		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	10.4	10.4	10.2	9.8	9.4	9.6	9.6	9.4
00301 DO SATUR PERCENT	77.0	77.0	75.6	72.6	69.6	71.1	71.1	69.6
00400 PH SU						7.90		
00410 T ALK CAC03 MG/L						264		
00515 RESIDUE DISS-105 C MG/L						352		
00530 RESIDUE TOT NFLT MG/L						0		
00535 RESIDUE VOL NFLT MG/L						0		
00608 NH3+NH4- N DISS MG/L						0.260		
00610 NH3+NH4- N TOTAL MG/L						0.270		
00619 UN-IONZD NH3-NH3 MG/L						0.003		
00625 TOT KJEL N MG/L						0.760		
00665 PHOS-TOT MG/L P						0.110		
00666 PHOS-DIS MG/L P						0.080		

INITIAL DATE	81/02/18	81/02/18	81/02/18	81/02/18	81/03/18	81/03/18	81/03/18	81/03/18
INITIAL TIME-DEPTH-BOTTOM	1030 0018	1030 0020	1030 0022	1030 0024	1130 0000	1130 0001	1130 0002	1130 0004
00010 WATER TEMP CENT	3.0	3.0	3.0	3.1	4.3		4.3	4.3
00011 WATER TEMP FAHN	37.4	37.4	37.4	37.6	39.7		39.7	39.7
00020 AIR TEMP CENT						4.0		
00035 WIND VELOCITY MPH						10.0		
00045 PRECIP TOT DAY IN						0.05		
00076 TURB TRBIDMTR HACH FTU				1.8		4.3		
00077 TRANSP SECCHI INCHES						44		
00094 CNDUCTVY FIELD MICROMHO				363		303		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	8.2	6.9	6.2	5.3	13.6		13.6	13.8
00301 DO SATUR PERCENT	60.7	51.1	45.9	39.3	103.8		103.8	105.3
00400 PH SU				7.85		8.40		
00410 T ALK CAC03 MG/L				305		221		
00515 RESIDUE DISS-105 C MG/L				344		334		
00530 RESIDUE TOT NFLT MG/L				4		7		
00535 RESIDUE VOL NFLT MG/L				4		7		
00608 NH3+NH4- N DISS MG/L				0.170		0.160		
00610 NH3+NH4- N TOTAL MG/L				0.220		0.170		

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE		81/02/18	81/02/18	81/02/18	81/02/18	81/03/18	81/03/18	81/03/18	81/03/18
INITIAL TIME-DEPTH-BOTTOM		1030 0018	1030 0020	1030 0022	1030 0024	1130 0000	1130 0001	1130 0002	1130 0004
00619 UN-IONZD NH3-NH3	MG/L				0.002				
00620 N03-N TOTAL	MG/L						1.870		
00625 TOT KJEL N	M3/L				0.620		1.230		
00665 PHOS-TOT	MG/L P				0.100		0.160		
00666 FHOS-DIS	MG/L P				0.070		0.100		
72025 DEPTH OF POND	FEET						24.00		
INITIAL DATE		81/03/18	81/03/18	81/03/18	81/03/18	81/03/18	81/03/18	81/03/18	81/03/18
INITIAL TIME-DEPTH-BOTTOM		1130 0006	1130 0008	1130 0010	1130 0012	1130 0014	1130 0016	1130 0018	1130 0020
00010 WATER TEMP	CENT	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2
00011 WATER TEMP	FAHN	39.7	39.6	39.6	39.6	39.6	39.6	39.6	39.6
00076 TURB TRBIDMTR.	HACH FTU				4.6				
00094 CNDUCTVY FIELD	MICROMHO				301				
00116 INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE	MG/L	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
00301 DO SATUR	PERCENT	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.3
00400 PH	SU				8.60				
00410 T ALK CAC03	MG/L				244				
00515 RESIDUE DISS-105	C MG/L				350				
00530 RESIDUE TOT NFLT	MG/L				8				
00535 RESIDUE VOL NFLT	MG/L				8				
00608 NH3+NH4- N DISS	MG/L				0.210				
00610 NH3+NH4- N TOTAL	MG/L				0.350				
00619 UN-IONZD NH3-NH3	MG/L				0.019				
00620 N03-N TOTAL	MG/L				1.880				
00625 TOT KJEL N	MG/L				1.280				
00665 PHOS-TOT	MG/L P				0.160				
00666 FHOS-DIS	MG/L P				0.100				
INITIAL DATE		81/03/18	81/03/18	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15
INITIAL TIME-DEPTH-BOTTOM		1130 0022	1130 0023	1200 0000	1200 0001	1200 0002	1200 0004	1200 0006	1200 0008
00010 WATER TEMP	CENT	4.2	4.2	12.8		11.9	11.2	11.2	11.2
00011 WATER TEMP	FAHN	39.6	39.6	55.0		53.4	52.2	52.2	52.2
00076 TURB TRBIDMTR	HACH FTU		3.6		5.8				
00094 CNDUCTVY FIELD	MICROMHO		305						
00116 INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE	MG/L	13.8	13.3	9.2		9.0	8.0	7.9	7.9
00301 DO SATUR	PERCENT	105.3	101.5	86.8		83.3	72.1	71.2	71.2
00400 PH	SU		8.40						
00410 T ALK CAC03	MG/L		217						
00515 RESIDUE DISS-105	C MG/L		348		286				
00530 RESIDUE TOT NFLT	MG/L		16		12				
00535 RESIDUE VOL NFLT	MG/L		16		11				
00608 NH3+NH4- N DISS	MG/L		0.310		0.030				
00610 NH3+NH4- N TOTAL	MG/L		0.320		0.040				
00619 UN-IONZD NH3-NH3	MG/L		0.011						

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/03/18	81/03/18	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15
INITIAL TIME-DEPTH-BOTTOM	1130 0022	1130 0023	1200 0000	1200 0001	1200 0002	1200 0004	1200 0006	1200 0008
00620 N03-N TOTAL MG/L		2.050		1.170				
00625 TOT KJEL N MG/L		1.050		0.630				
00665 PHOS-TOT MG/L P		0.160		0.130				
00666 PHOS-DIS MG/L P		0.110		0.070				
INITIAL DATE	81/04/l5	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15	81/04/15
INITIAL TIME-DEPTH-BOTTOM	1200 0010	1200 0012	1200 0014	1200 0016	1200 0018	1200 0020	1200 0022	1200 0023
00010 WATER TEMP CENT	11.2	11.2	11.2	11.2	11.2	11.0	10.8	
00011 WATER TEMP FAHN	52.2	52.2	52.2	52.2	52.2	51.8	51.4	
00076 TURB TRBIDMTR HACH FTU		8.1						35.6
00094 CNDUCTVY FIELD MICROMHO		320						338
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	7.9	7.8	8.2	8.3	7.1	7.1	7.1	
00301 DO SATUR PERCENT	71.2	70.3	73.9	74.8	64.0	64.0	64.0	
00400 PH SU		8.90						8.40
00410 T ALK CAC03 MG/L		195						207
00515 RESIDUE DISS-105 C MG/L		296						314
00530 RESIDUE TOT NFLT MG/L		16						81
00535 RESIDUE VOL NFLT MG/L		14						29
00608 NH3+NH4- N DISS MG/L		0.310						0.310
00610 NH3+NH4- N TOTAL MG/L		0.320						0.310
00619 UN-IONZD NH3-NH3 MG/L		0.054						
00620 N03-N TOTAL MG/L		1.200						1.680
00625 TOT KJEL N MG/L		0.870						1.520
00665 PHOS-TOT MG/L P		0.130						0.340
00666 PHOS-DIS MG/L P		0.070						0.030
INITIAL DATE	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13
INITIAL TIME-DEPTH-BOTTOM	1000 0000	1000 0001	1000 0002	1000 0004	1000 0006	1000 0008	1000 0010	1000 0012
00010 WATER TEMP CENT	13.8		13.2	13.2	13.2	13.0	12.8	12.4
00011 WATER TEMP FAHN	56.8		55.8	55.8	55.8	55.4	55.0	54.3
00020 AIR TEMP CENT		9.4						
00035 WIND VELOCITY MFH		0.0						
00045 PRECIP TOT DAY IN		0.00						
00076 TURB TRBIDMTR HACH FTU		0.7						0.3
00077 TRANSP SECCHI INCHES		126						
00094 CNDUCTVY FIELD MICROMHO		326						326
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	8.7		8.7	8.5	8.4	7.6	7.2	6.7
00301 DO SATUR PERCENT	83.7		82.1	80.2	79.2	71.7	67.9	62.0
00400 PH SU		8.60						8.50
00410 T ALK CAC03 MG/L		191						191
00515 RESIDUE DISS-105 C MG/L		296						302
00530 RESIDUE TOT NFLT MG/L		4						2
00535 RESIDUE VOL NFLT MG/L		4						2
00608 NH3+NH4- N DISS MG/L		0.260						0.280

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13
INITIAL TIME-DEPTH-BOTTOM	1000 0000	1000 0001	1000 0002	1000 0004	1000 0006	1000 0008	1000 0010	1000 0012
00610 NH3+NH4- N TOTAL MG/L		0.300						0.410
00619 UN-IOHZD NH3-NH3 MG/L								0.033
00620 N03-N TOTAL MG/L		0.643						0.643
00625 TOT KJEL N MG/L		1.190						1.090
00665 FHOS-TOT MG/L P		0.070						0.090
00666 PHOS-DIS MG/L P		0.050						0.060
72025 DEPTH OF POND FEET		26.00						
INITIAL DATE	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13	81/05/13
INITIAL TIME-OEPTH-BOTTOM	1000 0014	1000 0016	1000 0018	1000 0020	1000 0021	1000 0022	1000 0024	1000 0025
00010 'WATER TEMP CENT	12.0	11.5	11.0	10.2		10.0	10.0	10.0
00011 WATER TEMP FAHN	53.6	52.7	51.8	50.4		50.0	50.0	50.0
00076 TURB TRBIDMTR HACH FTU								53.0
00094 CNDUCTVY FIELD			MICROMHO					350
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	5.4	3.1	1.1	0.3		0.3	0.2	0.2
00301 DO SATUR PERCENT	50.0	28.7	9.9	2.7		2.7	1.8	1.8
00400 PH SU								7.80
00410 T ALK CAC03 MG/L								205
00515 RESIDUE DISS-105 C MG/L								316
00530 RESIDUE TOT NFLT MG/L								170
00535 RESIDUE VOL NFLT MG/L								34
00608 NH3+NH4- N DISS MG/L								1.060
00610 NH3+NH4- N TOTAL MG/L								1.520
00619 UN-IONZD NH3-NH3 MG/L								0.021
00625 TOT KJEL N MG/L								3.120
00665 PHOS-TOT MG/L P								0.740
00666 PHOS-DIS MG/L P								0.180
32211 CHLRFHYL A UG/L CORRECTD					20.00			
60050 ALGAE TOTAL /ML					120			
INITIAL DATE	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27
INITIAL TIME-DEPTH-BOTTOM	1015 0000	1015 0001	1015 0002	1015 0004	1015 0006	1015 0008	1015 0010	1015 0012
00010 WATER TEMP CENT	19.4		19.2	19.2	18.4	16.4	15.2	14.0
00011 WATER TEMP FAHN	66.9		66.6	66.6	65.1	61.5	59.4	57.2
00020 AIR TEMP CENT		16.4						
00035 WIND VELOCITY MPH		5.0						
00045 PRECIP TOT DAY IN		0.00						
00076 TURB TRBIDMTR HACH FTU		1.9						0.6
00077 TRANSP SECCHI INCHES		51						
00094 CNDUCTVY FIELD MICROMHO		355						380
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	16.4		15.8	15.8	10.6	9.2	6.5	4.6
00301 DO SATUR PERCENT	174.5		168.1	168.1	111.6	92.0	63.7	44.2
00400 PH SU		9.20						8.30
00410 T ALK CAC03 MG/L		179						208

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 HEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27
INITIAL TIME-DEPTH-BOTTOM	1015 0000	1015 0001	1015 0002	1015 0004	1015 0006	1015 0008	1015 0010	1015 0012
00515 RESIDUE DISS-105 C MG/L		280						300
00530 RESIDUE TOT NFLT MG/L		3						6
00535 RESIDUE VOL NFLT MG/L		3						5
00608 NH3+NH4- N DISS MG/L		0.350						0.260
00610 NH3+NH4- N TOTAL MG/L		0.460						0.300
00619 UN-IONZD NH3-NH3 MG/L								0.018
00620 NO3-N TOTAL MG/L		0.110						0.500
00625 TOT KJEL N MG/L		0.730						0.680
00665 PHOS-TOT MG/L P		0.060						0.060
00666 FHOS-DIS MG/L P		0.030						0.050
32211 CHLRFHYL A UG/L CORRECTD						30.00		
60050 ALGAE TOTAL /ML						160		
72025 DEPTH OF POND FEET		25.00						

INITIAL DATE	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/05/27	81/06/10	81/06/10
INITIAL TIME-DEPTH-BOTTOM	1015 001	1015 0016	1015 0018	1015 0020	1015 0022	1015 0024	0945 0000	0945 0001
00010 WATER TEMP CENT	13.6	12.2	11.8	11.4	10.8	10.2	21.0	
00011 WATER TEMP FAHN	56.5	54.0	53.2	52.5	51.4	50.4	69.8	
00020 AIR TEMP CENT								20.0
00035 WIND VELOCITY MPH								7.5
00045 PRECIP TOT DAY IN								0.00
00076 TURB TRBIDMTR HACH FTU						2.6		
00077 TRANSP SECCHI INCHES								25
00094 CNDUCTVY FIELD MICROMHO						386		328
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO FROBE MG/L	2.2	0.3	0.2	0.2	0.2	0.2	10.4	
00301 DO SATUR PERCENT	21.2	2.8	1.9	1.8	1.8	1.8	115.6	
00400 PH SU						7.90		9.50
00410 T ALK CAC03 MG/L						221		162
00515 RESIDUE DISS-105 C MG/L						320		260
00530 RESIDUE TOT NFLT MG/L						7		17
00535 RESIDUE VOL NFLT MC/L						5		15
00608 NH3+NH4- N DISS MG/L						1.040		0.420
00610 NH3+NH4- N TOTAL MG/L				1.080				0.660
00619 UN-IONZD NH3-NH3 MG/L						0.019		
00620 NO3-N TOTAL MG/L						0.230		0.021
00625 TOT KJEL N MG/L						1.320		2.020
00665 PHOS-TOT MG/L P						0.280		0.100
00666 FHOS-DIS MG/L P						0.260		0.020
72025 DEPTH OF POND FEET								25.00

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AM3NT/LAKE

INITIAL DATE	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10
INITIAL TIME-DEPTH-BOTTOM	0945 0002	0945 0004	0945 0006	0945 0008	0945 0010	0945 0012	0945 0014	0945 0016
00010 WATER TEMP CENT	21.2	21.2	21.2	21.2	21.2	15.0	13.8	13.2
00011 WATER TEMP FAHN	70.2	70.2	70.2	70.2	70.2	59.0	56.8	55.8
00094 CNDUCTVY FIELD MICROMHO						350		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	10.6	10.6	10.5	10.5	10.0	0.4	0.3	0.2
00301 DO SATUR PERCENT	117.8	117.8	116.7	116.7	111.1	3.9	2.9	1.9
00400 PH SU						9.20		
00410 T ALK CAC03 MS/L						176		
00515 RESIDUE DISS-105 C MG/L						268		
00530 RESIDUE TOT NFLT MG/L						19		
00535 RESIDUE VOL NFLT MG/L						17		
00608 NH3+NH4- N DISS MG/L						0.270		
00610 NH3+NH4- N TOTAL MG/L						0.470		
00619 UN-IONZD NH3-NH3 MG/L						0.173		
00620 N03-N TOTAL MG/L						0.036		
00625 TOT KJEL N MG/L						1.560		
00665 PHOS-TOT MG/L P						0.080		
00666 PHOS-DIS MG/L P						0.020		
32211 CHLRFHYL A UG/L CORRECTD		70.00						
60050 ALGAE TOTAL /ML		1510						

INITIAL DATE	81/06/10	81/06/10	81/06/10	81/06/10	81/06/24	81/06/24	81/06/24	81/06/24
INITIAL TIME-DEPTH-BOTTOM	0945 0018	0945 0020	0945 0022	0945 0024	1245 0000	1245 0001	1245 0002	1245 0004
00010 WATER TEMP CENT	12.5	11.7	11.0	10.9	23.2		23.0	22.0
00011 WATER TEMP FAHN	54.5	53.1	51.8	51.6	73.8		73.4	71.6
00020 AIR TEMP CENT						25.9		
00035 WIND VELOCITY MPH						7.5		
00045 PRECIP TOT DAY IN						0.00		
00076 TURB TRBIDMTR HACH FTU						4.8		
00077 TRANSP SECCHI INCHES						26		
00094 CNDUCTVY FIELD MICROMHO				420		370		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO FROBE MG/L	0.2	0.2	0.2	0.2	11.6		12.2	10.0
00301 DO SATUR PERCENT	1.9	1.9	1.8	1.8	133.3		140.2	113.6
00400 PH SU				8.00		8.90		
00410 T ALK CAC03 MG/L				218		170		
00515 RESIDUE DISS-105 C MG/L				306		294		
00530 RESIDUE TOT NFLT MG/L				7		9		
00535 RESIDUE VOL NFLT MG/L				5		9		
00608 NH3+NH4- N DISS MG/L				0.750		0.360		
00610 NH3iNH4- N TOTAL MG/L				0.980		1.000		
00619 UN-IONZD NH3-NH3 MG/L				0.023				
00620 NO3-N TOTAL MG/L				0.057		1.040		
00625 TOT KJEL N MG/L				1.540		1.900		
00665 PHOS-TOT MG/L P				0.330		0.170		
00666 PHOS-DIS MG/L P				0.250		0.080		

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 HEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/06/10	81/06/10	81/06/10	81/06/10	81/06/24	81/06/24	81/06/24	81/06/24
INITIAL TIME-DEPTH-BOTTOM	0945 0018	0945 0020	0945 0022	0945 0024	1245 0000	1245 0001	1245 0002	1245 0004
32211 CHLRPHYL A UG/L CORRECTD								80.00
60050 ALGAE TOTAL /ML								1950
72025 DEPTH OF POND FEET						25.00		
INITIAL DATE	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24
INITIAL TIME-DEPTH-BOTTOM	1245 0006	1245 0008	1245 0010	1245 0012	1245 0014	1245 0016	1245 0018	1245 0020
00010 WATER TEMP CENT	21.8	21.6	19.0	18.2	14.8	13.1	12.8	12.2
00011 WATER TEMP FAHN	71.2	70.9	66.2	64.8	58.6	55.6	55.0	54.0
00076 TURB TRBIDMTR HACH FTU				7.9				
00094 CNDUCTVY FIELD MICROMHO				401				
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PR03E MG/L	9.4	7.0	0.4	0.2	0.2	0.2	0.2	0.2
00301 DO SATUR PERCENT	106.8	79.5	4.3	2.1	2.0	1.9	1.9	1.9
00400 PH SU				7.70				
00410 T ALK CAC03 M5/L				176				
00515 RESIDUE DISS-105 C MG/L				298				
00530 RESIDUE TOT NFLT MG/L				10				
00535 RESIDUE VOL NFLT MG/L				10				
00608 NH3+NH4- N DISS MG/L				0.770				
00610 NH3+NH4- N TOTAL MG/L				0.910				
00619 UN-IONZD NH3-NH3 MG/L				0.019				
00620 N03-N TOTAL MG/L				0.796				
00625 TOT KJEL N MG/L				1.680				
00665 PHOS-TOT MG/L P				0.240				
00666 PHOS-DIS MG/L P				0.190				
INITIAL DATE	81/06/24	81/06/24	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	61/07/08
INITIAL TIME-DEPTH-BOTTOM	1245 0022	1245 0024	0830 0000	0830 0001	0830 0002	0830 0004	0830 0006	0830 0008
00010 WATER TEMP CENT	12.2	12.0	28.1		28.1	27.1	25.1	24.8
00011 WATER TEMP FAHN	54.0	53.6	82.6		82.6	80.8	77.2	76.6
00020 AIR TEMP CENT				27.0				
00035 WIND VELOCITY MPH				4.0				
00045 PRECIP TOT DAY IN				0.00				
00076 TURB TRBIDMTR HACH FTU		6.6						
00077 TRANSP SECCHI INCHES				27				
00094 CNDUCTVY FIELD MICROMHO		450		321				
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	13.4		13.4	9.1	0.4	0.2
00301 DO SATUR PERCENT	1.9	1.9	169.6		169.6	112.3	4.8	2.4
00400 PH SU		7.50		10.00				
00410 T ALK CAC03 MG/L		244		147				
00515 RESIDUE DISS-105 C MG/L		308		258				
00530 RESIDUE TOT NFLT MG/L		6		11				
00535 RESIDUE VOL NFLT MG/L		6		10				
00608 NH3+NH4- N DISS MG/L		1.660		0.080				
00610 NH3+NH4- N TOTAL MG/L		1.980		0.210				

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/06/24	81/06/24	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08
INITIAL TINE-DEPTH-BOTTOM	1245 0022	1245 0024	0830 0000	0830 0001	0830 0002	0830 0004	0830 0006	0830 0008
00619 UN-IONZD NH3-NH3 MG/L		0.016						
00620 N03-N TOTAL MG/L		0.092		0.050				
00625 TOT KJEL N MG/L		3.810						
00665 FHOS-TOT MG/L P		0.600		0.100				
00666 FHOS-OIS MG/L P		0.450		0.020				
32211 CHLRPHYL A UG/L CCRRECTD						93.00		
60050 ALGAE TOTAL /ML						4550		
72025 DEPTH OF FOND FEET				25.00				
INITIAL DATE	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08
INITIAL TIME-DEPTH-BOTTOM	0830 0010	0830 0012	0830 0014	0830 0016	0830 0018	0830 0020	0830 0022	0830 0024
00010 WATER TEMP CENT	20.4	17.2	15.1	14.0	13.4	12.3	11.9	11.3
00011 WATER TEMP FAHN	68.7	63.0	59.2	57.2	56.1	54.1	53.4	52.3
00094 CNDUCTVY FIELD MICRCMHO		421						440
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
00301 DO SATUR PERCENT	2.2	2.1	2.0	1.9	1.9	1.9	1.9	1.8
00400 PH SU		7.80						7.60
00410 T ALK CAC03 MG/L		246						'260
00515 RESIDUE DISS-105 C MG/L		330						338
00530 RESIDUE TOT NFLT MG/L		9						9
00535 RESIDUE VOL NFLT MG/L		4						6
00608 NH3+NH4- N DISS MG/L		1.600						2.790
00610 NH3+NH4- N TOTAL MG/L		1.710						2.890
00619 UN-IONZD NH3-NH3 MG/L		0.041						0.029
00620 NO3-N TOTAL MG/L		0.500						0.050
00625 TOT KJEL N MG/L		2.730						4.720
00665 PHOS-TOT MG/L P		0.510						0.770
00666 PHOS-DIS MG/L P		0.420						0.560
INITIAL DATE	81/07/22	81/07/22	81/07/22	81/07/22	81/07/22	81/07/22	81/07/22	81/07/22
INITIAL TIME-DEPTH-BOTTOM	1045 0000	1045 0001	1045 0002	1045 0004	1045 0005	1045 0006	1045 0008	1045 0010
00010 WATER TEMP CENT	25.2		25.2	24.9		24.5	23.1	20.9
00011 WATER TEMP FAHN	77.4		77.4	76.8		76.1	73.6	69.6
00020 AIR TEMP CENT		23.0						
00045 PRECIP TOT DAY IN		0.40						
00076 TURB TRBIDMTR HACH FTU		7.0						
00077 TRANSP SECCHI INCHES		30						
00094 CNDUCTVY FIELD MICRONHO		345						
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	6.6		6.1	6.1		0.3	0.2	0.2
00301 DO SATUR PERCENT	78.6		72.6	72.6		3.6	2.3	2.2
00400 PH SU		9.08						
00410 T ALK CAC03 MG/L		166						
00515 RESIDUE DISS-105 C MG/L		258						
00530 RESIDUE TOT NFLT MG/L		10						

(SAMPLE CONTINUED ON NEXT PAGE)

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STORET RETRIEVAL DATE 83/02/16
 RP-A06-A-1
42 25 08.0 089 49 44.0  4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS          STEPHENSON
UPPER MISSISSIPPI RIVER  070900
ROCK RIVER
21ILLAKE
        791215     DEPTH    0
/TYPA/AMBNT/LAKE


(SAMPLE CONTINUED FROM PREVIOUS PAGE)
     INITIAL DATE                       81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22
     INITIAL     TIME-DEPTH-BOTTOM      1045 0000 1045 0001 1045 0002 1045 0004 1045 0005 1045 0006 1045 0008 1045 0010
00535 RESIDUE   VOL NFLT    MG/L                    10
0060S NH3+NH4-  N DISS      MG/L                 0.020
00610 NH3+NH4-  N TOTAL     MG/L                 0.030
00620   NO3-N    TOTAL      MG/L                 0.030
00625 TOT KJEL     N        MG/L                 1.310
00665 PHOS-TOT            MG/L P                 0.080
00666 PHOS-DIS            MG/L P                 0 020
32211 CHLRPHYL   A UG/L                        CORRECTD                        47.00
60050  ALGAE     TOTAL      /ML                                                 4250
72025 DEPTH OF    POND      FEET                 24.00
     INITIAL DATE                       81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22  81/07/22
     INITIAL TIME-DEPTH-BOTTOM          1045 0012 1045 0014 1045 0016 1045 0018 1045 0020 1045 0022 1045 0023 1045 0024
00010  WATER      TEMP      CENT        18.1      15.0      14.2      13.0      12.2      11 9                11.7
00011  WATER      TEMP      FAHN        64.6      59.0      57.6      55.4      54 0          53.4            53.1
00076   TURB    TRBIDMTR  HACH FTU       3.0                                                          22.0
00094 CNDUCTVY  FIELD     MICROMHO       395                                                           445
00116  INTNSVE   SURVEY     IDENT     821705    821705    821705    821705    821705    821705    821705    821705
00299    DO      PROBE      MG/L           0.2          0.2         0.2         0.1          0 1           0 1 0.0
00301    DO      SATUR    PERCENT          2.1          2.0         1.9          0.9          0 9          0.9 0.0
00400 PH                    SU           7.80                                                                 7.40
00410  T ALK     CAC03      MG/L                                                             214     284
00515 RESIDUE   DISS-105  C       MG/L                                                       300     328
00530 RESIDUE   TOT NFLT    MG/L                                                               6      83
00535 RESIDUE   VOL NFLT    MG/L                                                               6      18
00608  NH3+NH4-  N DISS     MG/L       1.450                                                        5.540
00610 NH3+NH4-  N TOTAL     MG/L                                                        1.450      6.600
00619 UN-IONZD   NH3-NH3    MG/L        0.037
00620  N03-N     TOTAL      MG/L                                                        0.070      0.060
00625 TOT KJEL     N        M3/L       2.460                                                        7.740
00665 PHOS-TOT             MG/L         P                                               0.310      1.200
00666 PHOS-DIS             MG/L P      0.250                                                         0730
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STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-HA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05
INITIAL TIME-DEPTH-BOTTOM	0830 0000	0830 0001	0830 0002	0830 0004	0830 0005	0830 0006	0830 0008	0830 0010
00010 WATER TEMP CENT	25.1		25.1	24.9		23.0	21.4	19.8
00011 WATER TEMP FAHN	77.2		77.2	76.8		73.4	70.5	67.6
00020 AIR TEMP CENT		25.2						
00035 WIND VELOCITY MPH		6.0						
00045 PRECIP TOT DAY IN		0.00						
00076 TURB TRBIDMTR HACH FTU		2.1						
00077 TRANSP SECCHI INCHES		33						
00094 CNDUCTVY FIELD MICROMHO		355						
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	9.2		9.0	7.8		6.0	0.8	0.2
00301 DO SATUR PERCENT	109.5		107.1	92.9		69.0	8.9	2.2
00400 PH SU		9.30						
00410 T ALK CAC03 MG/L		189						
00515 RESIDUE DISS-105 C MG/L		284						
00530 RESIDUE TOT NFLT MG/L		5						
00535 RESIDUE VOL NFLT MG/L		5						
00608 NH3+NH4- N DISS MG/L		0.030						
00610 NH3+NH4- N TOTAL MG/L		0.110						
00620 NO3-N TOTAL MG/L		0.060						
00625 TOT KJEL N MG/L		1.020						
00665 PHOS-TOT MG/L P		0.090						
00666 PHOS-DIS MG/L P		0.020						
32211 CHLRPHYL A UG/L CORRECTD					53.00			
60050 ALGAE TOTAL /ML					8155			
72025 DEPTH OF POND FEET		25.00						

INITIAL DATE	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/19
INITIAL TIME-DEPTH-BOTTOM	0830 0012	0830 0014	0830 0016	0830 0018	0830 0020	0830 0022	0830 0024	0845 0000
00010 WATER TEMP CENT	18.2	16.5	14.2	13.1	12.9	12.2	12.0	22.6
00011 WATER TEMP FAHN	64.8	61.7	57.6	55.6	55.2	54.0	53.6	72.7
00076 TURB TRBIDMTR HACH FTU	5.2						13.3	
00094 CNDUCTVY FIELD MICROMHO	388						392	
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	0.2	0.2	0.2	0.2	0.2	9.4
00301 DO SATUR PERCENT	2.1	2.1	1.9	1.9	1.9	1.9	1.9	108.0
00400 PH SU	7.90						7.50	
00410 T ALK CAC03 MG/L	210						273	
00515 RESIDUE DISS-105 C MG/L	298						262	
00530 RESIDUE TOT NFLT MG/L	6						9	
00535 RESIDUE VOL NFLT MG/L	5						6	
00608 NH3+NH4- N DISS MG/L	1.420						4.740	
00610 NH3+NH4- N TOTAL MG/L	1.680						5.510	
00619 UN-IONZD NH3-NH3 MG/L	0.055						0.046	
00620 NO3-N TOTAL MG/L	0.080						0.070	
00625 TOT KJEL N MG/L	2.480						6.230	
00665 PHOS-TOT MG/L P	0.390						1.110	

(SAMPLE CONTINUED ON NEXT PAGE)

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STORET RETRIEVAL DATE 83/02/16
 RP-A06-A-1
42 25 08.0 089 49 44.0  4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS          STEPHENSON
UPPER MISSISSIPPI RIVER  070900
ROCK RIVER
21ILLAKE
        791215     DEPTH    0
/TYPA/AMBNT/LAKE
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(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/05	81/08/19
INITIAL TIME-DEPTH-BOTTOM	0830 0012	0830 0014	0830 0016	0830 0018	0830 0020	0830 0022	0830 0024	0845 0000
00666 PHOS-DIS MG/L P	0.310						0.930	

INITIAL DATE	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19
INITIAL TIME-DEPTH-BOTTOM	0845 0001	0845 0002	0845 0004	0845 0006	0845 0007	0845 0008	0845 0010	0e45 0012
00010 WATER TEMP CENT		22.9	22.9	22.9		22.9	22.0	20.1
00011 WATER TEMP FAHN		73.2	73.2	73.2		73.2	71.6	68.2
00020 AIR TEMP CENT	17.0							
00035 WIND VELOCITY MPH	0.0							
00045 PRECIP TOT DAY IN	0.30							
00076 TURB TRBIDMTR HACH FTU	1.0							4.3
00077 TRANSP SECCHI INCHES	42							
00094 CNDUCTVY FIELD MICROMHO	348							350
00116 INTNSVE SURVEY IDENT	821705	21705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L		9.3	9.3	9.3		9.3	0.4	0.4
00301 DO SATUR PERCENT		106.9	106.9	106.9		106.9	4.5	4.3
00400 PH SU	9.20							8.90
00410 T ALK CAC03 MG/L	187							189
00515 RESIDUE DISS-105 C MG/L	242							240
00530 RESIDUE TOT NFLT MG/L	5							8
00535 RESIDUE VOL NFLT MG/L	4							6
00608 NH3+NH4- N DISS MG/L	0.090							0.150
00610 NH3+NH4- N TOTAL MG/L	0.170							0.170
00619 UN-IONZD NH3-NH3 MG/L								0.050
00620 N03-N TOTAL MG/L	0.100							0.090
00625 TOT KJEL N MG/L	1.320							1.610
00665 PHOS-TOT MG/L P	0.100							0.150
00666 PHOS-DIS MG/L P	0.050							0.080
32211 CHLRPHYL A UG/L CORRECTD					27.00			
60050 ALGAE TOTAL /ML					6320			
72025 DEPTH OF POND FEET	25.00							

INITIAL DATE	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/09/02	81/09/02
INITIAL TIME-DEPTH-BOTTOM	0845 0014	0845 0016	0845 0018	0845 0020	0845 0022	0845 0024	0900 0000	0900 0001
00010 WATER TEMP CENT	16.0	15.0	14.1	13.9	12.6	12.0	20.4	
00011 WATER TEMP FAHN	60.8	59.0	57.4	57.0	54.7	53.6	68.7	
00020 AIR TEMP CENT								17.6
00035 WIND VELOCITY MFH								4.0
00045 PRECIP TOT DAY IN								0.00
00076 TURB TRBIDMTR HACH FTU						27.8		30.9
00077 TRANSP SECCHI INCHES								6
00094 CNDUCTVY FIELD MICROMHO						429		250
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	0.2	0.2	0.2	0.1	4.5	
00301 DO SATUR PERCENT	2.0	2.0	1.9	1.9	1.9	0.9	48.9	
00400 PH SU						7.60		8.10
00410 T ALK CAC03 MG/L						267		128

(SAMPLE CONTINUED OH NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/08/19	81/09/02	81/09/02
INITIAL TIME-DEPTH-BOTTOM	0845 0014	0845 0016	0845 0018	0845 0020	0845 0022	0845 0024	0900 0000	0900 0001
00515 RESIDUE DISS-105 C MG/L				288				190
00530 RESIDUE TOT NFLT MG/L						11		38
00535 RESIDUE VOL NFLT MG/L						9		9
00608 NH3+NH4- N DISS MG/L						4.470		0.180
00610 NH3+NH4- N TOTAL MG/L						4.470		0.330
00619 UN-IONZD NH3-NH3 MG/L						0.047		
00620 NO3-N TOTAL MG/L						0.110		1.040
00625 TOT KJEL N MG/L						5.800		1.480
00665 PHOS-TOT MG/L P						0.960		0.450
00666 PHOS-DIS MG/L P						0.800		0.290
32211 CHLRFHYL A UG/L CORRECTD								27.00
60050 ALGAE TOTAL /ML								3405
72025 DEPTH OF POND FEET								25.00

INITIAL DATE	81/09/02	81/09/02	81/09/02	81/09/02	81/09/02	81/09/02	81/09/02	81/09/02
INITIAL TIME-DEPTH-BOTTOM	0900 0002	0900 0004	0900 0006	0900 0008	0900 0010	0900 0012	0900 0014	0900 0016
00010 HATER TEMP CENT	20.4	20.4	20.4	20.0	19.1	19.0	17.1	16.0
00011 WATER TEMP FAHN	68.7	68.7	68.7	68.0	66.4	66.2	62.8	60.8
00076 TURB TRBIDMTR HACH FTU						30.2		
00094 CNDUCTVY FIELD MICROMHO						285		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	4.4	4.4	4.2	2.2	0.5	1.4	0.2	0.2
00301 DO SATUR PERCENT	47.8	47.8	45.7	23.9	5.3	14.9	2.1	2.0
00400 PH SU						7.80		
00410 T ALK CAC03 MG/L						160		
00515 RESIDUE DISS-105 C MG/L						232		
00530 RESIDUE TOT NFLT MG/L						34		
00535 RESIDUE VOL NFLT MG/L						11		
00608 NH3+NH4- N DISS MG/L						0.470		
00610 NH3+NH4- N TOTAL MG/L						0.540		
00619 UN-IOHZD NH3-NH3 MG/L						0.015		
00620 N03-N TOTAL MG/L						1.220		
00625 TOT KJEL N MS/L						1.470		
00665 PHOS-TOT MG/L P						0.450		
00666 PHOS-DIS MG/L P						0.320		

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE				81/09/02	81/09/02	81/09/02	81/09/02	81/09/17	81/09/17	81/09/17	81/09/17
INITIAL TIME-DEPTH-BOTTOM				0900 0018	0900 0020	0900 0022	0900 0024	0900 0000	0900 0001	0900 0002	0900 0004
00010	WATER	TEMP	CENT	14.0	13.4	12.9	12.9	18.0		18.1	18.1
00011	WATER	TEMP	FAHN	57.2	56.1	55.2	55.2	64.4		64.6	64.6
00020	AIR	TEMP	CENT						11.0		
00032	CLOUD	COVER	PERCENT						0		
00035	WIND	VELOCITY	MFH						9.0		
00045	FRECIP	TOT DAY	IN						0.00		
00076	TURB	TRBIDMTR	HACH FTU				4.1		4.8		
00077	TRANSP	SECCHI	INCHES						25		
00094	CNDUCTVY	FIELD	MICROMHO				440		300		
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299'	DO	PROBE	MS/L	0.2	0.2	0.2	0.2	8.4		8.4	8.5
00301	DO	SATUR	PERCENT	1.9	1.9	1.9	1.9	88.4		88.4	89.5
00400	PH		SU				7.50		9.00		
00410	T ALK	CAC03	MG/L				294		191		
00515	RESIDUE	DISS-105	C MG/L				318		252		
00530	RESIDUE	TOT NFLT	MG/L				32		10		
00535	RESIDUE	VOL NFLT	MG/L				11		7		
00608	NH3+NH4-	N DISS	MG/L				5.680		0.220		
00610	NH3+NH4-	N TOTAL	MG/L				6.480		0.340		
00619	UN-IONZD	NH3-NH3	MG/L				0.058				
00620	NO3-N	TOTAL	MG/L				0.070		0.550		
00625	TOT KJEL	N	MG/L				8.460		1.360		
00665	PHOS-TOT		MG/L P			1.440			0.270		
00666	FHOS-DIS		MG/L P				0.990		0.160		
32211	CHLRFHYL	A UG/L	CORRECTD								2.00
60050	ALGAE	TOTAL	/ML								6305
72025	DEPTH OF	POND	FEET						23.00		
INITIAL DATE				81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17
INITIAL TIME-DEPTH-BOTTOM				0900 0006	0900 0008	0900 0010	0900 0011	0900 0012	0900 0014	0900 0016	0900 0018
00010	WATER	TEMP	CENT	18.1	18.1	16.1		18.1	18.1	16.0	14.8
00011	WATER	TEMP	FAHN	64.6	64.6	64.6		64.6	64.6	60.8	58.6
00076	TURB	TRBIDMTR	HACH FTU				3.4				
00094	CNDUCTVY	FIELD	MICROMHO				300				
00116	IHTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	8.5	8.5	8.5		8.4	8.4	0.3	0.2
00301	DO	SATUR	PERCENT	89.5	89.5	89.5		88.4	88.4	3.0	2.0
00400	PH		SU				8.90				
00410	T ALK	CAC03	MG/L				191				
00515	RESIDUE	DISS-105	C MG/L				250				
00530	RESIDUE	TOT NFLT	MG/L				10				
00535	RESIDUE	VOL NFLT	MG/L				7				
00608	NH3+NH4-	N DISS	MG/L				0.290				
00610	NH3+NH4-	N TOTAL	MG/L				0.360				
00620	NO3-N	TOTAL	MG/L				0.560				
00625	TOT KJEL	N	MG/L				1.400				

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17	81/09/17
INITIAL TIME-DEPTH-BOTTOM	0900 0006	0900 0008	0900 0010	0900 0011	0900 0012	0900 0014	0900 0016	0900 0018
00665 PHOS-TOT MG/L P				0.280				
00666 PHOS-DIS MG/L P				0.160				
INITIAL DATE	81/09/17	81/09/17	81/10/07	81/10/07	81/10/07	81/10/07	81/10/07	81/10/07
INITIAL TIME-DEPTH-BOTTOM	0900 0020	0900 0022	1000 0000	1000 0001	1000 0002	1000 0004	1000 0006	1000 0008
00010 WATER TEMP CENT	13.2	12.8	14.0		14.0	14.0	14.9	14.0
00011 WATER TEMP FAHN	55.8	55.0	57.2		57.2	57.2	58.8	57.2
00020 AIR TEMP CENT				6.0				
00032 CLOUD COVER PERCENT				0				
00035 WIND VELOCITY MPH				10.0				
00036 WIND DIR.FROM NORTH-0				270				
00045 FRECIP TOT DAY IN				0.00				
00076 TURB TRBIDMTR HACH FTU		35.2		4.3				
00077 TRANSP SECCHI INCHES				34				
00094 CNDUCTVY FIELD MICROMHO		420		345				
00116 INTNSVE SURVEY IDENT	S21705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	11.2		11.2	11.0	10.9	10.8
00301 DO SATUR PERCENT	1.9	1.9	107.7		107.7	105.8	106.9	103.8
00400 PH SU		7.30		8.60				
00410 T ALK CAC03 MG/L		277		216				
00515 RESIDUE DISS-105 C MG/L		320		308				
00530 RESIDUE TOT NFLT MG/L		19		16				
00535 RESIDUE VOL NFLT MG/L		12		12				
00608 NH3+NH4- N DISS MG/L		5.680		0.280				
00610 NH3+NH4- N TOTAL MG/L		6.400		0.400				
00619 UN-IONZD NH3-NH3 MG/L		0.036						
00620 NO3-N TOTAL MG/L		0.140		0.720				
00625 TOT KJEL N MG/L		8.030		1.490				
00665 PHOS-TOT MG/L P		1.430		0.260				
00666 PHOS-DIS MG/L P		0.960		0.140				
72025 DEPTH OF POND FEET				21.00				

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 HEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/10/07	81/10/07	81/10/07	81/10/07	81/10/07	81/10/07	81/11/04	81/11/04
	INITIAL TIME-DEPTH-BOTTOM			1000 0010	1000 0012	1000 0014	1000 0016	1000 0018	1000 0020	1015 0000	1015 0001
00010	WATER	TEMP	CENT	14.0	14.0	14.0	14.0	14.0	14.0	11.0	
00011	WATER	TEMP	FAHN	57.2	57.2	57.2	57.2	57.2	57.2	51.8	
00020	AIR	TEMP	CENT								14.5
00032	CLOUD	COVER	PERCENT								100
00035	WIND	VELOCITY	MPH								0.0
00045	FRECIP	TOT DAY	IN								0.00
00076	TURB	TRBIDMTR	HACH FTU	5.4					4.3		0.7
00077	TRANSP	SECCHI	INCHES								84
00094	CNDUCTVY	FIELD	MICROMHO	340					340		358
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299.	DO	PROBE	MG/L	10.8	10.8	10.7	10.7	10.7	10.7	7.9	
00301	DO	SATUR	PERCENT	103.8	103.8	102.9	102.9	102.9	102.9	71.2	
00400	PH		SU	8.60					8.50		8.20
00410	T ALK	CAC03	MG/L	216					223		237
00515	RESIDUE	DISS-105	C MG/L	310					300		336
00530	RESIDUE	TOT NFLT	MG/L	16					15		2
00535	RESIDUE	VOL NFLT	MG/L	10					12		1
00608	NH3+NH4-	N DISS	MG/L	0.420					0.390		0.650
00610	NH3+NH4-	N TOTAL	MG/L	0.480					0.500		0.710
00619	UN-IONZD	NH3-NH3	MG/L	0.053					0.045		
00620	NO3-N	TOTAL	MG/L	0.750					0.730		1.370
00625	TOT KJEL	N	MG/L	1.730					1.620		1.370
00665	FHOS-TOT		MG/L P	0.290					0.260		0.180
00666	PHOS-DIS		MG/L P	0.150					0.140		0.150
72025	DEPTH OF	POND	FEET								25.00
	INITIAL DATE			81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04
	INITIAL TIME-DEPTH-EOTTOM			1015 0002	1015 0004	1015 0006	1015 0008	1015 0010	1015 0012	1015 0014	1015 0016
00010	WATER	TEMP	CENT	11.0	10.8	10.6	10.2	10.0	10.0	9.8	9.5
00011	WATER	TEMP	FAHN	51.8	51.4	51.1	50.4	50.0	50.0	49.6	49.1
00076	TURB	TRBIDMTR	HACH FTU						2.1		
00094	CNDUCTVY	FIELD	MICROMHO						352		
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.9	7.6	7.1	6.9	6.8	5.5	5.2	4.4
00301	DO	SATUR	PERCENT	71.2	68.5	64.0	61.1	60.2	48.7	46.0	38.9
00400	PH		SU						8.10		
00410	T ALK	CAC03	MG/L						237		
00515	RESIDUE	DISS-105	C MG/L						346		
00530	RESIDUE	TOT NFLT	MG/L						1		
00535	RESIDUE	VOL NFLT	MG/L						1		
00608	NH3+NH4-	N DISS	MG/L						0.700		
00610	NH3+IIH4-	N TOTAL	MG/L						0.700		
00619	UN-IONZD	NH3-NH3	MG/L						0.019		
00620	NO3-N	TOTAL	MG/L						1.260		
00625	TOT KJEL	N	MS/L						1.500		
00665	PHOS-TOT		MG/L P						0.180		

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 03.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 HEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE		81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04	81/11/04
INITIAL TIME-DEPTH-BOTTOM		1015 0002	1015 0004	1015 0006	1015 0008	1015 0010	1015 0012	1015 0014	1015 0016
00666 PHOS-DIS	MG/L P						0.160		
INITIAL DATE		81/11/04	81/11/04	81/11/04	81/11/04	81/12/03	81/12/03	81/12/03	81/12/03
INITIAL TIME-DEPTH-BOTTOM		1015 0018	1015 0020	1015 0022	1015 0024	1115 0000	1115 0001	1115 0002	1115 0004
00010 WATER TEMP	CENT	9.2	9.2	9.1	9.1	4.0		4.0	4.0
00011 WATER TEMP	FAHN	48.6	48.6	48.4	48.4	39.2		39.2	39.2
00020 AIR TEMP	CENT						2.5		
00035 WIND VELOCITY	MPH						3.0		
00045 PRECIP TOT DAY	IN						0.20		
00076 TURB TRBIDMTR	HACH FTU				2.1		6.7		
00077 TRANSP SECCHI	INCHES						38		
00094 CNDUCTVY FIELD	MICROMHO				350		291		
00116 INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE	MG/L	4.4	3.6	3.6	2.6	10.1		10.1	10.1
00301 DO SATUR	PERCENT	37.9	31.0	31.0	22.4	77.1		77.1	77.1
00400 FH	SU				8.00		8.10		
00410 T ALK CAC03	MG/L				235		250		
00515 RESIDUE DISS-105	C MG/L				322		316		
00530 RESIDUE TOT NFLT	MG/L				2		7		
00535 RESIDUE VOL NFLT	MG/L				1		3		
00608 NH3+NH4- N DISS	MG/L				0.930		0.480		
00610 NH3iNH4- N TOTAL	MG/L				0.930		0.560		
00619 UN-IONZD NH3-NH3	MG/L				0.019				
00620 N03-N TOTAL	MG/L				1.060		1.610		
00625 TOT KJEL N	MG/L				1.640		1.300		
00665 PHOS-TOT	MG/L P				0.220		0.150		
00666 PHOS-DIS	MG/L P				0.220		0.120		
72025 DEPTH OF POND	FEET						25.00		
INITIAL DATE		81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03
INITIAL TIME-DEPTH-BOTTOM		1115 0006	1115 0008	1115 0010	1115 0012	1115 0014	1115 0016	1115 0018	1115 0020
00010 WATER TEMP	CENT	4.0	4.0	4.0	4.0	4.0	4.0	4.2	4.2
00011 WATER TEMP	FAHN	39.2	39.2	39.2	39.2	39.2	39.2	39.6	39.6
00076 TURB TRBIDMTR	HACH FTU				6.2				
00094 CNDUCTVY FIELD	MICROMHO				290				
00116 INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO FROBE	MG/L	10.1	10.1	10.0	9.9	9.9	9.9	9.7	9.4
00301 DO SATUR	PERCENT	77.1	77.1	76.3	75.6	75.6	75.6	74.0	71.8
00400 PH	SU				8.10				
00410 T ALK CAC03	MG/L				239				
00515 RESIDUE DISS-105	C MG/L				322				
00530 RESIDUE TOT NFLT	MG/L				6				
00535 RESIDUE VOL NFLT	MG/L				3				
00608 NH3+NH4- N DISS	MG/L				0.490				
00610 NH3+NH4- N TOTAL	MG/L				0.580				
00619 UN-IONZD NH3-NH3	MG/L				0.010				

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-1
42 25 08.0 089 49 44.0 4
L LE-AQUA-NA SITE 1 NEAR DAM
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
Z1ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE				81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03	81/12/03
INITIAL TIME-DEPTH-BOTTOM				1115 0006	1115 0008	1115 0010	1115 0012	1115 0014	1115 0016	1115 0018	1115 0020
00620	N03-N	TOTAL	MG/L				1.600				
00625	TOT KJEL	N	MG/L				1.240				
00665	FHOS-TOT		MG/L P				0.150				
00666	FHOS-DIS		MG/L P				0.120				

INITIAL DATE				81/12/03	81/12/03
INITIAL TIME-DEPTH-BOTTOM				1115 0022	1115 0024
00010	WATER	TEMP	CENT	4.3	4.3
00011	WATER	TEMP	FAHN	39.7	39.7
00076	TURB	TRBIDMTR	HACH FTU		3.6
00094	CNDUCTVY	FIELD	MICROMHO		290
00116	INTNSVE	SURVEY	IDENT	821705	821705
00299	DO	PROBE	MG/L	9.4	8.4
00301	DO	SATUR	PERCENT	71.8	64.1
00400	PH		SU		8.10
00410	T ALK	CAC03	MG/L		239
00515	RESIDUE	DISS-105	C MG/L		312
00530	RESIDUE	TOT NFLT	MG/L		6
00535	RESIDUE	VOL NFLT	MG/L		3
00608	NH3+NH4-	N DISS	MG/L		0.540
00610	NH3+NH4-	N TOTAL	MG/L		0.720
00619	UN-IONZD	NH3-NH3	MG/L		0.013
00620	NO3-N	TOTAL	MG/L		1.550
00625	TOT KJEL	N	MG/L		1.410
00665	PHOS-TOT		MG/L P		0.190
00666	PHOS-DIS		MG/L P		0.130

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-3
42 25 16.0 089 50 05.0 4
L LE-AQUA-NA SITE 3 660 FT SW OF SITE 2
17177 ILLINOIS STEFHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/01/21	81/02/18
	INITIAL TIME-DEPTH-BOTTOM			1000 0000	1000 0001	1000 0002	1000 0003	1000 0004	1000 0005	1000 0006	0930 000.0
00010	WATER	TEMP	CENT	0.9	0.9	2.0	2.7	2.8	3.0	3.5	0.0
00011	WATER	TEMP	FAHN	33.6	33.6	35.6	36.9	37.0	37.4	38.3	32.0
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.8	9.8	9.5	9.4	9.4	10.5	8.1	11.6
00301	DO	SATUR	PERCENT	69.0	69.0	68.8	69.6	69.6	77.8	61.8	79.5
	INITIAL DATE			81/02/18	81/02/18	81/02/18	81/02/18	81/02/18	81/02/18	81/03/18	81/03/18
	INITIAL TIME-DEPTH-BOTTOM			0930 0001	0930 0002	0930 0003	0930 0004	0930 0005	0930 0006	1030 0000	1030 0001
00010	WATER	TEMP	CENT	0.0	1.1	1.9	2.1	2.4	3.1	5.4	5.1
00011	WATER	TEMP	FAHN	32.0	34.0	35.4	35.8	36.3	37.6	41.7	41.2
00116	INTHSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	FROBE	MG/L	11.6	11.6	11.0	11.0	11.2	6.4	14.0	14.1
00301	DO	SATUR	PERCENT	79.5	81.7	79.7	79.7	81.2	47.4	109.4	110.2
	INITIAL DATE			81/03/18	81/03/18	81/03/18	81/03/18	81/03/18	81/03/18	81/04/15	81/04/15
	INITIAL TIME-DEPTH-BOTTOM			1030 0002	1030 0003	1030 0004	1030 0005	1030 0006	1030 0007	1100 0000	1100 0001
00010	WATER	TEMP	CENT	5.1	5.0	5.0	5.0	5.0	5.0	13.0	13.0
00011	WATER	TEMP	FAHN	41.2	41.0	41.0	41.0	41.0	41.0	55.4	55.4
00116	INTHSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	14.1	14.1	14.1	14.1	14.1	14.1	9.9	9.9
00301	DO	SATUR	PERCENT	110.2	110.2	110.2	110.2	110.2	110.2	93.4	93.4
	INITIAL DATE			81/04/15	81/04/15	81/04/15	81/04/15	81/04/15	81/05/13	81/05/13	81/05/13
	INITIAL TIME-DEPTH-BOTTOM			1100 0002	1100 0003	1100 0004	1100 0005	1100 0006	0900 0000	0900 0001	0900 0002
00010	WATER	TEMP	CENT	13.0	12.8	12.0	12.0	9.8	13.2	13.2	13.2
00011	WATER	TEMP	FAHN	55.4	55.0	53.6	53.6	49.6	55.8	55.8	55.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	11.2	10.6	10.6	9.2	6.9	13.4	13.4	13.2
00301	DO	SATUR	PERCENT	105.7	100.0	98.1	85.2	61.1	126.4	126.4	124.5
	INITIAL DATE			81/05/13	81/05/13	81/05/13	81/05/13	81/05/27	81/05/27	81/05/27	81/05/27
	INITIAL TIME-DEPTH-BOTTOM			0900 0003	0900 0004	0900 0005	0900 0006	0915 0000	0915 0001	0915 0002	0915 0003
00010	WATER	TEMP	CENT	13.2	13.2	13.0	12.8	20.4	20.0	20.0	20.0
00011	WATER	TEMP	FAHN	55.8	55.8	55.4	55.0	68.7	68.0	68.0	68.0
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	10.1	9.1	9.1	9.1	18.6	14.2	15.2	15.4
00301	DO	SATUR	PERCENT	95.3	85.8	85.8	85.8	202.2	154.3	165.2	167.4

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-3
42 25 16.0 089 50 05.0 4
L LE-AQUA-NA SITE 3 660 FT SW OF SITE 2
17177 ILLINOIS STEPHEHSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/05/27	81/05/27	81/05/27	81/05/27	81/06/10	81/06/10	81/06/10	81/06/10
	INITIAL TIME-DEPTH-BOTTOM			0915 0004	0915 0005	0915 0006	0915 0007	0845 0000	0845 0001	0845 0002	0845 0003
00010	WATER	TEMP	CENT	20.0	19.8	19.1	18.2	21.2	21.2	21.2	21.2
00011	WATER	TEMP	FAUN	68.0	67.6	66.4	64.8	70.2	70.2	70.2	70.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROSE	MG/L	15.4	15.4	11.6	9.6	8.4	8.6	8.5	8.1
00301	DO	SATUR	PERCENT	167.4	167.4	123.4	101.1	93.3	95.6	94.4	90.0
	INITIAL DATE			81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/10	81/06/24
	INITIAL TIME-DEPTH-BOTTOM			0S45 0004	0845 0005	0845 0006	0845 0007	0845 0008	0845 0009	0845 0010	1145 0000
00010	WATER	TEMP	CENT	21.2	20.8	20.2	20.2	19.1	17.8	17.2	23.4
00011	WATER	TEMP	FAHN	70.2	69.4	68.4	68.4	66.4	64.0	63.0	74.1
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.9	2.4	0.3	0.2	0.2	0.2	0.2	8.4
00301	DO	SATUR	PERCENT	87.8	26.7	3.3	2.2	2.1	2.1	2.1	96.6
	INITIAL DATE			81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/06/24	81/07/08
	INITIAL TIME-DEPTH-BOTTOM			1145 0001	1145 0002	1145 0003	1145 0004	.1145 0005	1145 0006	1145 0007	0915 0000
00010	WATER	TEMP	CENT	22.9	22.2	21.6	21.2	20.8	20.8	20.2	28.2
00011	WATER	TEMP	FAHN	73.2	72.0	70.9	70.2	69.4	69.4	68.4	82.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	8.4	8.1	6.7	5.7	3.4	2.9	2.1	10.8
00301	DO	SATUR	PERCENT	96.6	92.0	76.1	63.3	37.8	32.2	22.8	136.7
	INITIAL DATE			81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/08	81/07/22
	INITIAL TIME-DEPTH-BOTTOM			0915 0001	0915 0002	0915 0003	0915 0004	0915 0005	0915 0006	0915 0007	1130 0000
00010	WATER	TEMP	CENT	28.2	28.0	27.2	26.6	25.7	24.3	23.9	25.2
00011	WATER	TEMP	FAHN	82.8	82.4	81.0	79.9	78.3	75.7	75.0	77.4
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	10.8	11.8	6.0	3.5	0.3	0.3	0.2	7.6
00301	DO	SATUR	PERCENT	136.7	149.4	74.1	43.2	3.7	3.5	2.4	90.5
	INITIAL DATE			81/07/22	81/07/22	81/07/22	81/07/22	81/07/22	81/07/22	81/08/05	81/08/05
	INITIAL TIME-DEPTH-BOTTOM			1130 0001	1130 0002	1130 0003	1130 0004	1130 0005	1130 0006	0915 0000	0915 0001
00010	WATER	TEMP	CENT	25.2	25.1	25.1	25.1	25.0	25.0	25.9	25.9
00011	WATER	TEMP	FAHN	77.4	77.2	77.2	77.2	77.0	77.0	78.6	78.6
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.2	7.2	7.1	7.1	6.9	6.4	9.1	9.1
00301	DO	SATUR	PERCENT	85.7	85.7	84.5	e4.5	82.1	76.2	111.0	111.0

STORET RETRIEVAL DATE 83/02/16
RP-A06-A-3
42 25 16.0 089 50 05.0 4
L LE-AQUA-NA SITE 3 660 FT SW OF SITE 2
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/08/05	81/08/05	81/08/05	81/08/C5	81/08/19	81/08/19	81/08/19	81/08/19
	INITIAL TIME-DEPTH-BOTTOM			0915 0002	0915 0003	0915 0004	0915 0005	0930 0000	0930 0001	0930 0002	0930 0003
00010	WATER	TEMP	CENT	25.9	25.9	25.9	25.9	22.8	22.8	22.8	22.6
00011	WATER	TEMP	FAHN	78.6	78.6	78.6	78.6	73.0	73.0	73.0	72.7
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PR03E	MG/L	8.9	8.8	7.8	5.6	7.9	7.9	7.8	7.8
00301	DO	SATUR	PERCENT	108.5	107.3	95.1	68.3	90.8	90.8	89.7	89.7
	INITIAL DATE			81/08/19	81/08/19	81/03/19	81/08/19	81/09/02	81/09/02	81/09/02	81/09/02
	INITIAL TIME-DEPTH-BOTTOM			0930 0004	0930 0005	0930 0006	0930 0007	0945 0000	0945 0001	0945 0002	0945 0003
00010	WATER	TEMP	CENT	22.5	22.2	22.2	22.2	20.2	20.2	20.2	20.2
00011	WATER	TEMP	FAHN	72.5	72.0	72.0	72.0	68.4	68.4	68.4	68.4
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
C029V	DO	PROBE	MG/L	8.9	9.0	7.6	5.8	4.5	4.5	4.3	4.3
00301	DO	SATUR	PERCENT	102.3	102.3	86.4	65.9	48.9	48.9	46.7	46.7
	INITIAL DATE			81/09/02	81/09/02	81/09/02	81/09/02	81/09/17	81/09/17	81/09/17	81/09/17
	INITIAL TIME-DEPTH-BOTTOM			0945 0004	0945 0005	0945 0006	0945 0007	0945 0000	0945 0001	0945 0002	0945 0003
00010	WATER	TEMP	CENT	20.0	20.0	19.8	17.2	18.0	18.0	18.0	18.0
00011	WATER	TEMP	FAHN	68.0	68.0	67.6	63.0	64.4	64.4	64.4	64.4
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	4.2	4.2	4.2	6.2	8.2	8.0	8.0	8.0
00301	DO	SATUR	PERCENT	45.7	45.7	45.7	63.9	86.3	84.2	84.2	84.2
	INITIAL DATE			81/09/17	81/09/17	81/09/17	81/09/17	81/10/07	81/10/07	81/10/07	81/10/07
	INITIAL TIME-DEPTH-BOTTOM			0945 0004	0945 0005	0945 0006	0945 0007	1045 0000	1045 0001	1045 0002	1045 0003
00010	WATER	TEMP	CENT	18.0	17.8	17.5	16.3	13.9	13.9	13.9	13.8
00011	WATER	TEMP	FAHN	64.4	64.0	63.5	61:3	57.0	57.0	57.0	56.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	8217C5	821705	821705	821705	821705
00299	DO	PROBE	MC/L	7.6	7.5	7.7	6.6	11.8	11.8	11.8	11.9
00301	DO	SATUR	PERCENT	80.0	78.9	81.1	66.0	113.5	113.5	113.5	114.4
	INITIAL DATE			81/10/07	81/10/07	81/10/07	81/10/07	81/11/04	81/11/04	81/11/04	81/11/04
	INITIAL TIME-DEPTH-BOTTOM			1045 0004	1045 0005	1045 0006	1045 0007	1100 0000	1100 0001	1100 0002	1100 0003
00010	WATER	TEMP	CENT	13.8	13.7	13.7	13.2	11.8	11.8	11.8	11.5
00011	WATER	TEMP	FAHN	56.8	56.7	56.7	55.8	53.2	53.2	53.2	52.7
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	11.7	11.5	10.7	9.2	8.7	8.7	8.7	8.7
00301	DO	SATUR	PERCENT	112.5	110.6	102.9	86.8	80.6	80.6	80.6	80.6

STORET RETRIEVAL DATE 63/02/16
RP-A06-A-3
42 25 16.0 089 50 05.0 4
L LE-AQUA-NA SITE 3 660 FT SW OF SITE 2
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AHBNT/LAKE

	INITIAL DATE			81/11/04	81/11/04
	INITIAL TIME-DEPTH-BOTTOM			1100 0004	1100 0005
00010	WATER	TEMP	CENT	11.5	11.5
00011	WATER	TEMP	FAHN	52.7	52.7
00116	INTNSVE	SURVEY	IDENT	821705	821705
00299	DO	PROBE	MG/L	8.7	8.7
00301	DO	SATUR	PERCENT	80.6 ,	80.6

STORET RETRIEVAL DATE 83/02/16
RPAA01
42 25 06.0 089 50 20.0 4
INFALL TO LAKE LE-AQUA-NA
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

	INITIAL DATE		81/01/21	81/02/18	81/03/18	81/04/15	81/05/13	81/05/27	81/06/10	81/06/24
	INITIAL TIME-DEPTH-BOTTOM		1120 0000	1050 0000	1150 0000	1220 0000	1020 0000	1035 0000	1005 0000	1305 0000
00076	TURB TRBIDMTR	HACH FTU	0.3	14.5	3.9	5.4	1.0	2.6	1.4	17.9
00116	INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515	RESIDUE DISS-105 C	MG/L	394	276	346	424	462	430	396	420
00530	RESIDUE TOT NFLT	MG/L	0	28	8	10	2	3	7	38
00535	RESIDUE VOL NFLT	MG/L	0	8	8	4	2	1 6		1 0
00608	NH3+NH4- N DISS	MG/L		0.550	0.300	0.000		0.100	0.110	0.220
00610	NH3+NH4- N TOTAL	MG/L	0.080	0.750	0.350	0.050	0.040	0.110	0.160	0.360
00615	NO2-N TOTAL	MG/L	0.020		0.025	0.032	0.054	0.030	0.066	0.077
00620	NO3-N TOTAL	MG/L	4.150		1.690	5.480	4.510	4.500	3.070	7.430
00625	TOT KJEL N	MG/L	0.420	1.720	1.290	0.330	0.760	0.430	0.720	1.320
00665	PHOS-TOT	MG/L P	0.060	0.460	0.140	0.130	0.060	0.110	0.120	0.400
00666	PHOS-DIS	MG/L P	0.060	0.310	0.100	0.100	0.050	0.090	0.080	0.310
	INITIAL DATE		81/07/08	81/07/22	81/08/05	81/08/19	81/09/02	81/09/17	81/10/07	81/11/04
	INITIAL TIME-DEPTH-BOTTCM		1010 0000	1145 0000	1010 0000	1025 0000	1040 0000	0945 0000	1140 0000	1155 0000
00076	TURB TRBIDMTR	HACH FTU		7.0	3.0	1.8	7.7	1.7	5.0	1.4
00116	INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515	RESIDUE DISS-105 C	MG/L	460	446	456	432	398	430	432	443
00530	RESIDUE TOT NFLT	MG/L	6	15	6	6	9	2	8	1
00535	RESIDUE VOL NFLT	MG/L	2	7	6	1	2	1	4	1
00608	NH3+NH4- N DISS	MG/L	0.120	0.020	0.120	0.040	0.020	0.050	0.060	0.050
00610	NH3+NH4- N TOTAL	MG/L	0.120	0.030	0.120	0.040	0.090	0.030	0.070	0.060
00615	NO2-N TOTAL	MG/L	0.090		0.030	0.020	0.040	0.030	0.050	0.030
00620	NO3-N TOTAL	MG/L	5.100	3.760	1.970	3.080	3.950	4.350	4.410	4.580
00625	TOT KJEL N	MG/L	0.790	0.810	0.280	0.670	0.650	0.430	1.530	0.320
00665	PHOS-TOT	MG/L P	0.240	0.190	0.120	0.200	0.240	0.110	0.190	0.110
00666	PHOS-DIS	MG/L P	0.090	0.160	0.090	0.180	0.210	0.090	0.160	0.080
	INITIAL DATE		81/12/03							
	INITIAL TIME-DEPTH-BOTTOM		1255 0000							
00076	TURB TRBIDMTR	HACH FTU	2.7							
00116	INTNSVE SURVEY	IDENT	821705							
00515	RESIDUE DISS-105 C	MG/L	404							
00530	RESIDUE TOT NFLT	MG/L	5							
00535	RESIDUE VOL NFLT	MG/L	2							
00608	NH3+NH4- N DISS	MG/L	0.070							
00610	NH3+NH4- N TOTAL	MG/L	0.070							
00615	N02-N TOTAL	MG/L	0.020							
00620	N03-N TOTAL	MG/L	4.810							
00625	TOT KJEL N	MG/L	0.310							
00665	PHOS-TOT	MG/L P	0.100							
00666	PHOS-DIS	MG/L P	0.080							

STORET RETRIEVAL DATE 83/02/16
RPAA02
42 25 12.0 089 49 12.0 4
OUTFALL TO LAKE LE-AQUA-NA
17177 ILLINOIS STEPHENSON
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

	INITIAL DATE		81/01/21	81/02/18	81/03/18	81/04/15	81/05/13	81/05/27	81/06/10	81/06/24
	INITIAL TIME-DEPTH-BOTTOM		1110 0000	1040 0000	1140 0000	1210 0000	1010 0000	1025 0000	0955 0000	1255 0000
00076	TURB TRBIDMTR	HACH FTU	1.3	0.7	3.3	7.5	1.4	0.3	12.5	5.2
00116	INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515	RESIDUE DISS-105 C	MG/L	354	324	462	300	302	294	260	278
00530	RESIDUE TOT NFLT	MG/L	0	4	4	10	2	2	21	9
00535	RESIDUE VOL HFLT	MG/L	0	4	4	10	2	2	18	9
00608	NH3+NH4- N DISS	MG/L	0.280	0.150	0.090	0.220	0.270	0.220	0.300	0.250
00610	NH3+NH4- N TOTAL	MG/L	0.450	0.230	0.100	0.230	0.330	0.240	0.730	0.590
00615	NO2-N TOTAL	MG/L	0.020			0.037	0.047	0.050	0.013	0.150
00620	NO3-N TOTAL	MG/L	1.270		4.360	1.130	0.595	0.230	0.078	1.020
00625	TOT KJEL N	MG/L	0.890	0.590	0.160	1.210	0.970	0.560	3.530	1.630
00665	PHOS-TOT	MG/L P	0.120	0.100	0.070	0.150	O.OSO	0.070	0.130	0.170
00666	PHOS-DIS	MG/L P	0.080	0.070	0.050	0.080	0.060	0.040	0.040	0.090

	INITIAL DATE		81/07/08	81/07/22	81/08/05	81/08/19	81/09/02	81/09/17	81/10/07	81/11/04
	INITIAL TIME-DEPTH-BOTTOM		1000 0000	1135 0000	1000 0000	1015 0000	1030 0000	1030 0000	1130 0000	1145 0000
00076	TURB TRBIDMTR	HACH FTU		4.3	2.2	0.5	29.5	3.4	3.6	2.1
00116	INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515	RESIDUE DISS-105 C	MG/L	278	278	304	252	192	256	304	326
00530	RESIDUE TOT HFLT	MG/L	6	5	8	3	32	8	16	2
00535	RESIDUE VOL NFLT	MG/L	5	5	8	2	8	6	12	1
00608	NH3+NH4- N DISS	MG/L	0.330	0.160	0.240	0.230	0.300	0.320	0.260	0.490
00610	NH3+NH4- N TOTAL	MG/L	0.330	0.320	0.330	0.250	0.380	0.390	0.390	0.500
00615	NO2-N TOTAL	MG/L	0.050		0.050	0.020	0.050	0.100	0.080	O.OSO
00620	NO3-N TOTAL	MG/L	0.190	0.180	0.210	0.220	1.030	0.570	0.750	1.340
00625	TOT KJEL N	MG/L	0.840	0.970	0.970	0.960		1.320		1.280
00665	PHOS-TOT	MG/L P	0.210	0.070	0.090	0.080	0.420	0.260	0.270	0.180
00666	PHOS-DIS	MG/L P	0.040	0.030	0.040	0.050	0.290	0.160	0.130	0.140

	INITIAL DATE		81/12/03
	INITIAL TIME-DEPTH-BOTTOM		1245 0000
00076	TURB TRBIDMTR	HACH FTU	4.4
00116	INTNSVE SURVEY	IDENT	821705
00515	RESIDUE DISS-105 C	MG/L	316
00530	RESIDUE TOT NFLT	MG/L	6
00535	RESIDUE VOL HFLT	MG/L	3
00608	NH3+NH4- N DISS	MG/L	0.380
00610	NH3+NH4- N TOTAL	MG/L	0.440
00615	NO2-N TOTAL	MG/L	0.040
00620	NO3-N TOTAL	MG/L	1.590
00625	TOT KJEL N	MG/L	1.150
00665	PHOS-TOT	MG/L P	0.150
00666	PHOS-DIS	MG/L P	0.110