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DIAGNOSTIC-FEASIBILITY STUDY OF JOHNSON SAUK TRAIL LAKE

by

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INTRODUCTION

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

Johnson Sauk Trail Lake is located in Henry County. It is a 57.4-acre lake with a maximum depth of 23 feet. The lake was formed in 1956 by the impoundment of King 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. Hunting in season for cock pheasants, quails, rabbits, doves, and squirrels, as well as bow hunting for deer, are permitted in the state park. 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.

The state park is open year round and is open to the general public from 8:00 a.m. till 10:00 p.m. The park has 60 trailer pads and 20 tent pads. The camping facilities are closed from December 1 to April 30.

The park offers free interpretive programs during summer months from June through August. Nature study and cultural and historical aspects of the region are taught through tours, nature walks, craft workshops, and camp fire events. Approximately 8 miles of extensive foot trails exist in the park for visitors' use.

Various youth groups make use of the park facilities during the spring, summer, and fall seasons. YMCA, YWCA, and church groups visit the park at various times for recreational and educational purposes. Cub Scouts spend a week in primitive camps as a part of their conservation education week. The YMCA holds their annual camp workshops in the park facilities..

Figure 1. Location map, Johnson Sauk Trail Lake

Table 1. General Information Pertaining to Johnson Sauk Trail Lake

Lake name	Johnson Sauk Trail Lake
IEPA/STORET lake code	RP-A01-D
State	Illinois
County	Henry; T15N., R5E.
Nearest municipality	Kewanee, Illinois
Latitude	41°-19'-45"
Longitude	89°-53'-00"
USEPA region	V
IEPA major basin name and code	Mississippi River, 07
IEPA minor basin name and code	Rock River, 09
Major tributary	King Creek
Receiving water body	Illinois and Mississippi Canal via King Creek
Water quality standards	General standards promulgated by the Illinois Pollution Control Board and applicable to waters designated for aquatic life

Also, an annual 2-day event, "Sauk Trail Rendezvous," which attracts 5,000-10,000 visitors, is held at the park. Two "Voyager" canoes, each with a 30-person capacity, are among the major attractions available during this special event. Arts and crafts display booths are set up in the park during the Rendezvous.

Approximately 70 cock pheasants, 80 quails, 35 rabbits, 1200 doves, and 50 squirrels were harvested in 1981. These are natural game. The park is currently involved in a put-and-take pheasant and quail program also. In 1981 park officials released 1200 pheasants and 2000 quails. Approximately 70 percent of the birds were harvested. There is no fee charged to the general public for the use of state park facilities except for camping fees and annual state fishing and hunting license fees.

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.

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 Jerry McClure and his staff of Johnson Sauk Trail 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. Analyses of trace metals and organochemicals in sediments, elutriated samples, and fish flesh samples were done by the IEPA laboratories.

Richard L. Stewart, District Soil Conservationist, Henry County, provided valuable information, including information on parameter values for the Universal Soil Loss Equation and on cropping practices in the watershed.

STUDY AREA

Johnson Sauk Trail Lake

Johnson Sauk Trail Lake lies within the state park of the same name and is located in Henry County. It is situated 6 miles north of Kewanee and 6 miles south of Interstate Highway 80. It is easily accessible from State Highway 78. The lake was formed in 1956 by the impoundment of King Creek. The lake currently has a water surface area of 57.4 acres with a maximum water depth of 23 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, redear, sunfish, and catfish. Public access to the lake exists, as indicated in figure 1. A ramp and docks for private

Table 2. Morphometric Details regarding Johnson Sauk Trail Lake

Surface area, acres	57.4 (23.2 ha)
Volume, acre-feet	471.5 ($0.58 \times 10^6 m^3$)
Mean depth, feet	8.2 (2.50 m)
Maximum depth, feet	23.0 (7.01 m)
Length of shoreline, miles	1.5 (2.41 km)
Average retention time, years	1.96
Total original capacity loss, percent	13.3
Annual capacity loss, percent	0.58
Watershed area, acres	876.1 (3.55 km^2)

and rental boats are provided on the northwest shore. Boats other than those that are manually propelled are limited to electric-powered motors. Swimming is prohibited. Bathymetric maps of the lake are shown in figure 2 for data gathered in 1956 and 1981.

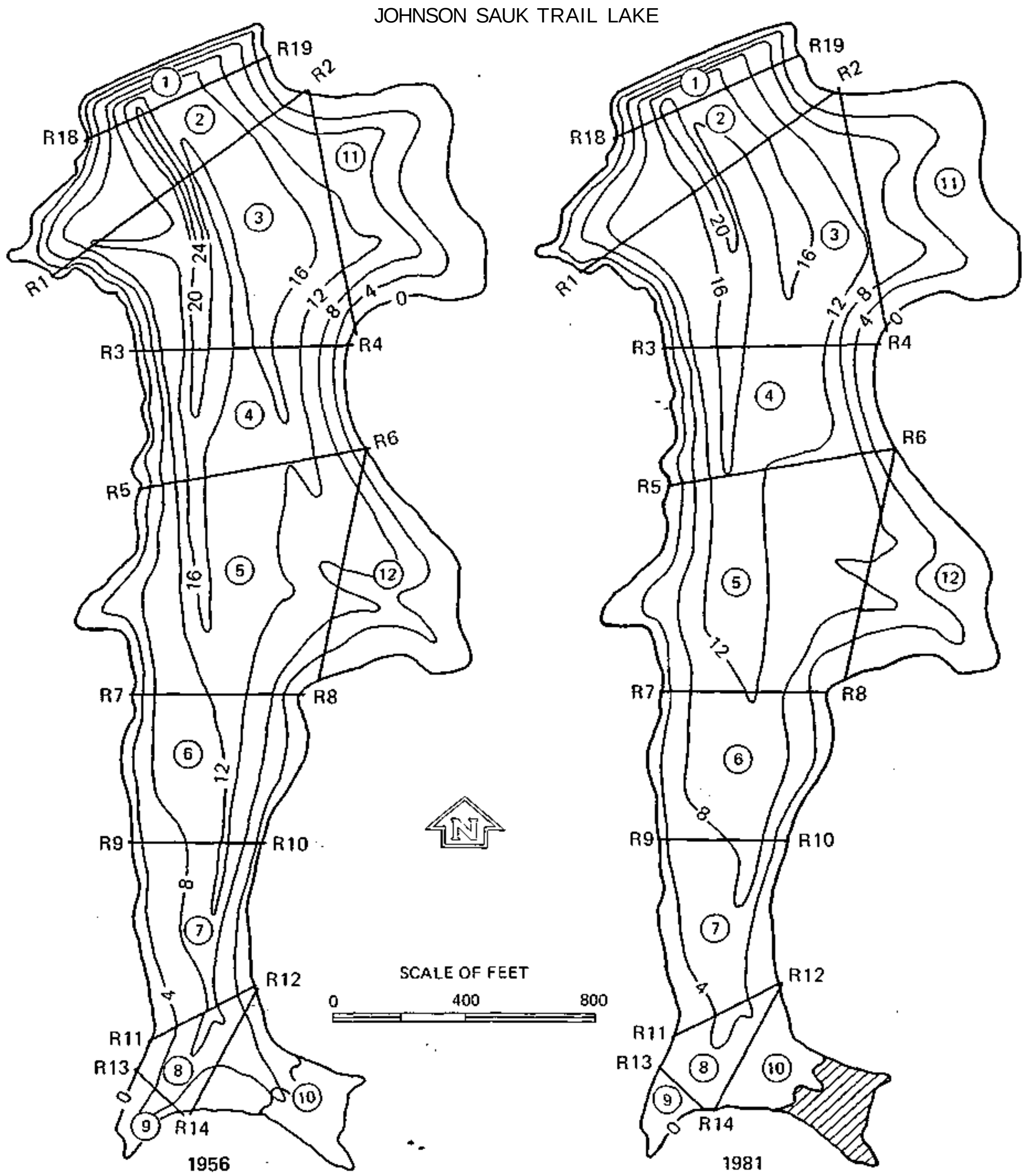

Figure 2. Bathymetric maps of Johnson Sauk Trail Lake (Contour intervals in feet)

Geological and Soil Characteristics of the Drainage Basin

The geology of the park area begins in the "basement" rock several hundred feet below the surface. It consists of ancient crystalline rocks, mainly granite. Above these rocks is bedrock dating from the Cambrian Period to the Mississippian Period. This consists of sedimentary rocks which were deposited by shallow seas which once covered this area. They are mainly limestones, dolomites, and sandstones.

Above all these rocks lie the Pennsylvania-age bedrocks of the Modesto and Carbondale Formations. They are covered by thick Pleistocene deposits. Bedrock formations of sandstone, limestone, coal, and clay crop out in the headwater streams and gullies. They underlie the main valley, probably at shallow depth, and although they are not exposed, they may comprise part of the walls of the main valley (Ekblaw, 1947, as quoted by IEPA, 1980).

The four glacial periods and the interglacial periods which occurred during "The Great Ice Age" of the Pleistocene epoch are responsible for shaping the park area and most of Illinois. The glaciers scoured and leveled the land, resulting in the low relief of the area. The glacial till and drift deposits are as much as 50 feet thick with a loess cover from 10-15 feet in thickness.

The uppermost Pleistocene deposits consist of the Lee Center Till member of the Wedron Formation (Wisconsinan stage of glaciation, Woodfordian substage), the Radnor Till member of the Glasford Formation (Illinoian Stage, Jubileean substage), and Peoria loess and Roxana silt from the Wisconsinan stage. Present soils have formed from this till and loess. The Lee Center Till Member is a silty clayey till while the Radnor Till member is a silty till with gravel, sand, and silt in some places. The loess consists of windblown silt and fine-grained sand from glacial outwash material.

The landscape of Johnson Sauk Trail State Park has been shaped by glacial ice, running water, and wind. This is an area of fairly low relief with the highest elevation approximately 800 feet above sea level. It gently slopes down to about 640 feet above sea level. The area is considered to be in a late youthful stage of erosion (Leighton et al., 1948). The watershed of Johnson Sauk Trail Lake is located within the Galesburg Plain of the Till Plains Section of the Central Lowland Province (ibid).

The present soils were formed after the retreat of the Wisconsinan glacier. The soils found in the lake area fall into two major classes (Russell, 1969):

1) Upland Prairie Soils were originally covered with wild prairie grasses. These soils are usually dark brown and high in organic matter. Upland prairie soils are found principally on flat to gently sloping land, usually free of timber. Prairie soils are usually deep.

2) Upland Timber Soils are usually found along stream systems over which timber grew for a long period of time. They are light

colored soils, low in organic matter. Timber soils are usually found on steeper slopes than the prairie soils.

The major soil type that is present in this area is silt loam.

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

Watershed sub-basin I has a rugged terrain with an average slope of 10 percent. Of the five sub-basins, it has the largest acreage with slopes of 18 to 30 percent. Sub-basin II has an average slope of 9 percent, which places it in the moderately to steep sloping category. Sub-basins III, IV, and V, with average slope values of 7.2, 6.5, and 7.7 percent, respectively, fall into the category of gently to moderately sloping.

The scope of the diagnostic-feasibility study did not include investigations pertaining to the groundwater hydrology in relation to the lake basin. 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 when the lake's water budget is considered.

Public Access to the Lake Area

There is no public transportation available for use to and from the lake and the state park. However, State Highway 78 provides easy access to the park area from Kewanee, IL, and Interstate Highway 80.

There is a public road circling the lake, providing ready and easy access to such activities as bank fishing, nature study, and hiking on various foot trails. Strategic lookout points with adequate parking facilities also exist around the lake. A map of the lake, identifying

Table 3. Areas in Different Slope Categories

Slope range (percent)	**Sub-basin area (acres)**					**Total area (acres)**	**Percent of total acreage**
	I	**II**	**III**	**IV**	**V**		
0-2	0	0	0	0	0	0	0
2-4	3.0	36.7	31.0	91.9	9.5	172.1	21.0
4-7	68.4	41.9	18.6	51.0	31.4	211.3	25.8
7-12	87.7	68.7	61.7	107.3	30.4	355.8	43.5
12-18	3.2	40.4	0	4.3	7.9	55.8	6.8
18-30	16.0	7.0	0.6	0	0	23.6	2.9
Total	178.3	194.7	111.9	254.5	79.2	818.6	100.0

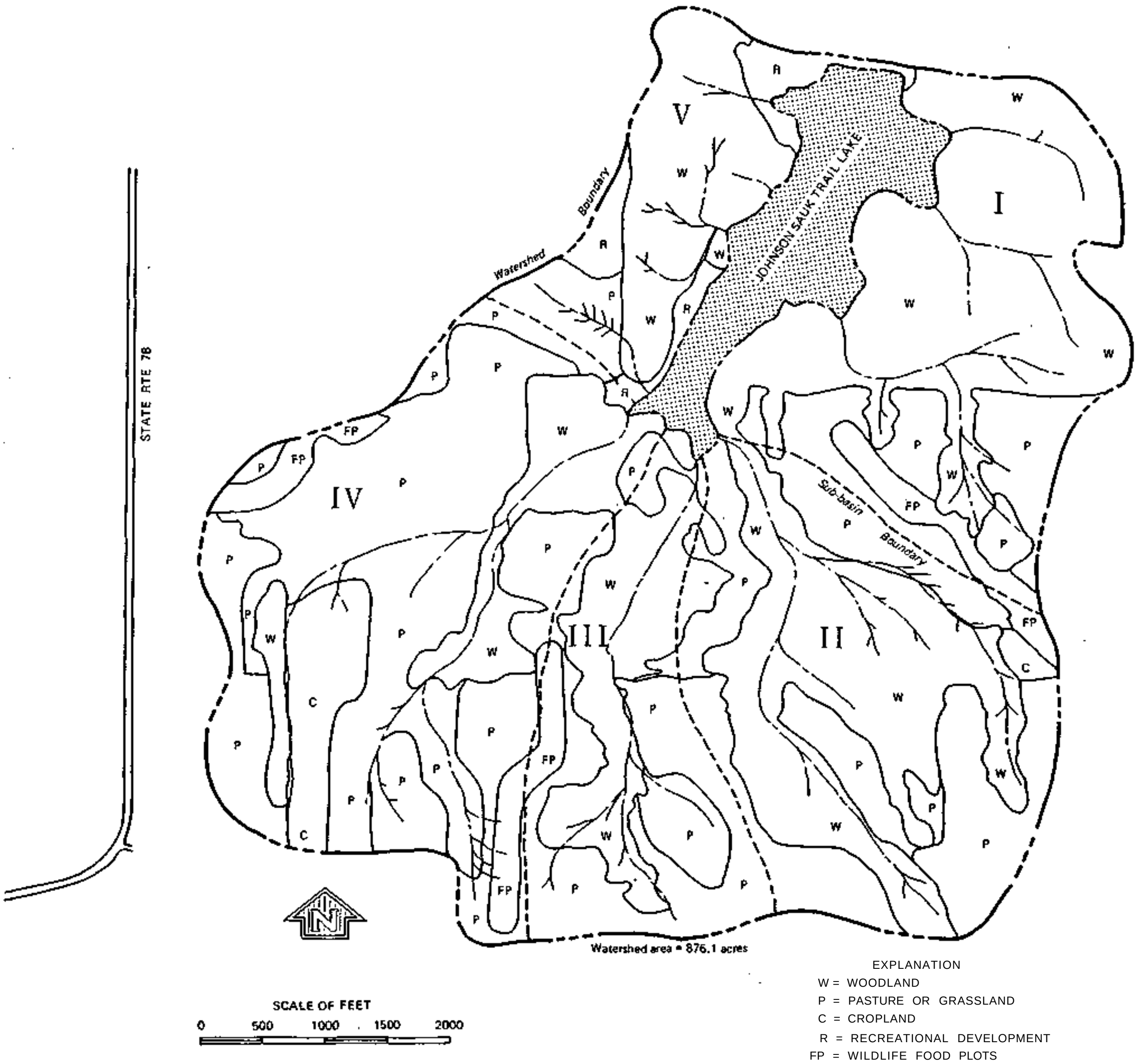

Figure 3. Johnson Sauk Trail Lake watershed land uses and sub-basin demarcations

public access points and facilities, is given in figure 4. Pertinent information on access points is tabulated in table 4.

There is a boat launching ramp on the northwest shore of the lake with a capacity sufficient for inland fishing boats. Although there is space for parking about 25 to 30 vehicles and trailers 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.

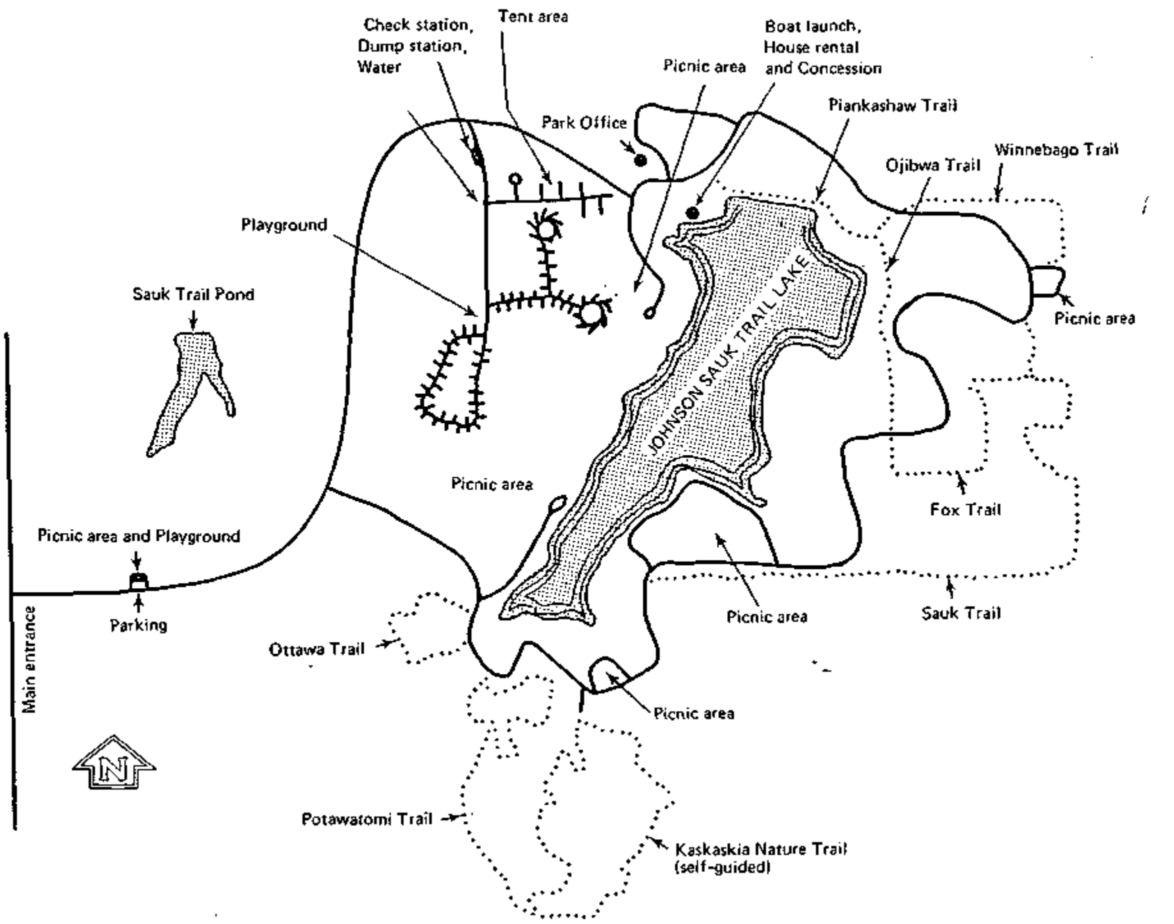

Figure 4. Public access -points and facilities, Johnson Sauk Trail Lake

Table 4. Public Access Points in Johnson Sauk Trail Lake

Location	**Type**	**Land area (acres)**	**Lake frontage**	**Types and capacities of facilities**
Concession stand landing	Boat launch	2.3	400 feet	Launching ramp with capacity sufficient for inland fishing boats, parking for 25 vehicles and trailers, and a concession stand
Entire lake shore	Bank fishing		2.3 miles	Easily accessible by foot; parking facilities and picnic areas all around the lake

Potential User Population

The lake resident population consists of the park ranger and his family. Kewanee and Annawan, which are located within 6 miles of the state park, have populations of about 15,000 and 800, respectively. The state park draws daily and weekend visitors from these two population centers. Other population centers reasonably close to the lake area are: the quad cities (Davenport, IA; Rock Island, IL; Moline, IL; and East Moline, IL); Galesburg, IL; and Rock Falls-Sterling, IL. All of these are within a 40-mile radius of the park. The combined population of these cities is in excess of 250,000. The park facilities are known to draw visitors from as far away as Rockford, IL, and Chicago, IL. The proximity of Interstate Highway 80 (figure 1) facilitates visits by interstate travelers.

The economic base of Kewanee, IL, is a mixture of commerce, agribusiness, light industries, and the employment opportunities provided by the international Caterpillar Company in the Peoria area. Likewise, John Deere Company in the quad cities area provides ongoing employment to the residents of Kewanee. In addition Kewanee Boiler Corporation, Hyster Company, Shalco Systems, and Chromalloy American Corporation are among the large industries in Kewanee providing significant employment opportunities to the area residents. The average annual family income is reported to be $14,000 to $15,000. There are no housing shortages and no urban blight in the Kewanee area. Johnson Sauk Trail Lake and the state park together are a resource which brings in transient visitors and the commercial opportunities provided by the visitors.

Detailed information related to the potential user population, including the major nearby population centers and pertinent economic characteristics, is given in table 5. It is known that the park facilities attract visitors from a wider area, with past attendance topping 379,000 in one year. 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 Johnson Sauk Trail Lake

There is no publicly owned lake within a 25-mile radius of Johnson Sauk Trail Lake. The lake and the state park are unique resources providing recreational amenities such as fishing, boating, camping, picnicking, and hunting.

There are about 19 lakes, sloughs, backwaters, and other water bodies with surface areas of more than 20 acres within a 50-mile radius of Johnson Sauk Trail Lake. Their names and information on areas, maximum depths, availability of public access, presence of launching ramps, and recreational facilities available at these lake sites are given in table 6. The locations of these water bodies are shown in figure 5.

All except one lake listed in table 6 are larger than Johnson Sauk Trail Lake. However, they are all much shallower than Johnson Sauk Trail Lake, except for Carlton Lake and Lake Storey. Only Carlton Lake is as well managed for fisheries as Johnson Sauk Trail Lake.

Table 5. Population and Economic Data for Areas near Johnson Sauk Trail Lake
(Population figures are in thousands)

County and population	Major city within the county and its population	Employment sources and number of people employed	Payroll (thousands of dollars)
Illinois			
Bureau, 39.11	Princeton, 7.34	Manufacturing - fabricated metal products, instruments/ devices, retail trade - restaurants, auto dealer services, contract construction, health and social services, 9.24	96,809
Henry, 57.97	Kewanee, 14.5	Manufacturing, retail trade, wholesale in durable and non-durable goods, health and membership organization services, 12.17	137,748
Knox, 61.61	Galesburg, 35.3	Manufacturing - machinery, fabricated metal products, retail trade - restaurants, auto dealers/services, health and social services, wholesale - durables and nondurables, 20.81	255,891
LaSalle, 112.03	LaSalle, 10.35 Peru, 10.89	Manufacturing (stone, clay, and glass products, machinery), retail and wholesale trade, services, 37.32	466,327
Lee, 36.3	Dixon, 15.7	Manufacturing - transportation equipment, lumber products, retail and wholesale trade, health and business services, 9.6	102,027
Marshall, 14.48	Henry, 2.66	Manufacturing - chemical and allied products, apparel and textile products, retail and wholesale trade, services, 2.34	28,197
Mercer, 19.20		Retail - restaurants and food services, wholesale - durables and nondurables, health services, manufacturing - metal industries, 1.89	18,354
Peoria, 200.47	Peoria,, 124.16	Manufacturing - machineries, primary metal industries, industrial alcohol, services - health, business, banking, retail - restaurants, general merchandise, wholesale - durables and nondurables, 96.96	1,488,893
Putnam, 6.09		Manufacturing - primary metal industries, retail trade, services, 1.63	31,045

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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)
Illinois (cont'd)			
Rock Island, 165.97	Mo line, 46.46 East Moline, 21.37	Manufacturing - machineries, printing, publishing, retail - restaurants, general merchandise, services - health, education, wholesale - durables and nondurables, 71.33	1,116,715
Stark, 7.39		Manufacturing - electrical equipment, communication/ electronic equipment, services - health, nursing/personal care, wholesale - durable, nondurable goods, 1.00	9,026
Warren, 21.94	Monmouth, 10.71	Manufacturing - food products, apparel and textile products, retail - restaurants, auto dealers/services, health and social services, wholesale - durables and nondurables, 4.81	53,000
Whiteside, 66.5	Sterling, 16.3 Rock Falls, 10.6	Manufacturing - metal products, machineries, retail trade - restaurants, general merchandise, wholesale - durable and nondurable goods, health and social services, 21.1	317,998
Woodford, 33.32	Eureka, 3.29	Manufacturing - machineries, food products, retail - restaurants, auto dealers/services, services - health, educational, wholesale - durables, nondurables, 5.46	60,445
Iowa			
Clinton, 57.3	Clinton, 32.8	Manufacturing - food, grain products, rubber/plastics, health and business services, retail and wholesale trade, 18.9	220,646
Scott, 160.02	Davenport, 103.26 Rock Island, 47.04	Manufacturing - construction machineries, foundries, services - health, business, retail trade - restaurants, general merchandise, wholesale - durable and nondurable goods, 61.79	954,959

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

Table 6. Lakes within Fifty Miles of Johnson Sauk Trail Lake

Name of lake	Area (acres)	Max. depth (feet)	Public access	Launching ramp	Recreational facilities*
Bureau County					
DePue Lake	520	8	Yes	Yes	WS,C,P.F
Goose Lake	2007	6	Yes	Yes	WS,C,P,F
Carroll County					
Mississippi River Backwaters	150		Yes	Yes	P,C,B,F,IF,SK, HI,HT
Knox County					
Lake Storey	132	33	Yes	No	S,C,P,F
Marshall County					
Marshall County Public Fishing Area	2557	5	Yes	Yes	C,P,F
Mercer County					
Keithsburg Natl. Wildlife Refuge	275	5	Yes	Yes	F
Putnam County					
Coleman Lake	55	6	Yes	No	F
Turner Lake	300	8	Yes	No	F
Sawmill Lake	630	5	Yes	Yes	C,P,F
Senachwine Lake	3324	8	Yes	No	F
Whiteside County					
Carlton Lake	77	27	Yes	Yes	P,C,F,B,HI,IS,IF

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

Source: Illinois State Atlas, 1980, Rockford Map Publishers Inc., 4525 Forest View Avenue, Rockford, IL 61125

Historical Lake Uses and Conditions at Johnson Sauk Trail Lake

The impoundment was created for recreational purposes only with fishing as the primary recreational use. The lake is used for ice fishing during winter months. Electric-powered boats in addition to row boats are allowed on the lake. Swimming is prohibited.- Rental paddle boats and canoes are available for public use at the lake site.

Johnson Sauk Trail State Park is a popular recreational facility in the region and draws hundreds of thousands of visitors each year. The historical data on park attendance are shown in table 7. The data shown in the table are for total park usage. Information on the number of users for different recreational categories is not available.

The data in table 7 indicate that there has been a trend of increases in park attendance from year to year. Fishing and various hunting activities add to the immense popularity of the lake and the park area.

The lake has experienced algal blooms with blue-greens as the dominant species, dense filamentous algal growths, and submerged aquatic vegetation in the shallow part of the lake since early in its existence. The lake has routinely been subjected to applications of algicides and herbicides for controlling algae and submerged macrophytes. Profuse algal growths and

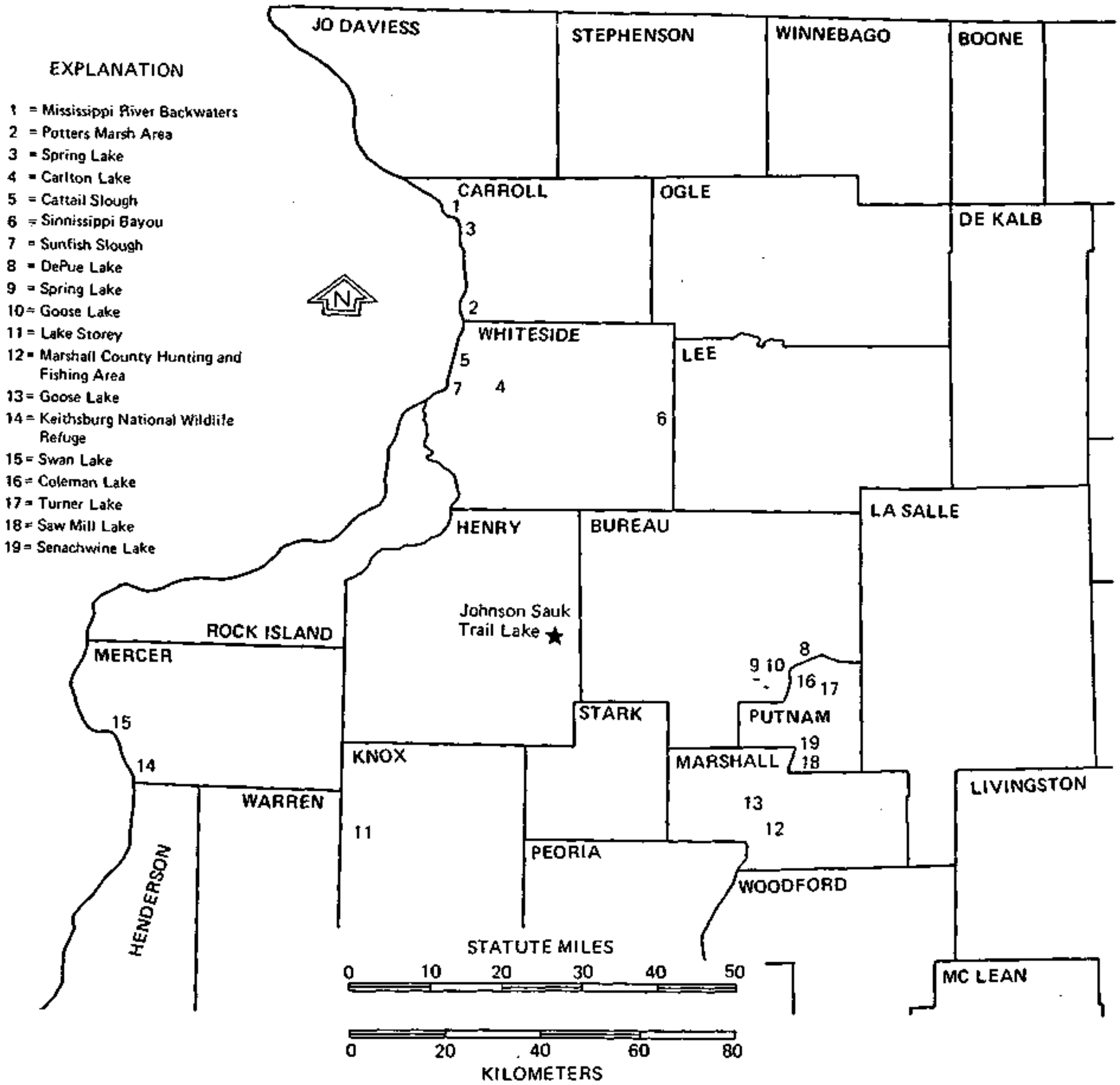


Figure 5. Names and locations of water bodies within SO miles of Johnson Sauk Trail Lake

macrophytes of weed proportions interfere with boating, fishing, and the general aesthetic enjoyment of the lake and its environs.

Prior to predominant state ownership of the lake's watershed, uncontrolled sediment transport from the agricultural land parcels within the watershed resulted in the sedimentation of the upper end of the lake. 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. Such conditions severely restrict fish habitats and alter the character and species makeup of the benthic macroinvertebrates in the profundal region of the lake.

Table 7. Historical Data on Park Attendance

Year	No. of visitors
1981	379,581
1980	359,380
1979	320,174
1978	292,513
1977	166,912
1976	230,534
1975	161,680

Table 8. Johnson Sauk Trail Lake Watershed Land Uses

	1970		1979	
Type of land use	Area (acres)	Percent of total	Area (acres)	Percent of total
Cropland	323.3	36.9	54.2	6.2
Pasture or grassland	153.1	17.5	351.9	40.2
Woodland	317.8	36.3	352.4	40.2
Recreational development	22.6	2.6	32.0	3.7
Wildlife food plots	0.0	0.0	28.2	3.2
Farmsteads	2.9	0.3	0.0	0.0
Water	56.4	6.4	57.4	6.6
Total	876.1		876.1	

With the progressive degradation of the lake's water quality, sports fisheries will be significantly affected. The segment of the park's visitors most affected by lake degradation are those who engage in fishing. There is no other public recreational lake comparable to Johnson Sauk Trail Lake within a 50-mile radius.

Land Uses and Nonpoint Pollutant Loadings

The watershed area for the lake is approximately 876 acres, and about 94 percent of it is now in state ownership. Detailed information on the land uses in the watershed and the changes which occurred between the years 1970 and 1979 is shown 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.

A significant shift in land use within the watershed occurred between 1970 and 1979. Cropland decreased from 36.9 to 6.2 percent. Pasture and grassland increased from 17.5 to 40.2 percent. There was a slight increase in woodland from 318 to 352 acres. Native oak and pine plantings surround the lake. The apparent increase in water surface area in 1979 over that in 1970 is probably due to the low lake water level in 1970 when the aerial photographs were taken.

The watershed, in general, is in excellent condition with excellent ground cover and very little land disturbance. All the five privately held land parcels lie on the outer fringes of the watershed. These land parcels are kept partly in permanent pastures and partly in cultivation. Two landowners raise a small number of dairy cattle and beef stock. Except for the wildlife food plots, there is no land disturbance activity within the state-owned portion of the watershed. The food plots, about 28 acres, are plowed and seeded with corn, sunflower, and millet by park officials, mainly to provide food and habitat for wild animals and birds. However, these food plots lie within a sodded boundary.

The land uses in each of the five sub-basins, developed from 1979 aerial photographs, are shown in table 9. These land use values were used in developing potential nonpoint pollution loadings to the lake originating from its watershed.

For estimating the soil loss rate from the watershed, the boundaries of land uses were first transposed on the watershed soil map. Fifteen categories of soil types, slopes, and erodibility potentials were identified. The soil types and their associated land uses within each subwatershed 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 annual 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 Henry 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 estimated soil losses for each of the five subwatersheds are shown in table 10.

Table 9. Johnson Sauk Trail Lake Watershed Land Uses, Acres

Land use	Sub-basin I	II	III	IV	V	Total
Cropland	0	28.1	0	26.1	0	54.2
Grassland, food plots, recreational areas	56.0	69.9	69.7	187.9	28..6	412.1
Woodland	122.4	96.6	42.3	40.5	50..6	352.4
Total	178.4	194.6	112.0	254.5	79,.2	818.7

Table 10. Soil Losses in Johnson Sauk Trail Lake Watershed

(Tons per year)

Land use	Sub-basin I	II	III	IV	V	Total
Cropland		104.80		113.15		217.95
Grassland, food plots, recreational areas	55.08	66.75	45.27	177.67	23.21	367.98
Woodland	4.72	4.47	1.59	1.49	1.61	13.88
Total	59.80	176.02	46.86	292.31	24.82	599.81

Table 11. Pollution Load from Nonpoint Sources in Johnson Sauk Trail Lake Watershed

Land use	Area (hectares)	Percent of watershed	Constituent	Loading (kilograms x 10^3/year)
Cropland	21.9	6.2	Susp. solids	197.7
			Total N	0.4
			Total P	0.1
Grassland	142.4	40.2	Susp. solids	305.9
			Total N	1.2
			Total P	0.2
Woodland	142.6	40.2	Susp. solids	12.6
			Total N	0.4
			Total P	0.03
Recreational development and food plots	13.0	6.9	Susp. solids	27.9
			Total N	0.04
			Total P	0.003

The total amount of soil loss in the watershed was estimated as 599.8 tons/year. Excluding the lake area, the mean soil erosion rate for the watershed is estimated as 0.73 tons/acre/year.

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 11. Nutrient export rates for nitrogen and phosphorus (in kilograms per hectare per year) were estimated as follows:

	Nitrogen	Phosphorus
Cropland	16.09	4.46
Grassland and food plots	8.65	1.5
Woodland/recreational development	2.86	0.236

All these values are the mean values for the respective land use indicated by Reckhow et al. (1980).

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 King 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.

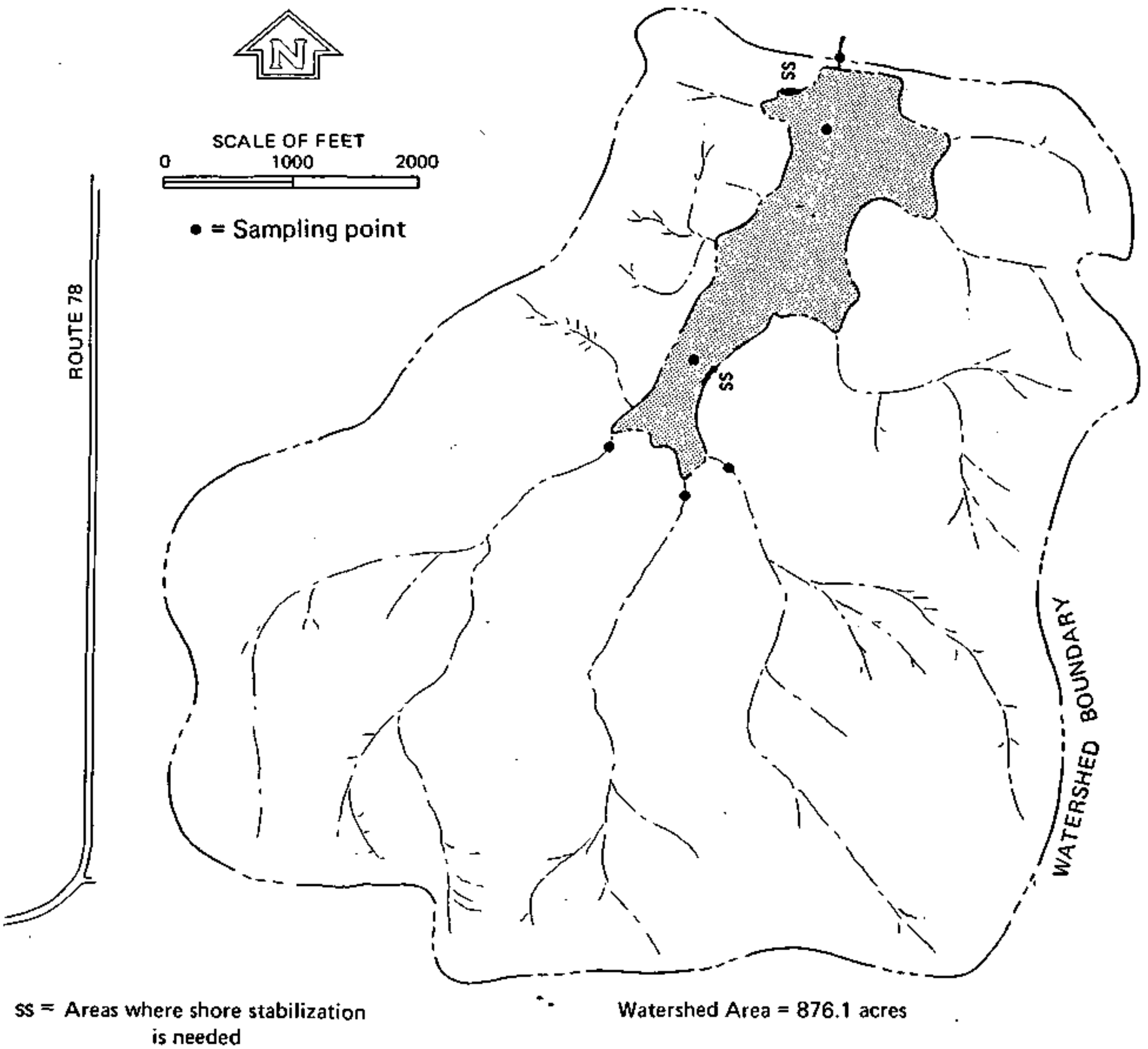


Figure 6. Watershed basin, Johnson Sauk Trail Lake

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 12.

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 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

Table 12. Analytical Procedures

Turbidity	Nephelometric method, using Turner Fluorometer, 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

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 13.

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 0.45 μm 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 samplas 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.

Table 13. 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 pus-ilium	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 crebea	Spherical	18
Other	*Peridinium cinctum*	Cylindrical	50x60
	Staurastrum paradoxum	Cylindrical	39x274

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. 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 to 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 Johnson Sauk Trail Lake 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 May and intensifies progressively during the summer months. The maximum water temperature of 28.0°C was observed on July 7, 1981. The lake experienced the maximum temperature differential of 12.0°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 6, 1981.

Lake stability has long been used by limnologists as an arbitrary measurement of the intensity of stratification in any body of water

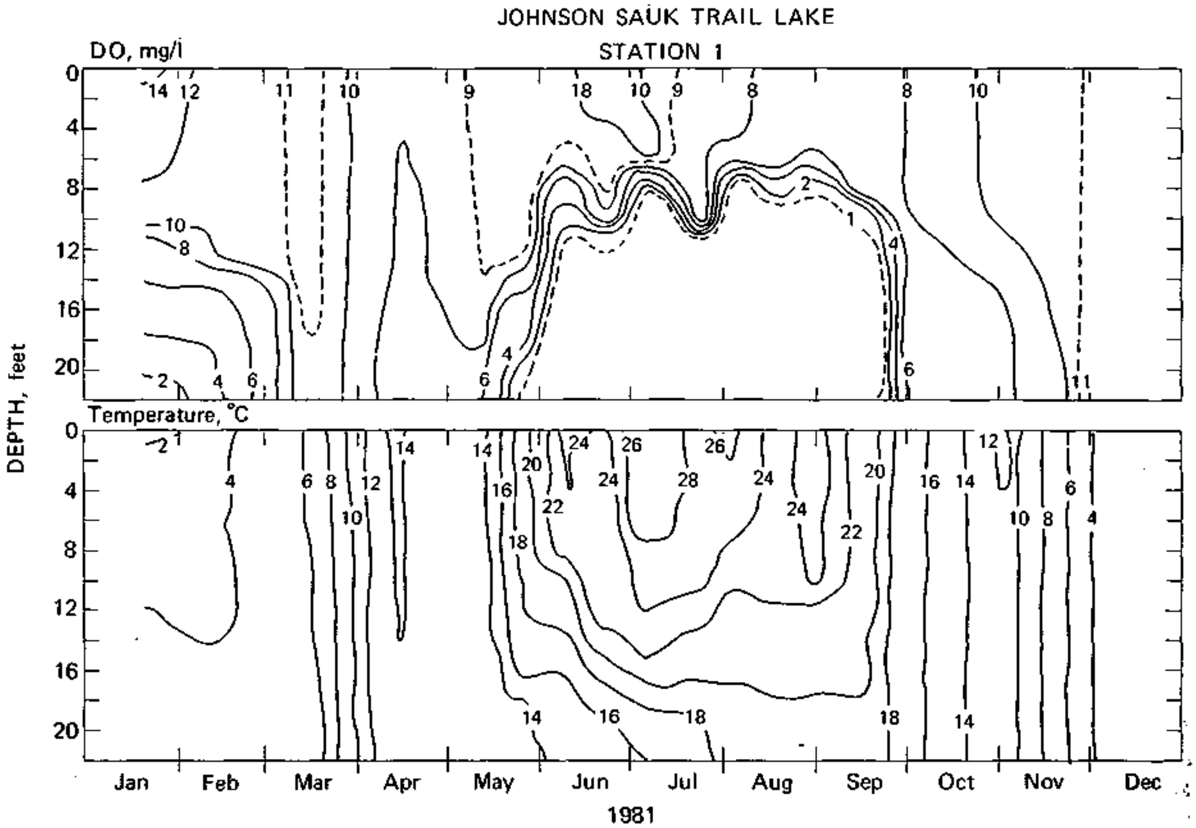


Figure 7. Isothermal and dissolved oxygen plots for the deep station

(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 3.86 x 10" foot-pounds (1.45 kilowatt-hours) on July 23, 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 x 10^6 foot-pounds (16.96 kilowatt-hours) on June 27, 1977. Lake Catherine is nearly three times as large as Johnson Sauk Trail Lake 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

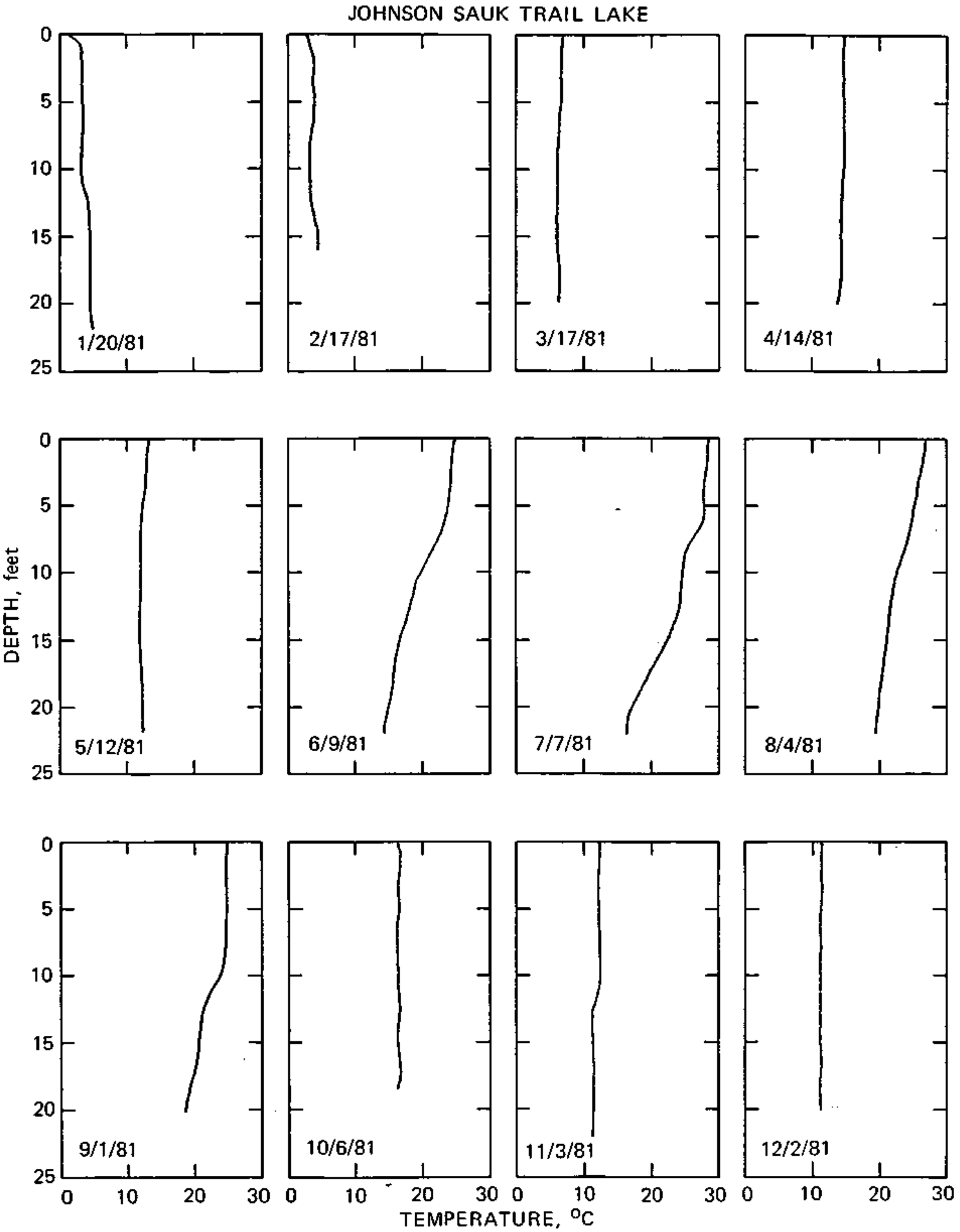


Figure 8. Temperature profiles at the deep station on selected dates

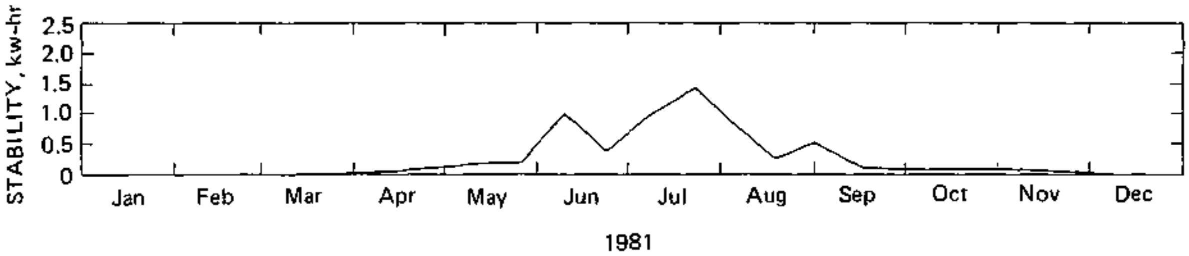


Figure 9. Temporal variations in lake stability

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).

The isopleths of dissolved oxygen for Johnson Sauk Trail Lake 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 8 feet from the surface and below. About 177 acre-feet or approximately 38 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 10 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, July, and August. Near bottom waters became anoxic in May and remained so until mid-September. Anoxic conditions prevailed at mid-depth during July and August.

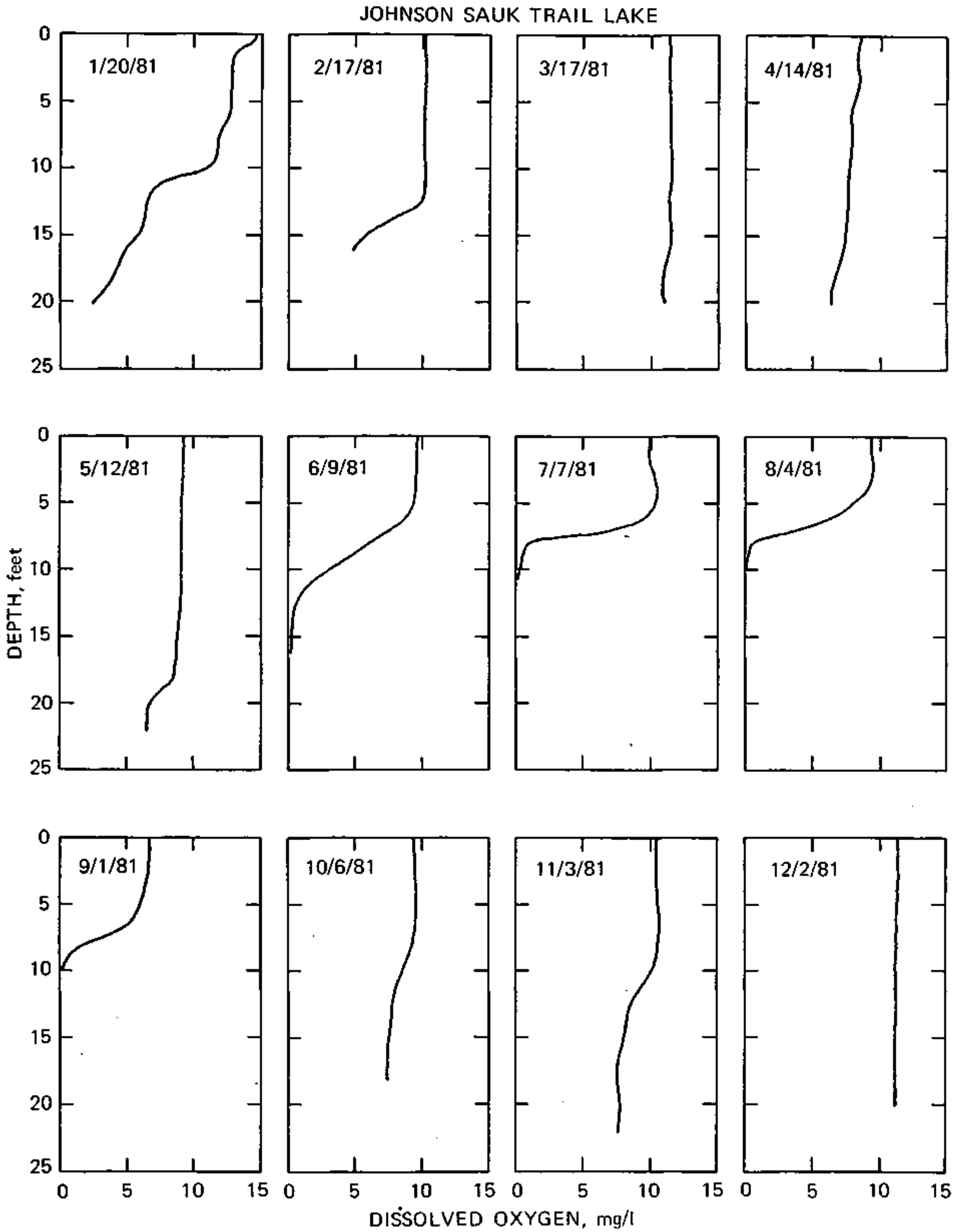


Figure 10. Dissolved oxygen profiles at the deep station on selected dates

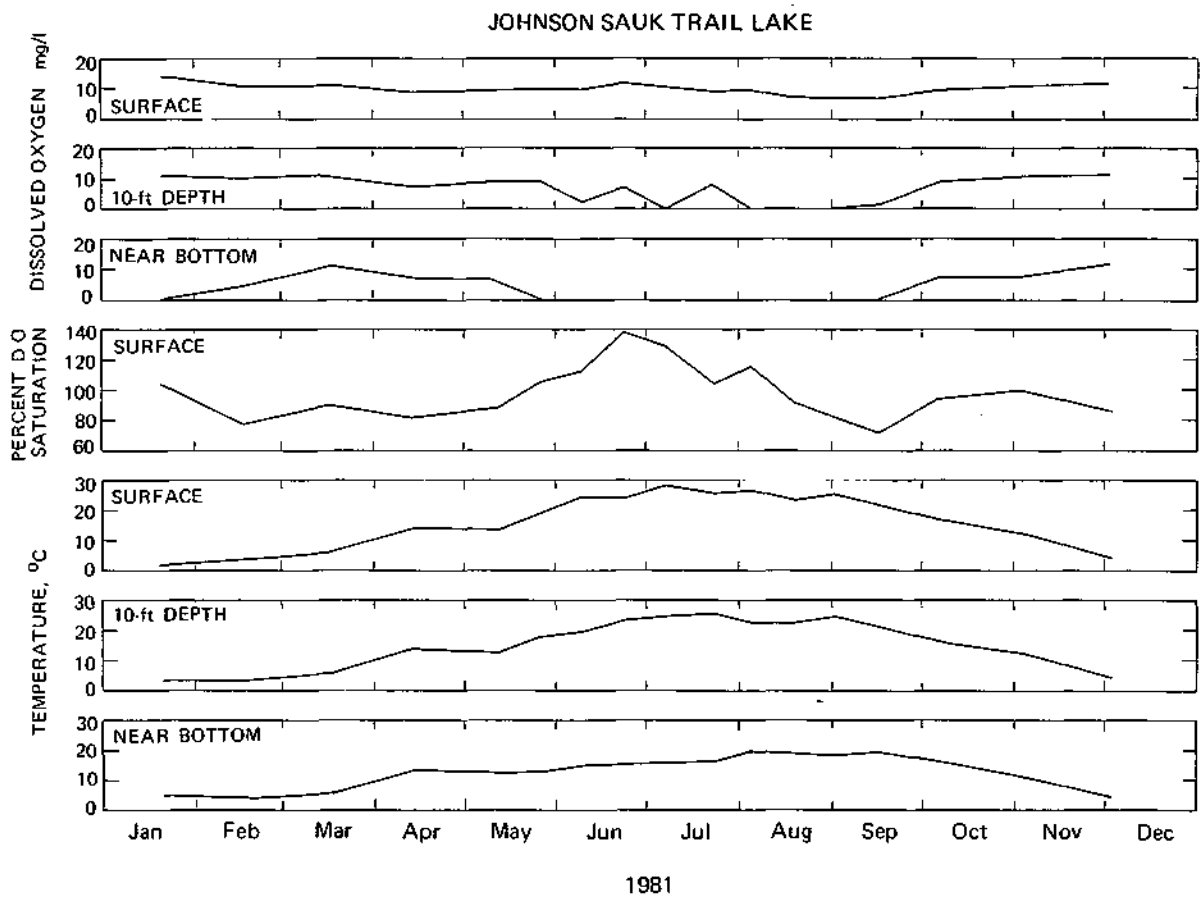


Figure 11. Temporal variations in BO, percent BO saturation, and temperature in the lake

Isothermal and iso-dissolved oxygen plots for the shallow station 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 July and August.

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 14 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 50 inches. A maximum value of 103 inches was observed in February when the lake had ice cover. The minimum of 6 inches

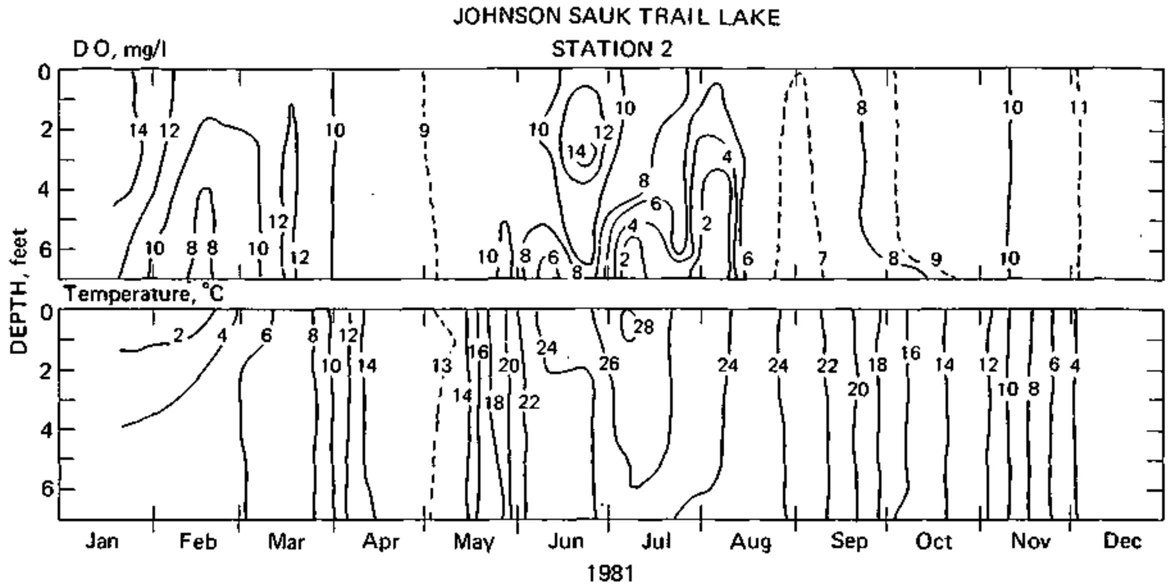


Figure 12. Isothermal and iso-dissolved oxygen plots for the shallow station

Table 14. Johnson Sauk Trail Lake Water Quality Characteristics

Parameter	Near surface Mean	Range	Mid-depth Mean	Range	Near bottom Mean	Range
Secchi readings (inches)	50	6-103				
Turbidity (NTU)	7.7	0.4-60.2	7.9	1.4-56.8	35.1	1.6-377.0
pH (dimensionless)		7.9-9.6		8.1-9.5		7.6-8.6
Alkalinity	157	67-187	168	139-195	188	126-250
Conductivity (μmho/cm)	281	98-371	291	185-370	312	214-445
Total phosphate-P	0.07	0.03-0.21	0.09	0.04-0.25	0.30	0.03-0.95
Dissolved phosphate-P	0.02	0.01-0.04	0.03	0.01-0.16	0.16	0.01-0.49
Total ammonia-N	0.19	0.03-0.42	0.30	0.12-1.16	1.03	0.17-3.41
Dissolved ammonia-N	0.13	0.02-0.21	0.25	0.05-1.15	0.87	0.12-2.72
Nitrate-N	0.10	0.03-0.27	0.10	0.03-0.17	0.12	0.05-0.34
Total Kjeldahl-N	1.01	0.52-2.39	1.10	0.57-2.25	1.76	0.75-4.36
Dissolved solids	242	72-296	256	196-306	267	192-306
Total suspended solids	9.3	0-52	12.9	0-83	27.6	0-158
Volatile susp. solids	6.2	0-12	7.6	0-18	8.5	0-22

Note: Values in mg/l unless otherwise indicated

occurred in April immediately after a heavy rainfall, indicating a significant sediment influx. About 5.69 inches of rainfall was recorded over a period of 7 days in late August, with 3.33 inches occurring in one 24-hour period. Secchi disc readings during June, July, and August were in the range of 18 to 51 inches.

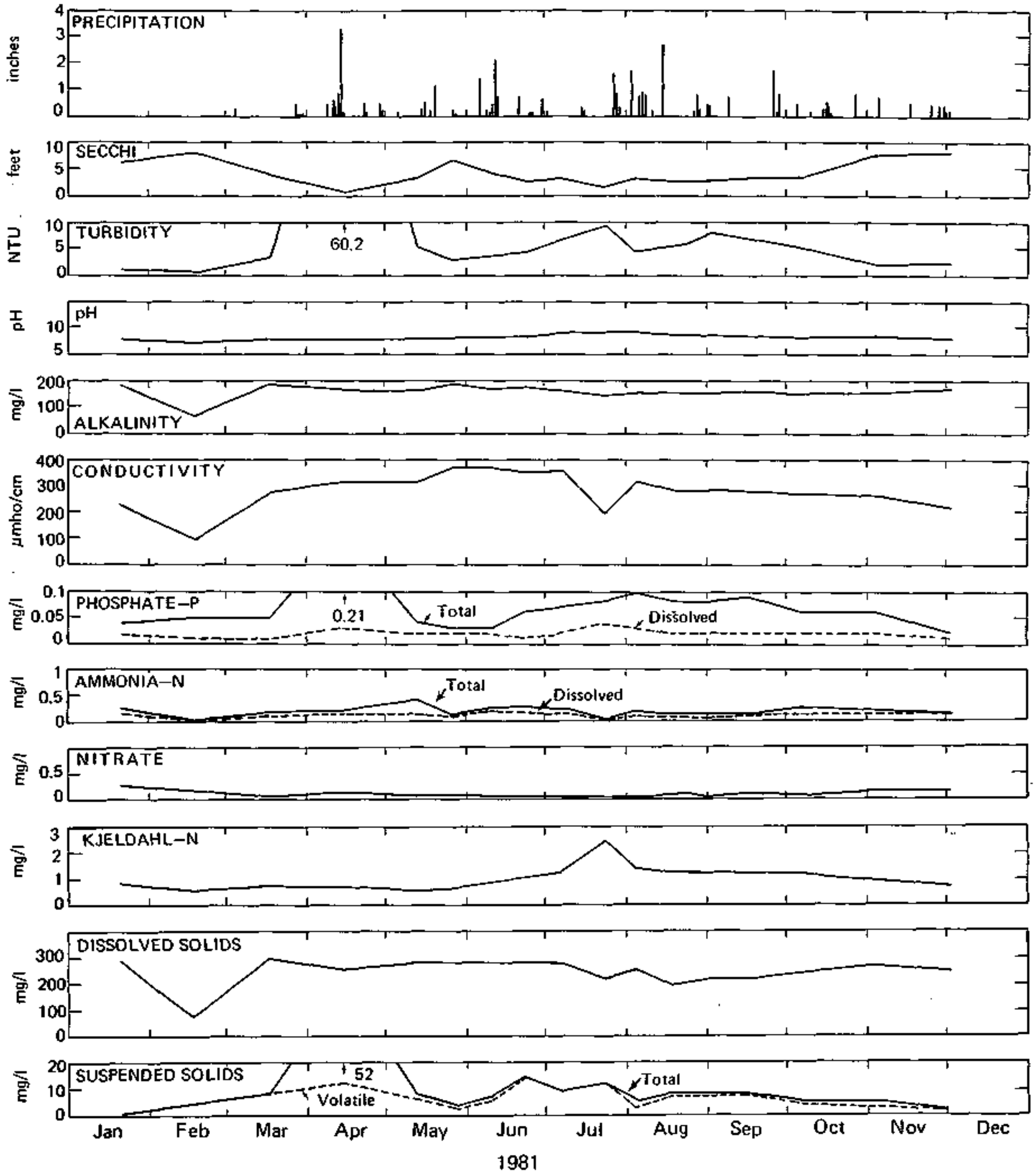


Figure 13. Temporal variations in near surface water quality characteristics at the deep station

<u>Turbidity</u>. 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 Johnson Sauk Trail Lake, 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 14. The turbidity of surface and mid-depth samples had relatively low mean values of 7.7 and 7.9 NTU, respectively, except for a single observation of 60.2 NTU on April 14, 1981. Lake turbidity at that time was nearly eight 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 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 Johnson Sauk Trail Lake are typical of Illinois lakes. The range of pH values was the highest for the surface waters (7.9-9.6) and the lowest for the near bottom waters (7.6-8.6). 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, mid-depth, and deep water samples were 157, 168, and 188 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

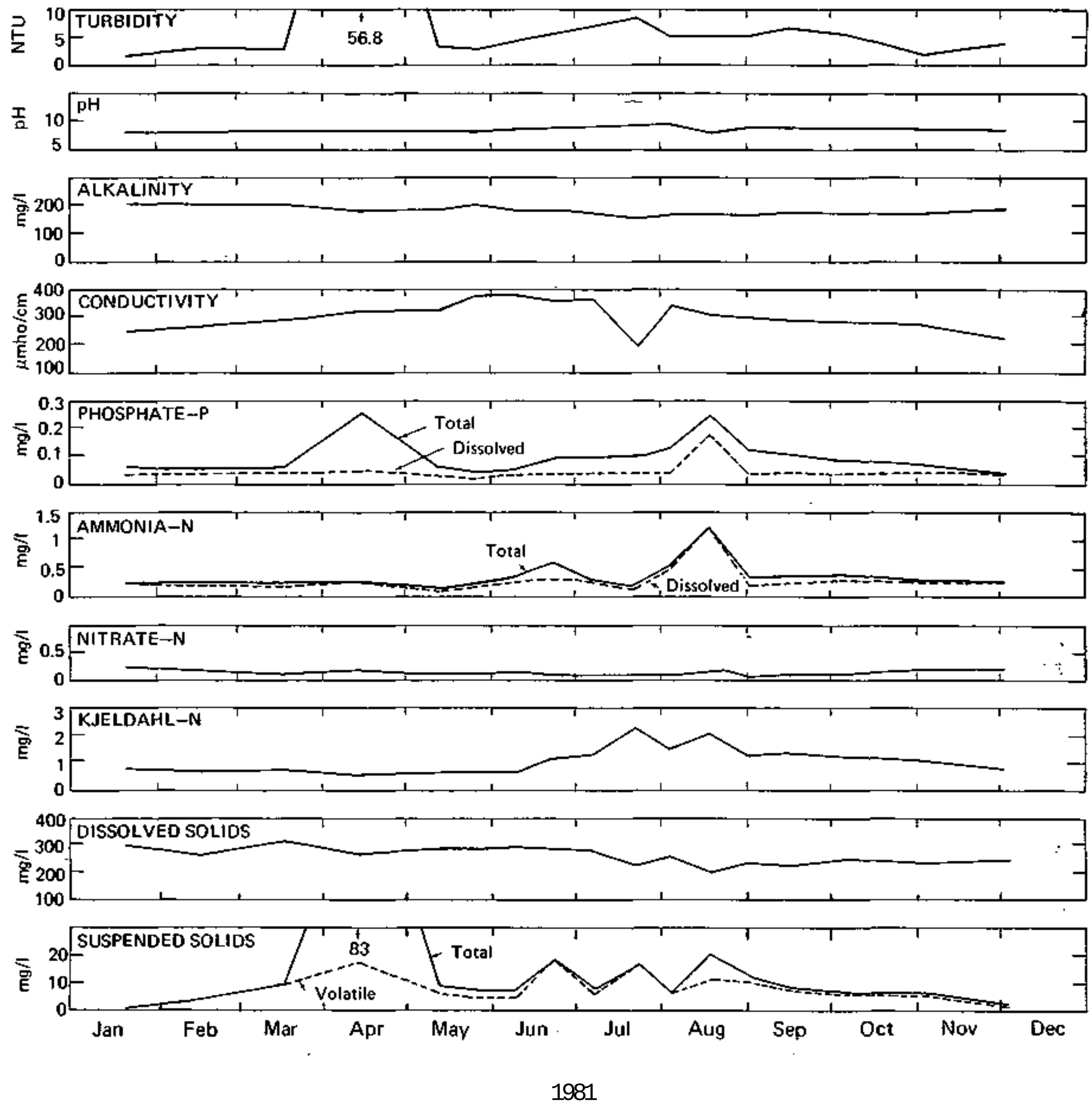


Figure 14. Temporal variations in mid-depth water quality characteristics at the deep station

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 281 µmho/cm for the surface, 291 µmho/cm for the mid-depth, and 312 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

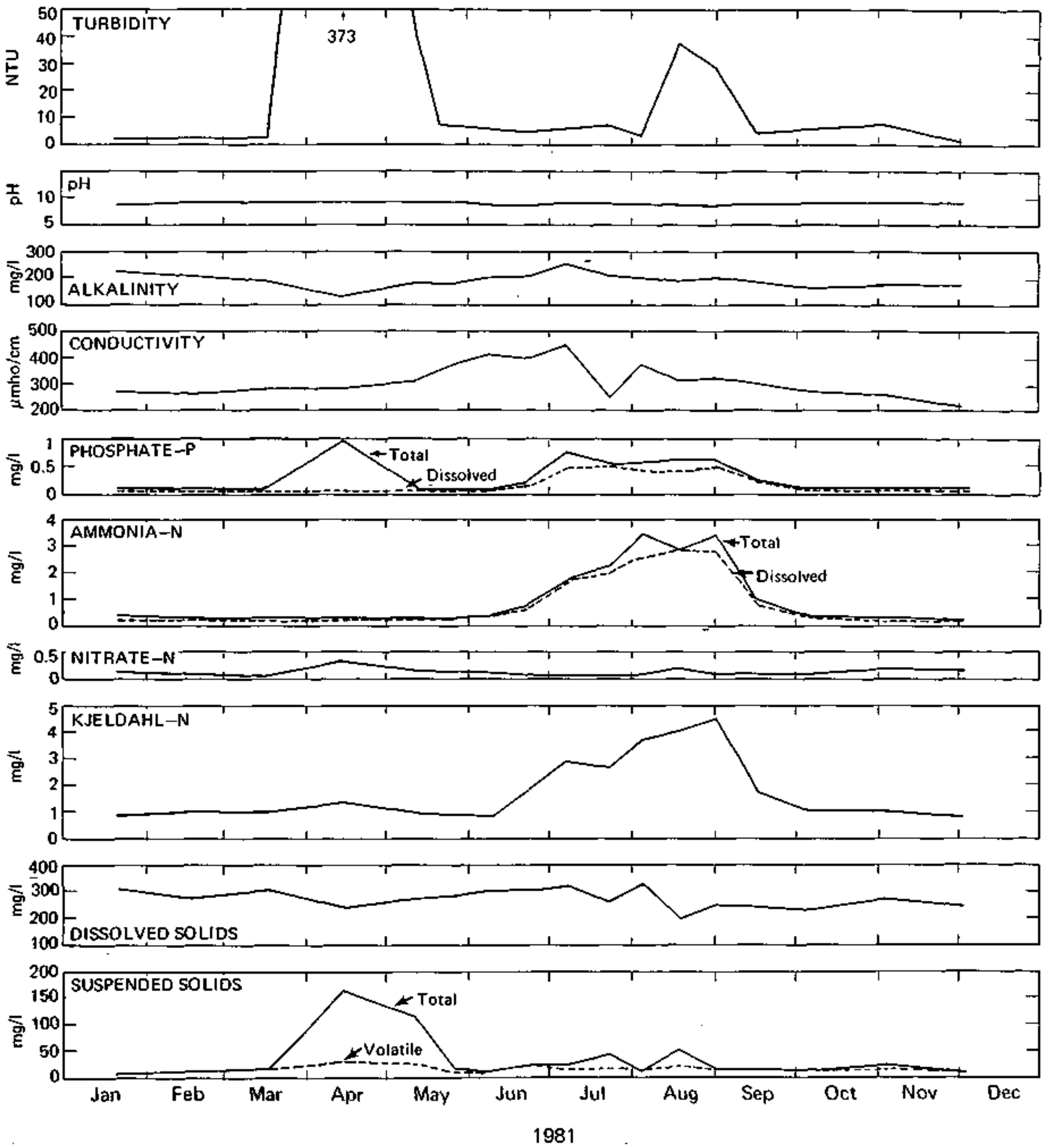


Figure 15. Temporal variations in near bottom water quality characteristics at the deep station

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/1, 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 14. Temporal variations in phosphorus content in the lake are depicted in figures 13, 14, and 15. Even the lowest observed total phosphorus value was 3 or 4 times higher than the critical value suggested by Sawyer (1952). The mean dissolved phosphorus levels in the lake varied from 0.07 mg/1 at the surface to 0.30 mg/1 near the bottom. Phosphorus level tended to increase in the lake after a heavy rainfall, and this phenomenon was most pronounced during the April 14, 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 0.09 and 0.02 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 0.95 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 0.14 to 0.67 with a mean value of 0.35. The high values ranging from 0.14 to 0.67 occurred during the months

January 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 0.17 to 0.50 with a mean of 0.29.

The dissolved phosphorus to total phosphorus ratio at mid-depth varied from 0.16 to 0.67 with a mean of 0.36 for the duration of the lake monitoring. Corresponding values for the deep station were 0.05 to 0.83, and 0.50. The mean values at these locations during the summer months were respectively 0.31 and 0.65. There was no biological uptake of dissolved phosphorus taking 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/1 is considered sufficient to stimulate nuisance algal blooms (Sawyer, 1952). The IPCB 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 14, and the temporal variations in these parameters are shown in figures 13, 14, and 15. Mean total 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 0.19 mg/l at the surface to 1.03 mg/1 at the bottom. Nitrate-nitrogen mean values were 0.10 mg/1 at the surface, 0.10 mg/1 at mid-depth, and 0.12 mg/1 at the bottom. Kjeldahl-nitrogen mean values showed an increasing trend toward the bottom of the lake.

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 Johnson Sauk Trail Lake are typical of midwestern lakes. Abnormally high suspended solids concentrations were found in the lake only for the April 14, 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 14 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 15. 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 7, 1981, with a concentration of 80 μg/l. Algal biomass was found to be the highest on September 1, 1981, with a concentration of 151.4 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, accounting for the very large biomass. There apparently is no correlation between biomass, chlorophyll-a, and the counts of algae found in Johnson Sauk Trail Lake.

The relative dominance of algal types found in the lake is shown in table 16. Blue-greens were found to be the dominant algae in the lake during the summer months. Blue-green species constituted 55.6 to 100.0

Table 15. Algal Types and Densities, Chlorophyll-a, and Biomass in Johnson Sauk Trail Lake
(Algal densities in counts per milliliter)

Date	BG	G	D	F	0	Total	Chlorophyll-a (μg/l)	Biomass (mm^3/l)
5/12/81	150	45	75			270	20	0.735
5/26/81	280					280	30	0.400
6/09/81	900				5	905	40	3.505
6/23/81	2645	395	100			3140	70	6.406
7/07/81	4630	1200	345	325		6500	80	72.602
7/23/81	5950	735	600	460		7745	67	149.416
8/04/81	8620	870	660	315		10465	53	24.656
8/18/81	20590	495	525	345		21955	40	35.950
9/01/81	10280	360	410	640	390	12080	47	151.411
9/16/81	16000		75		40	16115	40	26.676

Note: BG = blue-greens; G = greens; D = diatoms; F = flagellates; 0 = others percent of the total algae found in the lake between May 12 and September 16, 1981.

Benthic Organisms. The types and densities of benthic macroinvertebrate communities in the lake sediments are given in table 17. *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

Table 16. Relative Dominance of Algal Types
(Percent of total)

Date	BG	G	D	F	0
5/12/81	55.6	16.7	27.7		
5/26/81	100.0				
6/09/81	99.4				0.6
6/23/81	84.2	12.6	3.2		
7/07/81	71.2	18.5	5.3-	5.0	
7/23/81	76.8	9.5	7.7	5.9	
8/04/81	82.4	8.3	6.3	3.0	
8/18/81	93.8	2.3	2.4	1.6	
9/01/81	85.1	3.0	3.4	5.3	3.2
9/16/81	99.3		0.5	0.2	

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

Table 17. Benthic Macroinvertebrates Collected from
Johnson Sauk Trail Lake
(Individuals per square meter)

	Shallow station			
	6/9/81	**7/7/81**	**8/4/81**	**9/1/81**
Ceratopogonidae (biting midge)	43		14	
Chaoborus (phantom midge fly)	158	301	7,894	2,354
Chironomidae (midge fly)	316	14	402	43
Sphaerium (fingernail clam)	14			
Tubificidae (sludge worm)	129	345	301	230
Total	660	660	8,611	2,627
	Deep station			
Chaoborus	2,196	1,091	7,320	8,913
Chironomidae	2,052	2,454	1,220	144
Total	4,248	3,545	8,540	9,057

found in the samples. The overall averages of the macroinvertebrate densities were 3140 and 6350 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 3.80 in the shallow station versus 2.00 for the deep station.

Bacterial Densities. Bacterial densities found in the lake, the tributaries to the lake, and King Creek downstream of the impoundment are shown in table 18. Total coliform, fecal coliform, and fecal streptococcus densities are included in the table. Fecal coliform densities in the tributaries exceeded 400/100 ml during May through September 1981 except in one instance on June 23, 1981, for the east tributary.

Fecal coliform/fecal streptococcus ratios (FC/FS) in the lake varied from infinity on May 26, 1981 and September 18, 1981 (FS counts being zero) to 0.0 on June 10, 1981, with an average value of 3.9, excluding the two indeterminate values for the FC/FS ratio. According to the Clean Lakes Program Guidance Manual (USEPA, 1980a), ratios ≥ 4.0 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 < 0.70 indicate pollution derived from livestock or poultry.

The FC/FS values for the lake varied from 2.6 to 6.2. The FC/FS ratios for the east tributary ranged from 0.4 to 16.0 with a mean of 4.9. The FC/FS values for the middle tributary varied from 1.3 to 14.0 with a mean of 3.8. The corresponding values for the west tributary are 0.8 to 9.2 and 3.3. As there is no human habitation in the lake watershed, the source for the bacterial contamination cannot be attributed to humans. The FC/FS ratio values do not suggest contamination due to wildlife population.

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,

Table 18. Bacterial Densities in Johnson Sauk Trail Lake and Its Tributaries
(Counts per 100 milliliters)

Date, 1981	Lake station #1			East tributary			Middle tributary			West tributary			King Creek, downstream		
	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS
5/13					600	50		450	240			300			20
5/26	1300	380	0	1500	1400	90	1600		150	2000	1100	120	3400		230
6/10	380	0	100	2300	190	490	2400	900	880	3000	2510	2100	680	580	520
6/23	400	280	50	1400	1200	190	1300	970	150	960	720	130	1800	0	230
7/07	970	180	60	6100	3000	570	3000	1900	890	750		990	2200	2000	40
7/27	750	680	110	1500	1400	1200	1400	1200	960	5600	1100	1200	1500	400	330
8/06	1000	220	85	1200		690	4400	3000	2000	8900	5700	880	680	240	860
8/20	830	220	60	5200	440	520	3000	640	730	3500	750	920	680	70	220
9/03	1100	790	130	8200	1700	1200	8700	620	770	3500	1300	1300	500	320	140
9/18	2400	280	0	3800	540	1100	3500	960	800	1800	720	500	920	690	230

Note: TC = Total coliform; FC = Fecal coliform; FS = Fecal streptococcus 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 Johnson Sauk Trail Lake are shown in figure 16. All the macrophytes found in the lake were

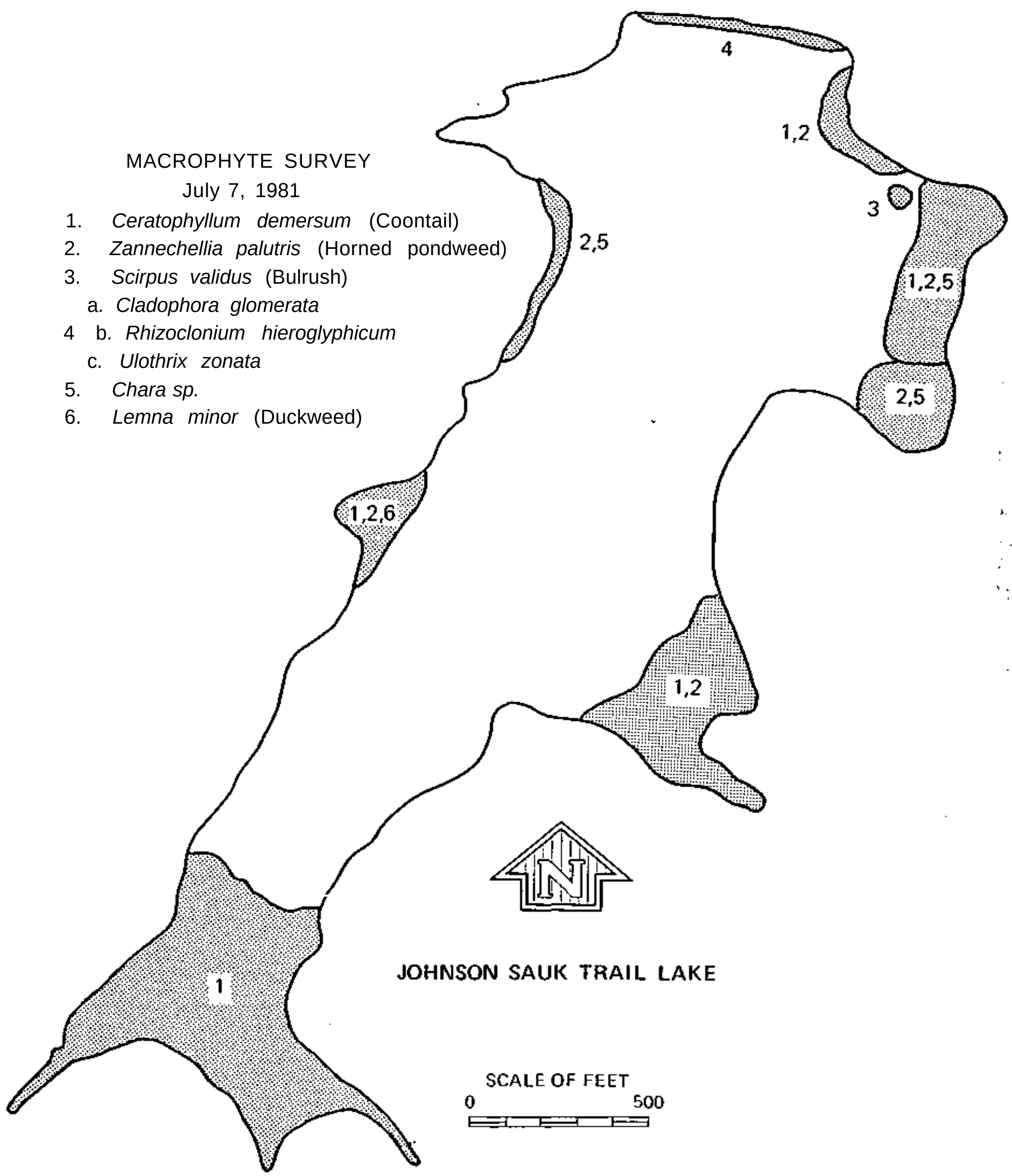


Figure 16. Types and areal extent of macrophytes

the submergent type except for a very small patch of bulrush. The dominant types of vegetation in the lake were horned pondweed and coontail. The shallow upper end of the lake was dense with coontail, which thrived in the lake at depths of 8 feet and less. About 15.4 acres of the lake, constituting 26.8 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. During June and July 1981 the shallow portion of the lake was partially treated with aquathol-K for macrophyte control.

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: 1.08 lbs; 1.08 lbs; 0.93 lbs; 0.91 lbs; and 0.89 lbs. A composite sample from five redear fish of sizes 0.51 lbs, 0.50 lbs, 0.48 lbs, 0.45 lbs, and 0.42 lbs was also analyzed. In addition, two separate analyses were performed on whole carp of sizes 6.10 lbs and 1.49 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 to 12.8 percent. Dieldrin concentrations in whole carp samples were 0.037 ppm for the 1.49-lb fish and 0.018 ppm for the 6.10-lb fish. Mercury levels in the carp samples were less than 0.03 ppm. They were 0.07 ppm in the redear fish samples and 0.33 ppm in the largemouth bass samples. The levels of pesticides and organochemicals found in the fish flesh samples are not cause for concern.

The concentrations of toxicants in the 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 Illinois Environmental Protection Agency conducted an intensive survey of Johnson Sauk Trail Lake on five sampling dates from June 20 through October 30, 1979, to determine the water quality and trophic state of the lake and to identify specific problems. A detailed report on the results of the survey can be found in the IEPA's report (1980), Limnology of Johnson Sauk Trail Lake - 1979.

The lake was found to stratify thermally during July and August, 1979. Associated with this was hypolimnetic dissolved oxygen depletion in July and August. Supersaturated conditions were recorded in 73 percent of the surface samples. Surface dissolved oxygen concentration reached 17.2 mg/l (200 percent saturation) in July and August during the peak of the phytoplankton production.

Mean values for total suspended solids, volatile suspended solids, turbidity, and secchi disc visibility in the surface waters were 11.3 mg/1, 9.7 mg/1, 5.3 NTU, and 27 inches, respectively.

Excessively high concentrations of phosphorus-were found at all sampling stations in the lake, with concentrations ranging from 0.09 to 1.20 mg/1. Excursions of the total phosphorus standard occurred in 100 percent of the samples. The highest concentrations of phosphorus were found in bottom samples collected in July and August.

Nitrate-nitrite was detected in only 6 of the 25 water samples collected. Ammonia-N concentrations of up to 5.1 mg/1 were found in the anaerobic bottom waters during July, and total Kjeldahl-N averaged 1.7 mg/1.

Phytoplankton densities in Johnson Sauk Trail Lake ranged from 306/ml in May to 34,530/ml in July 1979. These algal blooms were almost completely dominated by the undesirable blue-green genera Aphanizomenon and Anabaena. Chlorophyll-a concentrations ranged from 14.0 to 138.7 μg/l. Chlorophyll-a levels found in the lake were reported to be within the middle to upper range of values typical of eutrophic lakes.

Concentrations of heavy metals and persistent organics in water samples from Johnson Sauk Trail Lake were found by IEPA to be generally either below detectable limits or well below state standards. The exceptions were manganese and iron, which were high in the anaerobic hypolimnetic waters.

Volatile solids in the lake sediments were reported to be moderate to high, while total Kjeldahl-N, iron, manganese, and arsenic were found to be high in content.

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 second year of its existence, and copper sulfate was applied to the lake at the rate of 5.4 lbs/acre. Submerged aquatic vegetation and nuisance proportions of filamentous algae existed in the lake during 1958. Sodium arsenite was used to control macrophyte growths in 1958. Macrophyte control by chemical means has been practiced annually since the very beginning of the lake's existence with only a few exceptions, as in 1964, 1965, and 1978.

The IDOC fisheries biologists have monitored the lake periodically, determining 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. The historical data, pertaining to the depth at which the dissolved oxygen was found to be 1.0 mg/l, the pH, the alkalinity, and the maximum depth are listed in table 19. It should be noted that the lake was practically anoxic at depths 6 feet and below during February 1958, when the lake was not quite three years old.

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 19. Historical Data regarding Dissolved Oxygen, Alkalinity, and Maximum Depth

Date	**Depth at which DO of 1.0 mg/1 was observed (feet)**	**PH**	**Alkalinity (mg/1)**	**Maximum depth (feet)**
Feb. 24, 1958	6.0			16.0
June 11, 1959	14.0	7.5		
July 28, 1960	9.0	7.2		23.0
Feb. 1, 1962	14.0	7.1		20.0
Aug. 15, 1966	12.0	7.6		14.0
Aug. 6, 1969	11.0			21.0
Aug. 13, 1970	9.0	7.6		18.0
July 22, 1971		6.8	136*	12.5
Jan. 24, 1977	9.0	7.6		12.0

Note: Aqualator aerators were installed in 1977

*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.

Eleven 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 543.8 acre-feet to 471.5 acre-feet. This represents a loss in water storage of 13.3 percent in 26 years, or 0.51 percent per year. This rate of loss of capacity is slightly below 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 3.33 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 20.

With the aid of Brune's Curve (Brune, 1953), the trap efficiency of Johnson Sauk Trail Lake was estimated as 98 percent, based on an average capacity-inflow ratio of 1.96. The estimated soil loss from the watershed for the current land use is 0.73 tons/acre/year. The-average annual sedimentation in the lake was estimated as 3.33 tons/acre. This clearly reflects the beneficial results due to the changes in the lake's watershed land use for the better. Most of the sedimentation in the lake must have occurred during the first 10 to 15 years of its formation, after which the Illinois Department of Conservation began a program of land acquisition and watershed management.

Surficial Sediments

Sediment Oxygen Demand Rates. Results of **in-situ** measurements of sediment oxygen demand rates are shown in table 21. 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

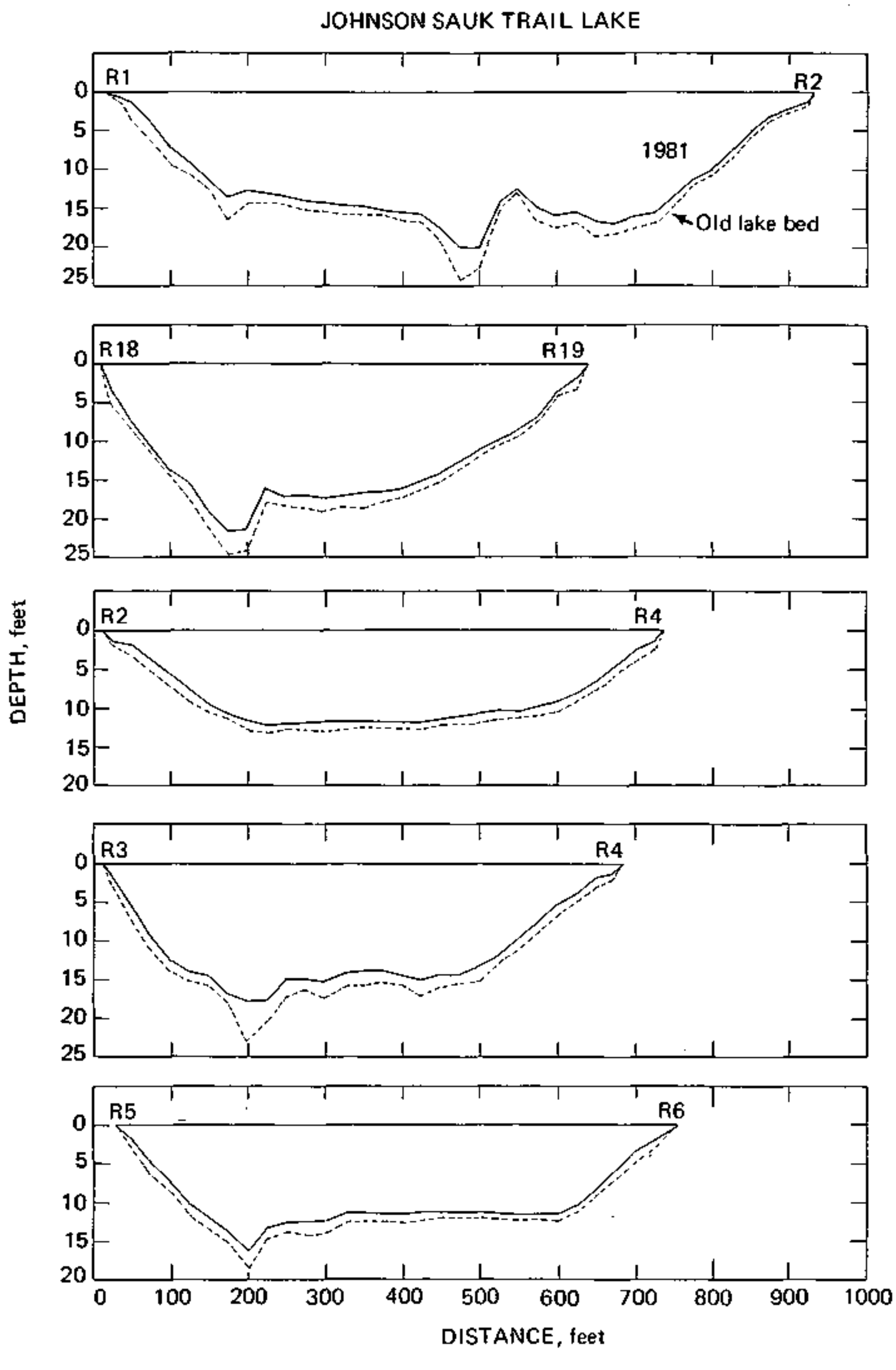


Figure 17. Reservoir cross sections at selected transects

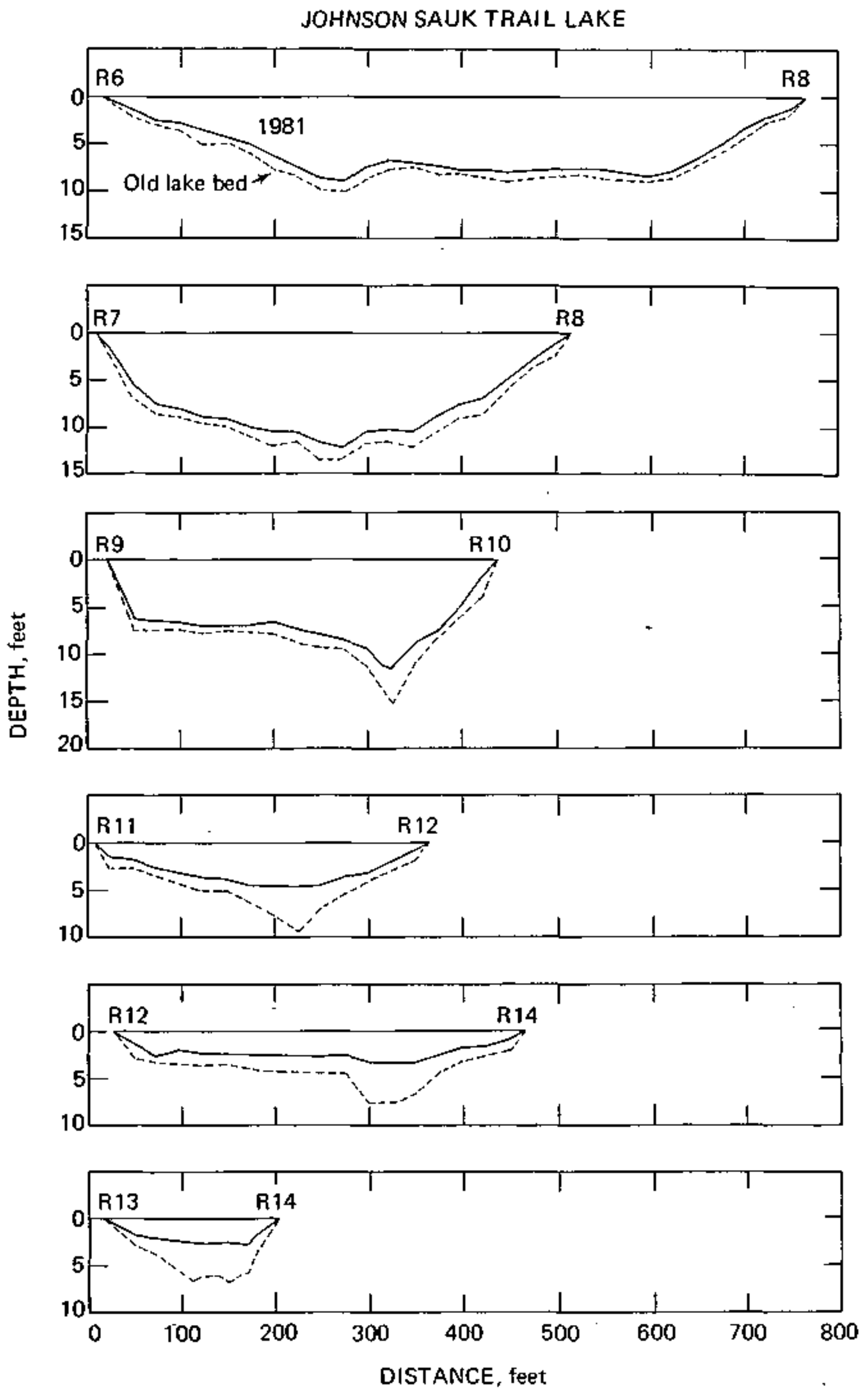


Figure 17. Concluded

Table 20. Summary of Sedimentation Data, Johnson Sauk Trail Lake

Age	**Years**	
Built 1956		
Survey 1981	26	
Watershed	**Sq mi**	**Acres**
Total area	1.37	876.1
Area excluding lake	1.28	818.7
Reservoir		
	Acres	
Surface area at spillway level	57.4	
Storage capacity at spillway level	**Acre-feet**	**Mil gal**
1956	543.8	177.2
1981	471.5	153.6
Capacity per square mile of drainage area*	**Acre-feet**	
1956	397	
1981	344	
Sedimentation	**Acre-feet**	
1956-1981	72.3	
Average annual accumulation of sediment**		
	Acre-feet from entire watershed	
1956-1981	**2.78**	
	Acre–feet per square mile	
1956-1981	2.17	
	Cubic feet per acre	
1956-1981	148	
	Tons per acre* **	
1956-1981	3.33	
Depletion of original storage	**Percent of original storage**	**Percent per year**
1956-1981	13.3	0.51

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

Table 21. *In-situ* Sediment Oxygen Demand Rates

Location	Date	Water depth (feet)	Ambient temperature, T(°C)	SOD ($g/m^2/day$) At T°C	At 25°C	At 20°C
Shallow sta.	7/21/81	8.0	27.4	3.27	2.93	2.33
Shallow sta.	10/20/81	8.0	12.1	0.60	1.09	0.86
Deep sta.	7/21/81	21.5	16.1	1.88	2.83	2.25
Deep sta.	10/20/81	21.5	12.1	1.67	3.03	2.41

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 22.

The sediment oxygen demand rates observed in Johnson Sauk Trail Lake 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 23. 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 39.9 percent dry solids (60.1 percent moisture content) with 5.8 percent volatile solids (94.2 percent fixed solids). Deep station samples were 27.9 percent dry solids (72.1 percent moisture content) with 7.9 percent volatile solids (92.1 percent fixed solids).

Table 22. Physical and Biological Data for SOD Measurement Dates

Location	Date	Benthic organisms (cts/m^2)	Algae (cts/ml)	Sediments % dry	Sediments % volatile
Shallow sta.	7/21/81	4,020	8,300	39.7	6.1
Shallow sta.	10/20/81	1,930	960	30.0	6.2
Deep sta.	7/21/81	3,460	4,810	31.4	8.2
Deep sta.	10/20/81	3,750	620	29.0	7.5

Table 23. Consistency of Surficial Sediments

Date	Shallow station % dry.	Shallow station % volatile	Deep station % dry	Deep station % volatile
6/09/81	39.2	6.0	28.8	7.0
7/07/81	43.0	4.5	27.3	7.1
8/04/81	33.5	6.9	25.5	8.3
9/01/81	44.0	5.6	30.0	9.0

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 Johnson Sauk Trail Lake appear to be typical of other man-made lakes in Illinois.

Elutriation Tests. Results of analyses of the elutriation tests are shown in table 24 for metals concentrations and in table 25 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 25, 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 24. Concentrations of Metals in Elutriated Samples

	Shallow station		**200 feet upstream of shallow station**	
Parameter	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**
Calcium	35	35	39	38
Magnesium	24	25	24	23
Sodium	6.6	6.4	9.0	8.8
Potassium	3.8	3.9	3.2	3.2
Manganese	1.1	1.1	2.0	2.0
Total Kjeldahl-N	1.5	1.9	1.8	1.7
Total phosphorus	0.03	0.05	0.04	0.03
COD	30	36	30	32
Barium	130	130	120	120
Beryllium	0.5	0.5	0.5	0.5
Boron	49	50	50	51
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	160	140	210	210
Nickel	5.0	5.0	5.0	5.0
Silver	3.0	3.0	3.0	3.0
Strontium	89	88	87	85
Vanadium	5.0	5.0	5.0	5.0
Zinc	31	30	43	39
Lithium	Trace	Trace	Trace	Trace
Lead	50	50	50	50

Note: Values for the first 8 parameters are in mg/1; all others are in µg/l. All analyses were performed on total samples.

Table 25. Concentrations of Organochemicals in Elutriated Samples
(Concentrations in micrograms per liter)

Parameter	Shallow station	200 feet upstream of shallow station	IPCB standards
PCB	0.1	<0.1	
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 26. 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 (11)*			
Top	9.3	90.7	11.4
Middle	12.0	88.0	11.2
Bottom	7.0	93.0	12.8
200 feet upstream of shallow station			
Sample 1 (23)*			
Top	5.6	94.4	16.0
Middle	4.0	96.0	23.5
Bottom	1.3	98.7	22.8
Sample 2 (22)*			
Top	4.5	95.5	9.6
Middle	1.7	98.3	26.7
Bottom	19.6	80.4	15.6

*Length of core sample in inches

Core Sediments

Particle Size Distributions. Results of particle size analyses are shown in table 26. Numbers within parentheses after the sample number designations indicate the length in inches of core samples obtained from the lake. Approximately 92.8 percent of the core sediments are composed of silt and clay, with clay constituting 16.6 percent of the total. Materials retained on a 0.062-mm sieve constituted 7.2 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 27. 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 28. The concentrations of metals found in the core samples from Johnson Sauk Trail Lake were generally less than

Table 27. Concentrations of Metals and Nutrients in Sediment Core Samples
(Concentrations in milligrams per kilogram)

	Shallow station						200 feet upstream of shallow station					
	Sample 1 (11)*			Sample 2 (8)*			Sample 1 (23)*			Sample 2 (22)*		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Arsenic	12.0	5.5	4.7	22.0	5.7	3.9	10.0	15.0	27.0	11.0	15.0	62.0
Cadmium	0.5	0.7	0.5	0.8	1.0	0.5	0.5	0.5	0.8	0.5	0.5	0.5
Chromium	18.0	15.0	11.0	18.0	14.0	14.0	20.0	19.0	18.0	19.0	18.0	19.0
Copper	19.0	12.0	16.0	16.0	11.0	10.0	17.0	17.0	17.0	17.0	18.0	21.0
Iron	18,000	1,200	9,000	16,000	13,000	12,000	21,000	19,000	18,000	19,000	18,000	22,000
Lead	16.0	13.0	16.0	17.0	15.0	12.0	15.0	15.0	17.0	16.0	13.0	19.0
Manganese	950	700	510	760	800	1,400	640	450	1,000	630	610	830
Mercury	0.03	0.53	0.03	0.04	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04
Zinc	66.0	48.0	50.0	75.0	52.0	47.0	73.0	71.0	77.0	70.0	68.0	90.0
Total Kjeldahl-N	1450.0	659.0	3360.0	2100.0	892.0	1020.0	974.0	1030.0	1670.0	1360.0	1170.0	1630.0
Total phos.	362.0	247.0	499.0	301.0	218.0	304.0	466.0	450.0	491.0	438.0	439.0	650.0
COD	31,000	24,000	84,000	63,000	33,000	27,000	25,000	20,000	28,000	35,000	21,000	26,000
Volatile solids (percent)	5.6	4.2	9.6	7.6	4.6	4.1	4.9	4.9	5.2	4.9	4.8	6.3

*Length of core sample in inches

Table 28. 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 mean values found by the IEPA for Illinois lakes, and were well within the range indicated by that agency.

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 27). 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 two observations for arsenic (27.0 and 62.0 mg/kg) all the values reported in table 27 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 Johnson Sauk Trail Lake sediments also were found to be in the normal range for Illinois lakes.

Concentrations of trace organics found in the sediment core samples are shown in table 29. The concentrations of all the parameters examined were below detection limits. 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 King Creek inflow into the lake, outflow from the lake, direct precipitation falling on the lake, and lake evaporation.

Table 29. Concentrations of Trace Organics in Sediment Core Samples
(Concentrations in micrograms per kilogram)

	Shallow station (11)*			200 feet upstream of shallow station (23)*		
Parameter	**Top**	**Middle**	**Bottom**	**Top**	**Middle**	**Bottom**
PCBs	<10	<10	<10	<10	<10	<10
Dieldrin	<1	<1	<1	<1	<1	<1
Chlordane	<2	<2	<2	<2	<2	<2
DDT	<10	<10	<10	<10	<10	<10
Heptachlor epoxide	<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

*Length of core sample in inches

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
0 = outflow through surface outlet

Streamflows and precipitation values for Johnson Sauk Trail Lake were obtained from actual field determinations, and evaporation losses were calculated on the basis of values suggested by Roberts and Stall (1967). Table 30 gives the monthly 1981 observed rainfall in the watershed, and the estimated evaporation losses.

Monthly water budgets for the lake during 1981 are shown in table 31. All the values are expressed in cubic feet per second. King 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 57.4 acres. The last column in table 31 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 7 of table 31. Groundwater flow into the lake during spring, summer, and fall will average about 0.64 cfs. Outflow exceeds inflow from March through August, indicating the magnitude of

Table 30. Precipitation and Estimated Evaporation in Johnson Sauk Trail Lake Watershed,1981

Month, 1981	Precipitation (inches)	Evaporation (inches)
March	0.83	1.70
April	6.94	3.20
May	2.29	4.60
June	6.15	5.57
July	3.35	6.20
August	8.28	5.00
September	3.45	3.51
October	2.35	2.20
November	2.30	1.00
December	0.15	0.40

Table 31. Monthly Water Budgets for Johnson Sauk Trail Lake

	Inflow (cfs)				Outflow (cfs)		
Month, 1981	East Trib.	Middle Trib.	West Trib.	Precipi-tation	King Creek	Evapo-ration	Inflow minus outflow
March	0.02	0.05	0.07	0.06	0.22	0.13	-0.15
April	0.45	0.14	0.54	0.56	3.01	0.26	-1.58
May	0.19	0.10	0.15	0.18	0.45	0.36	-0.19
June	0.14	0.24	0.22	0.49	1.56	0.45	-0.92
July	0.02	0.09	0.06	0.26	0.21	0.50	-0.18
August	0.10	0.23	0.20	0.64	1.58	0.39	-0.80
September	0.10	0.12	0.09	0.28	0.12	0.28	+0.40
October	0.06	0.10	0.07	0.18	0.07	0.17	+0.17
November	0.10	0.11	0.11	0.18	0.12	0.08	+0.30
December	0.04	0.09	0.06	0.01	0.10	0.03	+0.07

groundwater inflow. The lake recharges the groundwater table during the period September through December. The average rate is 0.24 cfs. However, there is very little exchange between the lake and the groundwater table during winter months as evidenced by the data for the month of December.

The lake level fluctuated from 0 to 4.6 inches above the spillway during 1981. The hydraulic retention time of the lake is 1.96 years when considering the measured inflows only, and 1.07 years 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 1akes.

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 Johnson Sauk Trail Lake 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 King Creek was the only sink readily quantifiable.

The flow weighted-average method of computing nutrient transport by a tributary was used in estimating the phosphorus and nitrogen loads delivered by King Creek. A summary of water quality characteristics observed for King Creek (including the east, middle, and west tributaries) during 1981 is shown in table 32. 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

The total amounts of inorganic nitrogen, dissolved phosphorus, and total phosphorus transported to the lake by the east, middle, and west tributaries during 1981 are shown in table 33.

Samples were collected from the middle tributary soon after significant rainstorms during April through August. The results of the analyses are shown in table 34. The values observed for various parameters including suspended solids and turbidity were within the range of values observed for routine samples.

The nitrogen and phosphorus concentrations measured in rainwater samples collected within the state park are shown in table 35. Nutrient input from a total of 36.09 inches of rainfall on the lake surface was

Table 32. Johnson Sauk Trail Lake Tributary and Outflow Water Quality Characteristics

Parameter	East tributary Mean	East tributary Range	Middle tributary Mean	Middle tributary Range	West tributary Mean	West tributary Range	Outflow Mean	Outflow Range
Turbidity	8.0	1.3-43.4	9.3	0.7-69.1	5.8	1.0-33.5	8.8	1.3-90.3
Total phosphate-P	0.11	0.06-0.23	0.15	0.07-0.48	0.15	0.07-0.30	0.06	0.02-0.27
Dissolved phosphate-P	0.04	0.01-0.07	0.08	0.01-0.11	0.09	0.04-0.13	0.02	0.01-0.04
Total ammonia-N	0.10	0.03-0.17	0.11	0.03-0.32	0.13	0.01-0.57	0.17	0.02-0.32
Dissolved ammonia-N	0.07	0.00-0.17	0.08	0.01-0.23	0.08	0.01-0.42	0.16	0.05-0.30
Nitrate-N	0.23	0.05-1.14	0.57	0.09-1.25	0.85	0.48-2.20	0.12	0.02-0.24
Total Kjeldahl-N	0.28	0.07-0.80	0.37	0.12-1.07	0.42	0.10-1.34	0.60	0.06-1.09
Dissolved solids	459	324-512	450	249-512	464	253-550	317	212-408
Total suspended solids	33.4	1-305	22.7	2-158	17.9	0-164	14.5	0-125
Volatile suspended solids	5.1	1-21	7.5	2-48	4.9	0-16	5.5	0-19

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

Table 33. Nutrient Budget for Johnson Sauk Trail Lake

Source	Inorganic nitrogen	Dissolved phosphorus	Total phosphorus
East tributary	138 (63)	11 (5)	30 (14)
Middle tributary	158 (72)	19 (9)	35 (16)
West tributary	187 (85)	26 (12)	46 (21)
Precipitation	1,573 (713)	26 (12)	52 (24)
Internal regeneration	29,550 (13,401)	246 (112)	246 (112)
Gross loading	31,606 (14,334)	328 (149)	409 (185)
Outflow	456 (207)	33 (15)	183 (83)
Net loading	31,150 (14,127)	295 (134)	226 (102)
Percent retainted	96.6	89.9	55.3

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

Table 34. Water Quality Characteristics of Middle Tributary after Significant Rainfalls

Date of sample collection	Turbidity (NTU)	Total phosphate-P (mg/l)	Total ammonia-N (mg/1)	Nitrate-N (mg/1)	Total Kjeldahl-N (mg/1)	Suspended solids (mg/1)
4/20/81	1.0	0.10	0.05	0.64	0.10	12
4/24/81	2.0	0.10	0.09	0.53	0.10	16
5/11/81	1.4	0.08	0.40	0.38	0.27	10
6/08/81	2.7	0.13	0.06	0.64	0.34	9
7/27/81	1.5	0.09	0.18	0.26	0.18	10
8/06/81	5.0	0.14	0.08	0.83	0.34	

Table 35. Rainwater Characteristics

Date of collection	Total phosphate-P (mg/l)	Ammonia-N (mg/l)	Nitrate-N (mg/l)
4/20/81	0.02	0.09	0.31
4/28/81	0.10	0.37	0.31
5/04/81	0.11	9.41	0.93
5/11/81	0.04	0.88	1.13
5/18/81	0.22	1.54	0.66
6/08/81	0.26	3.47	0.62
6/13/81		1.14	0.27
6/29/81		1.34	0.65
7/06/81		1.57	1.25
7/22/81		8.17	2.53
7/27/81	0.12	0.97	0.40
8/03/81	0.11	1.15	0.34
8/11/81	0.14	0.91	0.48
8/26/81	0.04	5.14	2.11
9/02/81	0.07	1.44	0.64
9/10/81	0.23	3.90	0.50
12/01/81	0.00	1.35	1.03

computed using the averages of the observed values shown in table 34. Dissolved phosphorus was taken as 50 percent of the total phosphorus.

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 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 (1980a) 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, 23 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 33. 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 33. Allowing for nutrient outflow from the impoundment, the net nutrient loadings have been found to be 60.8 g/m^2/yr for inorganic nitrogen, 0.58 g/m^2/yr for dissolved phosphorus, and 0.44 g/m^2/yr for total phosphorus. The relative importance of various sources of nutrients is tabulated in table 36. Internal regeneration is the dominant source of phosphorus to the lake.

Table 36. Relative Importance of Nutrient Sources

(Percent of total)

Sources	Inorganic nitrogen	Dissolved phosphorus	Total phosphorus
Tributaries	1.5	17.1	27.1
Precipitation	5.0	7.9	12.7
Internal regeneration	93.5	75.0	60.2

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 15), the dominance of cyanophyta in the lake (table 16), 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 Johnson Sauk Trail Lake 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 (1980a) 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 37.

The mean surface phosphorus concentration observed in Johnson Sauk Trail Lake for the months of November to March showed a value of 50 μg/l, which is two times the upper limit value for eutrophic lakes shown in table 37. The mean summer secchi disc transparency in the lake was 3.18 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 Johnson Sauk Trail Lake, 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 49 μg/l, which again was higher than the value indicated for eutrophic lakes.

Table 37. Quantitative Definitions of Lake Trophic State (USEPA, 1980a)

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 ($\mu g/m^2/day$)	7-25	75-700

Note: Mesotrophy exists between the limits for oligotrophy and eutrophy

Table 38. 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
1/20	1.39	0.04	35
2/17	0.75	0.05	15
3/17	0.98	0.05	20
4/14	1.01	0.21-	5
5/12	1.06	0.04	29
5/26	0.85	0.03	28
6/09	1.12	0.03	37
6/23	1.35	0.06	23
7/07	1.53	0.06	26
7/23	2.48	0.08	31
8/04	1.59	0.10	16
8/18	1.51	0.08	19
9/01	1.28	0.08	16
9/16	1.39	0.09	15
10/06	1.47	0.06	25
11/03	1.19	0.06	20
12/02	1.04	0.03	35

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 38 indicate that nitrogen-phosphorus ratios were generally greater than 15, denoting a phosphorus-limiting condition in the lake. The values were less than 15 on April 14, 1981, mainly due to the influx of sediment-related phosphorus after the heavy rainfall prior to the sample collection.

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 Johnson Sauk Trail Lake is 8.2 feet. The loading rates of total inorganic nitrogen and dissolved phosphorus for the lake were found to be 61.7 and 0.8 $g/m^2/yr$, respectively.

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:

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

where

P = total phosphorus, mean concentration during the winter equilibrium condition between fall and spring turnover, in yg/1

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

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

$\bar{Z}$ = lake mean depth, in meters

ρ = flushing rate, number of times per year

The total phosphorus loading to the lake is 800 $mg/m^2/yr$, the phosphorus retention coefficient is 0.55, the mean depth of the lake is 2.50 meters, and the flushing rate is 0.51 times per year. Using these values in the above expression, the predicted mean winter phosphorus concentration is 247 yg/1. The measured mean phosphorus concentration was 50 yg/1.

The disparity between the computed and observed values for phosphorus concentration is probably due to the inaccuracy in the literature value used for the rate of phosphorus release from bottom sediments during summer months under anaerobic conditions. The evaluation of internal recycling of phosphorus using the value of Vollenweider (1968) provides a conservative estimate. However, the actual rate of release of phosphorus for Johnson Sauk Trail Lake, and quite likely the rate for ammonia, is much less than the values indicated in the literature.

BIOLOGICAL RESOURCES AND ECOLOGICAL RELATIONSHIPS

Lake Fauna

The lake has an optimal sized watershed. The ratio of the watershed area to the lake area is about 15:1. As the major portion of the watershed is under permanent ground cover, and since agriculture is a very minor and insignificant part of the land uses in the watershed, the lake receives only small amounts of eroded top soil, fertilizer, and other nutrients. Nitrogen contribution to the lake from the watershed is only 1.5 percent of the total, and the remainder emanates from precipitation and lake bottom sediments. Corresponding values for phosphorus are 27.1 and 72.9 percent.

The lake is extremely fertile. The insect life within the lake is rich and varied; and an abundance of frogs, snails, crayfish, and leeches provide an excellent food supply for fish in the littoral zones of the lake. However in the profundal region of the lake, Chironomidae and other pollution-tolerant organisms are the dominant macroinvertebrates. The diversity of 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 Department of Conservation has maintained a continual program of fish stocking of the type and size found necessary as a result of their yearly fish census. Largemouth bass (Micropterus salmoides), bullhead, bluegill (Lepomis macrochirus), redear sunfish (Lepomis microlophus), channel catfish (Ictalurus punctatus), rock bass, northern pike (Esox lucius), etc. have been used in stocking the lake over the past 25 years. Other fish found in the lake are yellow perch, green sunfish, white crappie, pumpkinseed fish, black bullhead, yellow bullhead, and banded darter.

The lake experienced a severe winter fish kill in late February 1963. In 1964 rotenone was used to completely eradicate the fish in the lake, and the lake was restocked in late fall of that year with fingerlings of large-mouth bass, and bluegill and adult rock bass. In 1971, partial selective removal of undesirable fish (green sunfish, bluegills, etc.) by seining was carried out. The lake level was lowered by 7'-10".during this seining operation. Partial treatments with rotenone and antimycin applications were used over the years to control the bluegill and greenfish populations.

The results of the 1981 fish census taken by the Department of Conservation are summarized below. The spring population check was carried out by 90 minutes of shoreline electrofishing and a 4-hour gill net set from the bank out to a depth of 13 feet. Twenty-one largemouth bass, 162 bluegill, 23 redear, three catfish, one northern pike, and other fish were collected. The composite sample consisted of 11 different fish species. Bass were dominated by the 1978 year class, which averaged 10 inches in length. The bluegill population appeared good, with fish 6 inches or longer constituting a third of the sample.

The summer population check involved one hour of electrofishing and 60 minutes of seine hauls. Thirty largemouth bass, 240 bluegills, 25 redear sunfish, 17 black crappie, and other fish were collected. Thirteen different fish species with a total count of 353 were collected during this survey. Bluegill was found to have produced a big year class, and the bass reproduction was found to be adequately represented.

The fall population check consisted of 86 minutes of day electrofishing and 96 minutes of night electrofishing, five seine hauls, and two 4-hour gill net sets. A total of 255 largemouth bass, 411 bluegills, 25 black crappie, 23 white crappie, 22 channel catfish, eight carp, and one northern pike were caught. Other fishes included 33 green sunfish, 2 black bullheads, and "6 yellow bullheads. A total of 13 species were collected. 1981 was reported as a good year for fishing in Johnson Sauk Trail Lake.

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 large tway blade orchid is found in a few areas.

Timber. Approximately 350 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, 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).

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 (R. 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 roughlegged 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 JOHNSON SAUK TRAIL LAKE

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/l 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) Improve fish habitat in the lake during summer and winter months by eliminating anoxic conditions in the lake.
2) Minimize internal regeneration of nutrients in the lake.
3) Improve the aesthetic quality of the lake waters and enhance recreational opportunities in the lake.
4) Control algal blooms and dense macrophyte growth in the lake which occur during the prime recreational period.
5) 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
- 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 (1980a) 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).

There is no point source waste discharge within the Johnson Sauk Trail Lake watershed. Body wastes generated in the comfort stations are stored in concrete vaults and removed periodically to waste disposal sites.

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.

About 94 percent of the watershed of Johnson Sauk Trail Lake is in state ownership. As stated previously, the watershed, in general, is in excellent condition with good ground cover and very little land disturbance. The privately held land parcels lie on the outer fringes of the watershed. These land parcels are kept partly in permanent pastures and partly in cultivation. Except for the wildlife food plots, there is no land disturbance activity within the state-owned portion of the watershed. The food plots, about 28 acres, are plowed and seeded by park officials with corn, sunflower, millet, etc., mainly to provide food and habitat for the wild animals and birds. However, these food plots lie within a sodded boundary.

As pointed out earlier, nitrogen contribution to the lake from the watershed is only 1.5 percent of the total. Lake bottom sediments under anoxic conditions are the major source of this nutrient. Also only about 17 percent of the dissolved phosphorus (table 36), which is readily available for bio-assimilation, comes from the watershed. Internal regeneration of phosphorus under anoxic conditions is again the important source of phosphorus which was found to be the limiting nutrient in algal growth (table 38).

The nitrogen, phosphorus, and sediment loads transported by the tributaries during 1981 were not excessive except for the observations made on April 14, 1981. The sampling was immediately preceded by a rainfall of 5.19 inches in four days, with 3.33 inches falling on April 13, 1981. Such a high intensity of rainfall was not experienced subsequently during 1981. Nutrients and sediment concentrations in samples obtained from the middle tributary immediately after rainfall events (table 34) had values within the range of values observed during the regular sampling schedules (table 32). The maxima indicated for phosphorus, nitrogen, and suspended solids in table 32 all occurred on April 14, 1981. The measured inflow to the lake on this date was 12.34 cfs and the outflow from the lake was 45.00 cfs.

The lake's watershed is in excellent condition. The private land, holders within the watershed could be encouraged to adopt no-till or conservation tillage practices if they are not already using them. The wildlife food plots should also be similarly managed, as an example for the private farmers.

An educational program to promote conservation tillage in the watershed should be undertaken by the Soil and Water Conservation District in cooperation with the District Soil Conservationist of the U.S. Department of Agriculture. This would involve no additional costs in the proposed lake management program.

Prevention of Bank Erosion. The banks of the tributaries to the lake are well protected and are in stable condition. However, two segments of about 150 feet each of lake shoreline need to be stabilized to prevent bank erosion. These segments are indicated in figure 6. In these two segments the banks are unstable and tend to cave in. Unless stabilized, the banks will deteriorate and contribute to lake sedimentation. The entire lakeshore is used for bank fishing, hiking, and picnicking. In view of the heavy use of the lakeshore areas, unstable banks are a safety hazard. The lake shoreline could be stabilized using crushed rock gabions.

The estimated cost for bank stabilization is $10,000.

In-Lake Treatment and Control Measures

Even though not all of the in-lake treatment and control measures listed earlier are applicable to Johnson Sauk Trail Lake, 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.

Dilution and Dispersion. 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 Johnson Sauk Trail Lake watershed, dilution is not a technically and economically viable solution for this lake.

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).

Even though the internal phosphorus regeneration within the lake is a significant factor in the eutrophic condition of the lake, and phosphorus inactivation is an appropriate technique for the lake in view of its overall long hydraulic retention period of 1.96 years, this technique is not an economically viable solution for several reasons. First, the lake will experience periodic high rates of inflow-outflow episodes which will disrupt the inactivate floc blanket on the bottom sediment. Another reason is that the hydraulic retention time of the lake at a flow rate of 45.0 cfs experienced by the lake on April 14, 1981, is only 5.3 days. Also, the nutrient inactivation technique does not address the lake's problem of anoxic conditions during summer and winter months. Another viable in-lake treatment technique which can address these two problems simultaneously will be discussed later.

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.

Zannechellia (horned pondweed) and Ceratophyllum (coontail) were the dominant species in Johnson Sauk Trail Lake during 1981. The upper end of the lake consisted entirely of coontail. The responses of coontail to drawdown were found not to be definitive. Cook (1980a) has reported 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.

Dunst et al. (1974) have summarized worldwide experiences in lake rehabilitation techniques. Among several hundred lakes, only two lakes, both in Florida, were reported to consider lake drawdown and consolidation as a management technique. Preliminary results from Apopka Lake (Florida) indicated that the technique had little effect on inorganic nitrogen and phosphorus levels in the sediment.

The effectiveness of sediment consolidation by lake drawdown and exposure is highly dependent on the sediment characteristics. Lake sediment in the shallow portion of Johnson Sauk Trail Lake is 90 to 95 percent silt and clay. The surficial sediments in the shallow portion of the lake have only about 60 percent water content and about 5.8 percent organic content (table 23). Dunst et al. (1974) are of the opinion that this technique will be viable only if the water content is about 90 percent.

The capacity of Johnson Sauk Trail Lake has decreased by only 13.3 percent in 26 years, which is a normal rate for man-made lakes in Illinois. Recreational opportunities have not been impacted adversely because of this slight decrease in lake volume. As lake drawdown for sediment consolidation is not likely to increase the lake capacity to any significant degree, and as it will interfere with fishing and other recreational activities, it is not considered a viable technique for Johnson Sauk Trail Lake. It will be difficult to convince the public to forego their recreational opportunities for any length of time because of lake drawdown, particularly when the end results will be in doubt.

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 . 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 Johnson Sauk Trail Lake.

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: 1) 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 Mascoma 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 Johnson Sauk Trail Lake 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 $400 per chemical treatment, the total annual cost of chemical application to control blue-green algae will be $1600.

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 15.4 acres of weed bed in Johnson Sauk Trail Lake, if 10 acres are treated selectively to promote bank fishing and open water fishing in the shallow portions of the lake, the cost will be about $2000 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 Johnson Sauk Trail Lake is a technically viable and preferable alternative to herbicide treatment as currently practiced. The cost of each harvesting operation will be about $2500, which will include costs of labor, fuel and maintenance, repairs, disposal, amortization of equipment, and financing. Assuming that at least 10.0 acres of weed bed will be harvested each year, the nutrient removal will amount to 125 pounds per harvest. This is 42 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 Illinois State Water Survey initiated water quality management procedures involving destratification and in-lake chemical treatment to control algae in Lake Catherine in 1978 (Kothandaraman et al., 1980) and in Lake Eureka in 1981 (Kothandaraman and Evans, 1982). The procedures have been very successful. 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.

As a result of the water quality management procedures, the clarity in Lake Catherine improved significantly compared to the adjoining Channel Lake (Kothandaraman et al., 1980). Although no quantitative survey of the areal extent of the submerged vegetation in Lake Catherine was made either before or after the management techniques were instituted, no complaints about aquatic weeds were received from the lakeshore residents. There was no significant increase in the water clarity in Lake Eureka (Kothandaraman and Evans, 1982). However, a decrease in macrophyte growth in the bay areas of the lake was observed during 1982 compared to the conditions in the lake during 1980 and 1981. On the basis of the Water Survey's experience, it can be hypothesized that the macrophyte problem will not be aggravated when the management plan is implemented.

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 Johnson Sauk Trail Lake. 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 Johnson Sauk Trail Lake. 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 Johnson Sauk Trail Lake, 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.

<u>Dredging</u>. 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 effeGts 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 Johnson Sauk Trail Lake 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 7, 8, 9, and 10, as designated in figure 2, have undergone significant amounts of silt accumulation (table 39), and these areas will be the prime targets for silt removal. The amount of silt removal needed from these areas will be 13.7 acre-feet or about 22,100 cubic yards. The bay areas designated by segments 11 and 12 should also be dredged for macrophyte control. This will increase the dredging volume to 31,800 cubic yards.

The unit cost of sediment removal from Johnson Sauk Trail Lake is assumed to be $12.00 per cubic yard. This is at 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 small compared to the projects undertaken elsewhere in the nation. The unit cost decreases with the increase in magnitude of the sediment removal to be carried out. Also, the rate used here includes the cost of final disposal of the sediment. The excavated material will have to be disposed of either on agricultural land, in which case the material has to be spread uniformly and disked into the ground; in landfill sites involving a haulage of about 10 miles; or by a combination of these two alternatives. Assuming a rate of $12.00 per cubic yard for sediment removal and disposal, the cost of sediment removal will be $382,000.

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

Table 39. Summary of Sedimentation Data for Johnson Sauk Trail Lake

Segment*	Volume (acre-feet) 1956	1981	Loss of original capacity % of total	% per year
1	16.9	15.6	7.7	0.31
2	59.4	53.7	9.6	0.38
3	141.9	126.0	11.2	0.45
4	66.9	58.9	12.0	0.48
5	119.7	105.4	12.0	0.48
6	46.2	38.8	16.0	0.64
7	28.7	22.0	23.3	0.93
8	7.1	3.9	45.1	1.80
9	1.4	0.6	59.7	2.39
10	6.8	3.8	44.1	1.76
11	31.2	27.3	12.5	0.50
12	17.6	15.5	11.9	0.48

*Refer to figure 2 for segment designations

it is not economically feasible and probably not technically feasible to deepen the lake to reach nutrient-poor strata in the lake.

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 Johnson Sauk Trail Lake is matched to the inflow to the lake (i.e., 0.44, 0.60, 0.17, and 0.53 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 38 percent of the lake volume is anaerobic. 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 57.4 acres and 471.5 acre-feet for Johnson Sauk Trail Lake. Because of the high lake bottom sediment oxygen demand rates in Johnson Sauk Trail Lake, 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 50 ug/l during winter months. This is 10 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 13.3 percent since the formation of Johnson Sauk Trail Lake, 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. 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 Johnson Sauk Trail Lake, the ratio of watershed to water surface areas is 15:1.

Also, one has to keep in mind that this lake experienced hypolimnetic oxygen depletion, algal blooms, and dense macrophyte growths from the early years 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 $1600 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 $4000 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 $5000 in annual costs for weed control.

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

6) Aeration and destratification, plus harvesting and removal of macrophytes.
   Cost: As in item 1, plus $5000 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 $382,000.

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 Johnson Sauk Trail Lake

Based on technical, environmental, and economic considerations, the following in-lake management techniques were chosen for implementation in Johnson Sauk Trail Lake:

- Aeration/destxatification 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 10 of the 15.4 acres covered with dense macrophyte growth.
- Lake shoreline stabilization (total length of 300 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 $1600. The annual cost for weed harvesting will be $5000. The shoreline protection and stabilization cost for two segments, each 150 feet long, will be $10,000. The total cost of project implementation for the first year will thus be $32,800 to $33,100, 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 lake water quality management scheme is shown in table 40.

Benefits Expected from In-Lake Management

The lake stratifies during summer months and approximately 38 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 246 pounds under anaerobic conditions to about 25 pounds under aerobic conditions. Likewise, the internal nitrogen loading would be reduced from 29,550 pounds to 2955 pounds. The harvesting and removal of macrophytes from the lake will result in a phosphorus export of 250 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 221 pounds will occur. There will also be a concomitant reduction in nitrogen loading by 26,595 pounds. The concentration of phosphorus during spring turnover is likely to be reduced from the current level of 0.050 mg/l to 0.023 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

Table 40. Schedule for Lake Water Quality Management Activities

Number of months after full funding is received

1 2 3 4 5 6 7 8 **9** 10 11 12

Watershed management — None

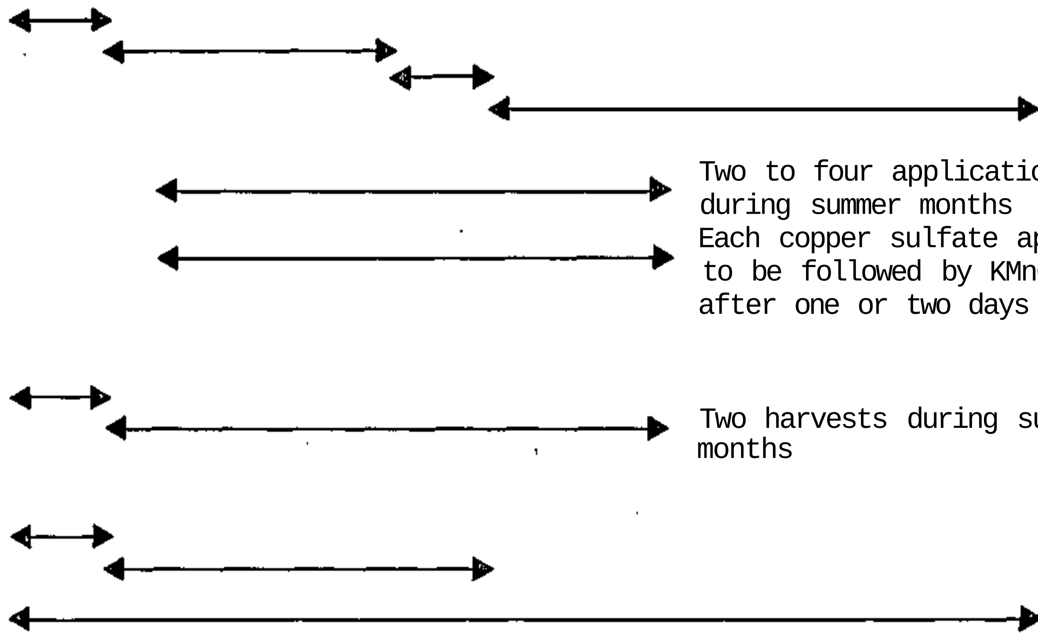
Aeration/destratification
- Selection of a system
- Design and fabrication
- Installation
- Operation and monitoring

Algae control
- Chelated copper sulfate — Two to four applications during summer months
- Potassium permanganate — Each copper sulfate application to be followed by $KMnO_4$ application after one or two days

Macrophyte harvesting
- Award of contract
- Harvesting and removal — Two harvests during summer months

Lake shore stabilization
- Award of contract
- Implementation

Project management



will be increased from 62 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.
- 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.

Environmental Evaluation

- 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 Johnson Sauk Trail lake 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. Wet lands 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 13 percent, sediment removal is not warranted at this time.

COST-BENEFIT ANALYSIS OF WATER QUALITY MANAGEMENT

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	1,600
3.	Macrophyte control	5,000
	Total annualized costs	9,880

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 reached a plateau. This is primarily attributable to the dense macrophyte growth 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 much smaller lake, Lake Le-Aqua-Na, attracted 532,761 visitors during 1976 (personal communication with IDOC).

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 41. 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 41)					
	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 41 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:

379,581 ($2.51 - $2.22) + (530,000-379,581) ($2.51)
= $(110,078 + 377,552)
= $487,630

Thus, the net increase in anticipated annual benefits is $487,630.
Total discounted benefit
(7-1/8 percent and 10 years) = $3,405,000

314 Grant amount 37,495

$$\frac{\text{Total discounted benefit}}{\text{314 Grant amount}} = 90.8$$

Table 41. 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[3]	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 opportunities	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[1]	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

Concluded on next page

Table 41. 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

Johnson Sauk Trail Lake, formed in 1956 by the damming of King Creek, is a 57.4-acre lake with a total watershed area of about 876.1 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, camping, and hunting. The park system is open to the public throughout the year.

More than 90 percent of the watershed is in state ownership and the rest is in small private land holdings. Agriculture is a very minor land use in the watershed, constituting only 6.2 percent. Except for a few small tracts of land (28.2 acres; 3.2 percent of total) which are used as wildlife food plots, there is no activity within the state-owned portion of the watershed which involves land disturbance. There is no point source waste discharge within the watershed.

The lake has exhibited very high biological productivity since the early years of its formation, requiring algicide and herbicide applications to control algae and macrophytes. The lake experiences summer stratification. During the peak stratification period, the lake was found to be totally anoxic at depths below 8 feet from the surface. About 38 percent of the lake volume is devoid of oxygen at that time. Average summer secchi disc transparency was found to be about 3.2 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 50 μg/l. Inorganic nitrogen and total phosphorus loadings to the lake were estimated respectively as 61.7 and 0.8 $g/m^2/yr$.

The three main tributaries to the lake were not found to convey unusual amounts of suspended sediment loads under normal rainfall conditions. Even tributary samples obtained immediately after storm events indicated values for turbidity and suspended sediments within the range of values observed for routine samples.

The lake exhibits a high biological productivity. Algal growths of bloom proportions were encountered during summer months, with blue-greens the dominant species. The ratios of total nitrogen and 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 15.4 acres of the lake was covered with dense growth of macrophytes. Coontail and pondweed were the dominant vegetation found in the lake.

Based on a sediment survey of the lake, it was estimated that the volume of water storage has decreased 13.3 percent in 26 years, a rate of 0.51 percent per year. This is slightly below the average value of the sedimentation rates observed in 101 other Illinois lakes and reservoirs. The lake received sediments from its watershed at the rate of 3.3 tons/acre/year.

Analyses of surficial sediments, core samples, and fish flesh for trace metals and organochemicals of concern indicate that the concentra-

tions 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 Johnson Sauk Trail Lake:

- 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 in two stretches of the lake totalling 300 feet in length.

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APPENDIX

1981 Water Quality Data,
Johnson Sauk Trail Lake, Henry County, Illinois

STORET RETRIEVAL DATE; 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20
INITIAL TIME-DEPTH-BOTTOM	1100 0000	1100 0001	1100 0002	1100 0004	1100 0006	1100 0008	1100 0010	1100 0012
00010 WATER TEMP CENT	1.8		3.5	3.8	3.6	3.5	3.5	4.1
00011 WATER TEMP FAHN	35.2		38.3	38.8	38.5	38.3	38.3	39.4
00020 AIR TEMP CENT		5.0						
00032 CLOUD COVER PERCENT		0						
00035 WIND VELOCITY MPH		0.0						
00045 PRECIP TOT DAY IN		0.00						
00076 TURB TRBIDMTR HACH FTU		1.0						1.6
00077 TRANSP SECCHI INCHES		72						
00094 CNDUCTVY FIELD MICROMHO		230						240
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	14.6		12.6	12.8	12.6	11.8	11.6	6.3
00301 DO SATUR PERCENT	105.8		96.2	97.7	96.2	90.1	88.5	48.1
00400 PH SU		8.60						8.10
00410 T ALK CAC03 M3/L		185						195
00515 RESIDUE DISS-105 C MG/L		290						290
00530 RESIDUE TOT NFLT MG/L		0						0
00535 RESIDUE VOL NFLT MG/L		0						0
00608 NH3+NH4- N DISS MG/L		0.170						0.210
00610 NH3+NH4- N TOTAL MG/L		0.250						0.210
00619 UN-IONZD NH3-NH3 MG/L								0.004
00620 N03-N TOTAL MG/L		0.270						0.200
00625 TOT KJEL N MG/L		0.870						0.830
00665 PHOS-TOT MG/L P		0.040						0.060
00666 PHOS-DIS MG/L P		0.020						0.020
72025 DEPTH OF POND FEET		23.00						

INITIAL DATE	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/02/17	81/02/17	81/02/17
INITIAL TIME-DEPTH-BOTTOM	1100 0014	1100 0016	1100 0018	1100 0020	1100 0022	1220 0000	1220 0001	1220 0002
00010 WATER TEMP CENT	4.1	4.2	4.2	4.5	5.0	3.6		4.0
00011 WATER TEMP FAHN	39.4	39.6	39.6	40.1	41.0	38.5		39.2
00020 AIR TEMP CENT							12.5	
00035 WIND VELOCITY MPH							0.0	
00045 PRECIP TOT DAY IN							0.00	
00076 TURB TRBIDMTR HACH FTU					1.6		0.4	
00077 TRANSP SECCHI INCHES							103	
00094 CNDUCTVY FIELD MICROMHO					265		98	
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	6.2	4.8	4.0	2.2	0.5	10.4		10.4
00301 DO SATUR PERCENT	47.3	36.6	30.5	17.2	3.9	79.4		79.4
00400 PH SU					7.65		7.90	
00410 T ALK CAC03 MG/L					217		67	
00515 RESIDUE DISS-105 C MG/L					306		72	
00530 RESIDUE TOT NFLT MG/L					0		4	
00535 RESIDUE VOL NFLT MG/L					0		4	
00608 NH3+NH4- N DISS MG/L					0.160		0.050	
00610 NH3+NH4- N TOTAL MG/L					0.370		0.050	

(SAMPLE CONTINUED ON NEXT PAGE)

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STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE]

	INITIAL DATE			81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/02/17	81/02/17	81/02/17
	INITIAL TIME-DEPTH-BOTTOM			1100 0014	1100 0016.	1100 0018	1100 0020	1100 0022	1220 0000	1220 0001	1220 0002
00619	UN-IONZD	NH3-NH3	MG/L					0.002			
00620	N03-N	TOTAL	MG/L					0.130			
00625	TOT KJEL	N	MG/L					0.750		0.520	
00665	PHOS-TOT		MG/L P					0.050		0.050	
00666	PHOS-DIS		MG/L P					0.020		0.010	
72025	DEPTH OF	POND	FEET							17.00	

	INITIAL DATE			81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/03/17
	INITIAL TIME-DEPTH-BOTTOM			1220 0004	1220 0006	1220 0008	1220 0010	1220 0012	1220 0014	1220 0016	1315 0000
00010	WATER	TEMP	CENT	4.0	4.0	3.5	3.5	3.5	4.0	4.2	6.4
00011	WATER	TEMP	FAHN	39.2	39.2	38.3	38.3	38.3	39.2	39.6	43.5
00076	TURB	TRBIDMTR	HACH FTU			2.8				1.8	
00094	CNDUCTVY	FIELD	MICROMHO			256				260	
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	10.4	10.4	10.4	10.4	10.4	6.7	4.4	11.2
00301	DO	SATUR	PERCENT	79.4	79.4	79.4	79.4	79.4	51.1	33.6	89.6
00400	PH		SU			8.10				8.10	
00410	T ALK	CAC03	MG/L			195				203	
00515	RESIDUE	DISS-105	C MG/L			260				268	
00530	RESIDUE	TOT NFLT	MG/L			4				4	
00535	RESIDUE	VOL NFLT	MG/L			4				4	
00608	NH3+NH4-	N DISS	MG/L			0.170				0.120	
00610	NH3+NH4-	N TOTAL	MG/L			0.200				0.220	
00619	UN-IONZD	NH3-NH3	MG/L			0.003				0.004	
00625	TOT KJEL	N	MG/L			0.700				0.950	
00665	PHOS-TOT		MG/L P			0.050				0.050	
00666	FHOS-DIS		MG/L P			0.030				0.040	

	INITIAL DATE			81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17
	INITIAL TIME-DEPTH-BOTTOM			1315 0001	1315 0002	1315 0004	1315 0006	1315 0008	1315 0010	1315 0012	1315 0014
00010	WATER	TEMP	CENT		6.2	6.2	6.1	6.0	6.0	6.0	6.0
00011	WATER	TEMP	FAHN		43.2	43.2	43.0	42.8	42.8	42.8	42.8
00020	AIR	TEMP	CENT	5.0							
00035	WIND	VELOCITY	MPH	5.0							
00045	PRECIP	TOT DAY	IN	0.00							
00076	TURB	TRBIDMTR	HACH FTU	3.3					2.7		
00077	TRANSP	SECCHI	INCHES	45							
00094	CNDUCTVY	FIELD	MICROMHO	278					278		
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L		11.2	11.2	11.3	11.3	11.3	11.3	11.3
00301	DO	SATUR	PERCENT		89.6	89.6	90.4	90.4	90.4	90.4	90.4
00400	PH		SU	8.40					8.40		
00410	T. ALK	CAC03	MG/L	187					189		
00515	RESIDUE	DISS-105	C MG/L	296					306		
00530	RESIDUE	TOT NFLT	MG/L	8					9		
00535	RESIDUE	VOL NFLT	MG/L	8					9		

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

	INITIAL DATE			81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17
	INITIAL TIME-DEPTH-BOTTOM			1315 0001	1315 0002	1315 0004	1315 0006	1315 0008	1315 0010	1315 0012	1315 0014
00608	NH3+NH4-	N DISS	MG/L	0.130					0.150		
00610	NH3+NH4-	N TOTAL	MG/L	0.190					0.210		
00619	UN-IONZD	NH3-NH3	MG/L						0.008		
00620	N03-N	TOTAL	MG/L	0.081					0.074		
00625	TOT KJEL	N	MS/L	0.710					0.780		
00665	PHOS-TOT		MG/L P	0.050					0.060		
00666	PHOS-DIS		MG/L P	0.010					0.030		
72025	DEPTH OF	POND	FEET	21.00							

	INITIAL DATE			81/03/17	81/03/17	81/03/17	81/04/14	81/04/14	81/04/14	81/04/14	81/04/14
	INITIAL TIME-DEPTH-BOTTOM			1315 0016	1315 0018	1315 0020	1100 0000	1100 0001	1100 0002	1100 0004	1100 0006
00010	WATER	TEMP	CENT	5.9	5.9	5.9	14..2		14.2	14.2	14.1
00011	WATER	TEMP	FAHN	42.6	42.6	42.6	57..6		57.6	57.6	57.4
00020	AIR	TEMP	CENT					10.2			
00035	WIND	VELOCITY	MPH					15.0			
00045	PRECIP	TOT DAY	IN					3.30			
00076	TURB	TRBIDMTR	HACH FTU			2.7		60.2			
00077	TRANSP	SECCHI	INCHES					6			
00094	CNDUCTVY	FIELD	MICROMHO			280		312			
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	11.3	10.9	11.0	8.3		8.1	8.1	7.9
00301	DO	SATUR	PERCENT	90.4	87.2	88.0	79.8		77.9	77.9	76.0
00400	PH		SU			7.90		8.40			
00410	T ALK	CAC03	MG/L			185		164			
00515	RESIDUE	DISS-105	C MG/L			300		254			
00530	RESIDUE	TOT NFLT	MG/L			7		52			
00535	RESIDUE	VOL NFLT	MG/L			5		12			
00608	NH3+NH4-	N DISS	MG/L			0.140		0.210			
00610	NH3+NH4-	N TOTAL	MG/L			0.220		0.220			
00619	UN-IONZD	NH3-NH3	MG/L			0.003					
00620	N03-N	TOTAL	MG/L			0.047		0.141			
00625	TOT KJEL	N	MG/L			0.950		0.650			
00665	PHOS-TOT		MG/L P			0.050		0.210			
00666	PHOS-DIS		MG/L P			0.010		0.030			
72025	DEPTH OF	POND	FEET					21.00			

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE				81/04/14	81/04/14	81/04/14	81/04/14	81/04/14	81/04/14	81/04/14	81/05/12
INITIAL TIME-DEPTH-BOTTOM				1100 0008	1100 0010	1100 0012	1100 0014	1100 0016	1100 0018	1100 0020	1045 0000
00010	WATER	TEMP	CENT	14.1	14.1	14.0	14.0	13.9	13.8	13.6	13.2
00011	WATER	TEMP	FAHN	57.4	57.4	57.2	57.2	57.0	56.8	56.5	55.8
00076	TURB	TRBIDMTR	HACH FTU		56.8					373.0	
00094	CNDUCTVY	FIELD	MICROMHO		308					276	
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.8	7.7	7.6	7.5	7.1	6.5	6.3	9.2
00301	DO	SATUR	PERCENT	75.0	74.0	73.1	72.1	68.3	62.5	60.6	86.8
00400	PH		SU		8.30					8.00	
00410	T ALK	CAC03	MG/L		169					126	
00515	RESIDUE	DISS-105	C MG/L		262					234	
00530	RESIDUE	TOT NFLT	MG/L		83					158	
00535	RESIDUE	VOL NFLT	MG/L		17					22	
00608	NH3+NH4-	N DISS	MG/L		0.230					0.240	
00610	NH3+NH4-	N TOTAL	MG/L		0.230					0.240	
00619	UN-IONZD	NH3-NH3	MG/L		0.014					0.007	
00620	N03-N	TOTAL	MG/L		0.155					0.338	
00625	TOT KJEL	N	MG/L		0.570					1.300	
00665	FHOS-TOT		MG/L P		0.250					0.950	
00666	PHOS-DIS		MG/L P		0.040					0.050	
INITIAL DATE				81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12
INITIAL TIME-DEPTH-BOTTOM				1045 0001	1045 0002	1045 0004	1045 0006	1045 0008	1045 0010	1045 0012	1045 0014
00010	WATER	TEMP	CENT		13.0	12.9	12.9	12.4	12.2	12.2	12.2
00011	WATER	TEMP	FAHN		55.4	55.2	55.2	54.3	54.0	54.0	54.0
00020	AIR	TEMP	CENT	11.0							
00035	WIND	VELOCITY	MPH	0.0							
00043	PRECIP	TOT DAY	IN	0.00							
00076	TURB	TRBIDMTR	HACH FTU	5.1						3.0	
00077	TRANSP	SECCHI	INCHES	38							
00094	CNDUCTVY	FIELD	MICROMHO	315						312	
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	FROBE	MG/L		9.2	9.2	9.2	9.2	9.2	9.0	9.0
00301	DO	SATUR	PERCENT		86.8	86.8	86.8	85.2	85.2	83.3	83.3
00400	PH		SU	8.50						8.30	
00410	T ALK	CAC03	MG/L	160						175	
00515	RESIDUE	. DISS-105	C MG/L	278						280	
00530	RESIDUE	TOT NFLT	MG/L	8						8	
00535	RESIDUE	VOL NFLT	MG/L	6						6	
00608	NH3+NH4-	N DISS	MG/L	0.110						0.050	
00610	NH3+NH4-	N TOTAL	MG/L	0.420						0.120	
00619	UN-IONZD	NH3-NH3	MG/L							0.006	
00620	N03-N	TOTAL	MG/L	0.083						0.069	
00625	TOT KJEL	N	MG/L	0.560						0.690	
00665	PHOS-TOT		MG/L P '	0.040						0.060	
00666	PHOS-DIS		MG/L P	0.020						0.020	
32211	CHLRPHYL	A UG/L	CORRECTD				20.00				

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

	INITIAL DATE	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12
	INITIAL TIME-DEPTH-BOTTOM	1045 0001	1045 0002	1045 0004	1045 0006	1045 0008	1045 0010	1045 0012	1045 0014
60050	ALGAE TOTAL /ML				270				
72025	DEPTH OF POND FEET	23.00							
	INITIAL DATE	81/05/12	81/05/12	81/05/12	81/05/12	81/05/26	81/05/26	81/05/26	81/05/26
	INITIAL TIME-DEPTH-BOTTOM	1045 0016	1045 0018	1045 0020	1045 0022	1130 0000	1130 0001	1130 0002	1130 0004
00010	WATER TEMP CENT	12.2	12.2	12.2	12.2	19.2		18.2	18.2
00011	WATER TEMP FAHN	54.0	54.0	54.0	54.0	66.6		64.8	64.8
00020	AIR TEMP CENT						24.0		
00035	WIND VELOCITY MFH						2.0		
00045	PRECIP TOT DAY IN						0.00		
00076	TURB TRBIDMTR HACH FTU				41.0		2.6		
00077	TRANSP SECCHI INCHES						76		
00094	CNDUCTVY FIELD MICROMHO				312		371		
00116	INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO PROBE MG/L	8.5	8.4	6.2	6.4	9.7		9.7	9.7
00301	DO SATUR PERCENT	78.7	77.8	57.4	59.3	103.2		102.1	102.1
00400	PH SU				8.30		8.70		
00410	T ALK CAC03 MG/L				175		187		
00515	RESIDUE DISS-105 C MG/L				270		272		
00530	RESIDUE TOT NFLT MG/L				106		4		
00535	RESIDUE VOL NFLT MG/L				20		3		
00608	NH3+NH4- N DISS MG/L				0.190		0.120		
00610	NH3+NH4- N TOTAL MG/L				0.210		0.130		
00619	UN-IONZD NH3-NH3 MG/L				0.011				
00620	N03-N TOTAL MG/L				0.131		0.080		
00625	TOT KJEL N MG/L				0.860		0.640		
00665	PHOS-TOT MG/L P				0.180		0.030		
00666	FHOS-DIS MG/L P				0.030		0.020		
72025	DEPTH OF POND FEET						23.00		
	INITIAL DATE	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26
	INITIAL TIME-DEPTH-BOTTOM	1130 0006	1130 0008	1130 0010	1130 0012	1130 0013	1130 0014	1130 0016	1130 0018
00010	WATER TEMP CENT	18.2	18.1	18.0	18.0		17.4	16.2	13.9
00011	WATER TEMP FAHN	64.8	64.6	64.4	64.4		63.3	61.2	57.0
00076	TURB TRBIDMTR HACH FTU				2.6				
00094	CNDUCTVY FIELD MICROMHO				370				
00116	INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO PROBE MG/L	9.7	9.8	9.2	9.1		7.7	5.1	4.3
00301	DO SATUR PERCENT	102.1	103.2	96.8	95.8		79.4	51.0	41.3
00400	PH SU				8.70				
00410	T ALK CAC03 MG/L				189				
00515	RESIDUE DISS-105 C MG/L				278				
00530	RESIDUE TOT NFLT MG/L				7				
00535	RESIDUE VOL NFLT MG/L				4				
00608	NH3+NH4- N DISS MG/L				0.120				
00610	NH3+NH4- N TOTAL MG/L				0.130				

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE			81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26
INITIAL TIME-DEPTH-BOTTOM			1130 0006	1130 0008	1130 0010	1130 0012	1130 0013	1130 0014	1130 0016	1130 0018
00619 UN-IONZD	NH3-NH3	MG/L				0.023				
00620 N03-N	TOTAL	MG/L				0.090				
00625 TOT KJEL	N	MG/L				0.720				
00665 PHOS-TOT		MG/L P				0.040				
00666 PHOS-DIS		MG/L P				0.010				
32211 CHLRPHYL	A UG/L	CORRECTD					30.00			
60050 ALGAE	TOTAL	/ML					280			
INITIAL DATE			81/05/26	81/05/26	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09
INITIAL TIME-DEPTH-BOTTOM			1130 0020	1130 0022	1130 0000	1130 0001	1130 0002	1130 0004	1130 0006	1130 0008
00010 WATER	TEMP	CENT	12.8	12.6	24.2		24.0	24.0	23.8	22.4
00011 WATER	TEMP	FAHN	55.0	54.7	75.6		75.2	75.2	74.8	72.3
00020 AIR	TEMP	CENT				25.5				
00035 WIND	VELOCITY	MPH				4.0				
00045 PRECIP	TOT DAY	IN				0.00				
00076 TURB	TRBIDMTR	HACH FTU		7.1						
00077 TRANSP	SECCHI	INCHES				51				
00094 CNDUCTVY	FIELD	MICROMHO		370		368				
00116 INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO	PROBE	MG/L	1.1	0.2	9.3		9.3	9.2	8.9	5.7
00301 DO	SATUR	PERCENT	10.4	1.9	109.4		109.4	108.2	104.7	64.8
00400 PH		SU		8.20		8.70				
00410 T ALK	CAC03	MG/L		172		166				
00515 RESIDUE	DISS-105	C MG/L		280		274				
00530 RESIDUE	TOT NFLT	MG/L		11		7				
00535 RESIDUE	VOL NFLT	MG/L		2		5				
00608 NH3+NH4-	N DISS	MG/L		0.170		0.210				
00610 NH3+NH4-	N TOTAL	MG/L		0.170		0.260				
00619 UN-IONZD	NH3-NH3	MG/L		0.007						
00620 N03-N	TOTAL	MG/L		0.140		0.040				
00625 TOT KJEL	N	MG/L		0.800		0.820				
00665 PHOS-TOT		MG/L P		0.060		0.030				
00666 PHOS-DIS		MG/L P		0.030		0.020				
32211 CHLRPHYL	A UG/L	CORRECTD								40.00
60050 ALGAE	TOTAL	/ML								905
72025 DEPTH OF	POND	FEET				23.00				

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09
	INITIAL TIME-DEPTH-BOTTOM			1130 0010	1130 0011	1130 0012	1130 0014	1130 0016	1130 0018	1130 0020	1130 0022
00010	WATER	TEMP	CENT	19.2		18.4	17.2	16.0	15.8	15.0	14.6
00011	WATER	TEMP	FAHN	66.6		65.1	63.0	60.8	60.4	59.0	58.3
00094	CNDUCTVY	FIELD	MICROMHO		370						409
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	2.4		0.5	0.3	0.1	0.1	0.1	0.1
00301	DO	SATUR	PERCENT	25.5		5.3	3.1	1.0	1.0	1.0	1.0
00400	PH		SU		8.60						7.90
00410	T ALK	CAC03	MG/L		170						197
00515	RESIDUE	DISS-105	C MG/L		286						296
00530	RESIDUE	TOT NFLT	MG/L		7						5
00535	RESIDUE	VOL NFLT	MG/L		4						4
00608	HH3+NH4-	N DISS	MG/L		0.210						0.340
00610	NH3+NH4-	N TOTAL	MG/L		0.290						0.350
00619	UN-IONZD	NH3-NH3	MG/L								0.009
00620	N03-N	TOTAL	MG/L		0.121						0.078
00625	TOT KJEL	N	MG/L		0.710						0.810
00665	PHOS-TOT		MG/L P		0.050						0.070
00666	PHOS-DIS		MG/L P		0.020						0.040
	INITIAL DATE			81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23
	INITIAL TIME-DEPTH-BOTTOM			1145 0000	1145 0001	1145 0002	1145 0003	1145 0004	1145 0006	1145 0008	1145 0010
00010	WATER	TEMP	CENT	24.0		23.8		23.4	23.2	23.2	23.0
00011	WATER	TEMP	FAHN	75.2		74.8		74.1	73.8	73.8	73.4
00020	AIR	TEMP	CENT		23.0						
00035	WIND	VELOCITY	MPH		3.5						
00045	PRECIP	TOT DAY	IN		0.00						
00076	TURB	TRBIDMTR	HACH FTU		4.0						
00077	TRANSP	SECCHI	INCHES		18						
00094	CNDUCTVY	FIELD	MICROMHO		349						
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROSE	MG/L	11.6		11.6		9.8	9.6	9.2	7.8
00301	DO	SATUR	PERCENT	136.5		136.5		112.6	110.3	105.7	89.7
00400	PH		SU		8.84						
00410	T ALK	CAC03	MG/L		171						
00515	RESIDUE	DISS-105	C MG/L		276						
00530	RESIDUE	TOT NFLT	MG/L		14						
00535	RESIDUE	VOL NFLT	MG/L		14						
00608	NH3+NH4-	N DISS	MG/L		0.140						
00610	NH3+NH4-	N TOTAL	MG/L		0.260						
00620	N03-N	TOTAL	MG/L		0.043						
00625	TOT KJEL	N	MG/L		1.050						
00665	FHOS-TOT		MG/L P		0.060						
00666	PHOS-DIS		MG/L P		0.010						
32211	CHLRPHYL	A UG/L	CORRECTD				70.00				
60050	ALGAE	TOTAL	/ML				3140				
72025	DEPTH OF	POND	FEET		23.00						

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/07/07
	INITIAL TIME-DEPTH-BOTTOM			1145 0011	1145 0012	1145 0014	1145 0016	1145 0018	1145 0020	1145 0022	1000 0000
00010	WATER	TEMP	CENT		22.8	21.4	19.9	17.0	15.8	15.4	28.0
00011	WATER	TEMP	FAHN		73.0	70.5	67.8	62.6	60.4	59.7	82.4
00076	TURB	TRBIDMTR	HACH FTU	5.4						4.4	
00094	CNDUCTVY	FIELD	MICROMHO	350						390	
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L		1.3	0.3	0.2	0.2	0.2	0.2	9.9
00301	DO	SATUR	PERCENT		14.9	3.3	2.2	2.1	2.0	2.0	125.3
00400	FH		SU	8.72						8.12	
00410	T ALK	CAC03	MG/L	171						203	
00515	RESIDUE	DISS-105	C MG/L	278						300	
00530	RESIDUE	TOT NFLT	MG/L	18						18	
00535	RESIDUE	VOL NFLT	MG/L	18						16	
00608	NH3+NH4-	N DISS	MG/L	0.280						0.560	
00610	NH3+NH4-	N TOTAL	MG/L	0.560						0.710	
00619	UN-IONZD	NH3-NH3	MG/L							0.031	
00620	N03-N	TOTAL	MG/L	0.064						0.057	
00625	TOT KJEL	N	MG/L	1.190						1.710	
00665	PHOS-TOT		MG/L P	0.090						0.220	
00666	PHOS-DIS		MG/L P	0.020						0.090	

	INITIAL DATE			81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07
	INITIAL TIME-DEPTH-BOTTOM			1000 0001	1000 0002	1000 0004	1000 0006	1000 0008	1000 0010	1000 0011	1000 0012
00010	WATER	TEMP	CENT		27.8	27.8	27.8	25.2	24.2		24.0
00011	WATER	TEMP	FAHN		82.0	82.0	82.0,	77.4	75.6		75.2
00020	AIR	TEMP	CENT	25.8							
00035	WIND	VELOCITY	MPH	0.0							
00045	PRECIP	TOT DAY	IN	0.00							
00077	TRANSP	SECCHI	INCHES	36							
00094	CNDUCTVY	FIELD	MICROMHO	358						355	
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PR03E	MG/L		9.8	10.2	10.0	0.4	0.3		0.2
00301	DO	SATUR	PERCENT		124.1	129.1	126.6	4.8	3.5		2.4
00400	PH		SU	9.40						9.00	
00410	T ALK	CAC03	MG/L	160						160	
00515	RESIDUE	DISS-105	C MG/L	268						274	
00530	RESIDUE	TOT NFLT	MG/L	9						7	
00535	RESIDUE	VOL NFLT	MG/L	9						6	
00608	NH3+NH4-	N DISS	MG/L	0.160						0.190	
00610	NH3+KH4-	N TOTAL	MG/L	0.220						0.250	
00620	N03-N	TOTAL	MG/L	0.060						0.060	
00625	TOT KJEL	N	MG/L	1.250						1.310	
00665	PHOS-TOT		MG/L P	0.060						0.090	
00666	PHOS-DIS		MG/L P	0.020						0.030	
32211	CHLRPHYL	A UG/L	CORRECTD				80.00				
60050	ALGAE	TOTAL	/ML				6500				
72025	DEPTH OF	POND	FEET	23.00							

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE		81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/23	81/07/23	81/07/23
	INITIAL TIME-DEPTH-BOTTOM		1000 0014	1000 0016	1000 0018	1000 0020	1000 0022	1045 0000	1045 0001	1045 0002
00010	WATER TEMP	CENT	22.8	21.2	19.0	16.2	16.0	25.8		25.6
00011	WATER TEMP	FAUN	73.0	70.2	66.2	61.2	60.8	78.4		78.1
00045	PRECIP TOT DAY	IN							0.00	
00076	TURB TRBIDMTR	HACH FTU							9.2	
00077	TRANSP SECCHI	INCHES							18	
00094	CNDUCTVY FIELD	MICROMHO					445		195	
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	8.4		8.4
00301	DO SATUR	PERCENT	2.3	2.2	2.1	2.0	2.0	102.4		102.4
00400	PH	SU					8.30		9.50	
00410	T ALK CAC03	MG/L					250		143	
00515	RESIDUE DISS-105	C HG/L					316		216	
00530	RESIDUE TOT NFLT	MG/L					20		12	
00535	RESIDUE VOL NFLT	MG/L					8		12	
00608	NH3+NH4- N DISS	MG/L					1.570		0.020	
00610	NH3+NH4- N TOTAL	MG/L					1.660		0.030	
00619	UN-IONZD NH3-NH3	MG/L					0.112			
00620	N03-N TOTAL	MG/L					0.050		0.060	
00625	TOT KJEL N	MG/L					2.840		2.390	
00665	PHOS-TOT	MG/L P					0.760		0.080	
00666	PHOS-DIS	MG/L P					0.420		0.040	
72025	DEPTH OF POND	FEET							21.00	
	INITIAL DATE		81/07/23	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23
	INITIAL TIME-DEPTH-BOTTOM		1045 0003	1045 0004	1045 0006	1045 0008	1045 0010	1045 0011	1045 0012	1045 0014
00010	WATER TEMP	CENT		25.6	25.6	25.5	25.5		23.0	21.8
00011	WATER TEMP	FAHN		78.1	78.1	77.9	77.9		73.4	71.2
00076	TURB TRBIDMTR	HACH FTU						8.3		
00094	CNDUCTVY FIELD	MICROMHO						185		
00116	INTNSVE SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO PROBE	MG/L		8.4	8.4	8.4	8.4		0.6	0.2
00301	DO SATUR	PERCENT		102.4	102.4	102.4	102.4		6.9	2.3
00400	PH	SU						9.50		
00410	T ALK CAC03	MG/L						139		
00515	RESIDUE DISS-105	C MG/L						222		
00530	RESIDUE TOT NFLT	MG/L						16		
00535	RESIDUE VOL NFLT	MG/L						16		
00608	NH3+NH4- N DISS	MG/L						0.060		
00610	NH3+NH4- N TOTAL	MG/L						0.140		
00620	N03-N TOTAL	MG/L						0.060		
00625	TOT KJEL N	MG/L						2.250		
00665	PHOS-TOT	MG/L P						0.100		
00666	PHOS-DIS	MG/L P						0.020		
32211	CHLRPHYL A UG/L	CORRECTD	67.00							
60050	ALGAE TOTAL	/ML	7745							

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMSNT/LAKE

	INITIAL DATE			81/07/23	81/07/23	81/07/23	81/07/23	81/08/04	81/08/04	81/08/04	81/08/04
	INITIAL TIME-DEPTH-BOTTOM			1045 0016	1045 0018	1045 0020	1045 0022	0940 0000	0940 0001	0940 0002	0940 0004
00010	WATER	TEMP	CENT	20.5	18..9	17.0	16.3	26.2		26.0	25.8
00011	WATER	TEMP	FAHN	68.9	66..0	62.6	61.3	79.2		78.8	78.4
00020	AIR	TEMP	CENT						25.2		
00035	WIND	VELOCITY	MFH						5.0		
00045	PRECIP	TOT DAY	IN						0.00		
00076	TURB	TRBIDMTR	HACH FTU			6.9			4.2		
00077	TRANSP	SECCHI	INCHES						36		
00094	CNDUCTVY	FIELD	MICROMHO			245			315		
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	621705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	0.2	0.,2	0.2	0.2	9.2		9.2	9.1
00301	DO	SATUR	PERCENT	2.2	2..1	2.1	2.0	112.2		112.2	111.0
00400	PH		SU			8.00			9.60		
00410	T ALK	CAC03	MG/L			209			151		
00515	RESIDUE	DISS-105	C MG/L			256			246		
00530	RESIDUE	TOT NFLT	MG/L			38			5		
00535	RESIDUE	VOL NFLT	MG/L			12			3		
00608	NH3+NH4-	N DISS	MG/L			1.860			0.100		
00610	NH3+NH4-	N TOTAL	MG/L			2.190			0.180		
00619	UN-IONZD	NH3-NH3	MG/L			0.082					
00620	N03-N	TOTAL	MG/L			0.080			0.060		
00625	TOT KJEL	N	MG/L			2.590			1.350		
00665	PHOS-TOT		MG/L P			0.590			0.100		
00666	PHOS-DIS		MG/L P			0.490			0.030		
72025	DEPTH OF	POND	FEET						23.00		
	INITIAL DATE			81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04
	INITIAL TIME-DEPTH-BOTTOM			0940 0006	0940 0008	0940 0010	0940 0011	0940 0012	0940 0014	0940 0016	0940 0018
00010	WATER	TEMP	CENT	25.2	23.8	22.1		21.8	21.2	20.7	19.6
00011	WATER	TEMP	FAHN	77.4	74.8	71.8		71.2	70.2	69.3	67.3
00076	TURB	TRBIDMTR	HACH FTU				4.9				
00094	CNDUCTVY	FIELD	MICROMHO				328				
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	FROBE	MG/L	6.9	0.3	0.2		0.2	0.2	0.2	0.2
00301	DO	SATUR	PERCENT	82.1	3.5	2.3		2.3	2.2	2.2	2.2
00400	PH		SU				9.30				
00410	T ALK	CAC03	MG/L				151				
00515	RESIDUE	DISS-105	C MG/L				256				
00530	RESIDUE	TOT NFLT	MG/L				6				
00535	RESIDUE	VOL NFLT	MG/L				6				
00608	NH3+NH4-	N DISS	MG/L				0.450				
00610	NH3+NH4-	N TOTAL	MG/L				0.490				
00620	N03-N	TOTAL	MG/L				0.060				
00625	TOT KJEL	N	MG/L				1.480				
00665	PHOS-TOT		MG/L P				0.130				
00666	PHOS-DIS		MG/L P				0.030				
32211	CHLRPHYL	A UG/L	CORRECTD	53.00							

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04
INITIAL TIME-DEPTH-BOTTOM	0940 0006 >	0940 0008	0940 001C)	0940 0011	0940 0012	0940 0014	0940 0016	0940 0018
60050 ALGAE TOTAL /ML	10465							
INITIAL DATE	81/08/04	81/08/04	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18
INITIAL TIME-DEPTH-BOTTOM	0940 0020	0940 0022	0830 0000	0830 0001	0830 0002	0830 0004	0830 0005	0830 0006
00010 WATER TEMP CENT	19..4	19.4	23.2		23.2	23.0		23.0
00011 WATER TEMP FAHN	66..9	66.9	73.8		73.8	73.4		73.4
00020 AIR TEMP CENT				24.0				
00035 WIND VELOCITY MPH				4.0				
00045 FRECIP TOT DAY IN				0.00				
00076 TURB TRBIDMTR HACH FTU		3.5		5.8				
00077 TRANSP SECCHI INCHES				29				
00094 CNDUCTVY FIELD MICROMHO		375		283				
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0 .2	0.2	6.9		6.9	6.6		6.7
00301 DO SATUR PERCENT	2..1	2.1	79.3		79.3	75.9		77.0
00400 PH SU		7.80		9.20				
00410 T ALK CAC03 MG/L		197		149				
00515 RESIDUE DISS-105 C MG/L		324		190				
00530 RESIDUE TOT NFLT MG/L		9		8				
00535 RESIDUE VOL NFLT MG/L		6		7				
00608 NH3+NH4- N DISS MG/L		2.460		0.100				
00610 NH3+NH4- N TOTAL MG/L		3.410		0.110				
00619 UN-IONZD NH3-NH3 MG/L		0.097						
00620 N03-N TOTAL MG/L		0.080		0.100				
00625 TOT KJEL N MG/L		3.630		1.300				
00665 PHOS-TOT MG/L P		0.570		0.080				
00666 PHOS-DIS MG/L P		0.410		0.020				
32211 CHLRFHYL A UG/L CORRECTD							40.00	
60050 ALGAE TOTAL /ML							21955	
72025 DEPTH OF POND FEET				23.00				
INITIAL DATE	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18
INITIAL TIME-DEPTH-BOTTOM	0830 0008	0830 0010	0830 0011	0830 0012	0830 0014	0830 0016	0830 0018	0830 0020
00010 WATER TEMP CENT	23..0	22.8		21.8	21.2	20.5	20.0	19.0
00011 WATER TEMP FAHN	73..4	73.0		71.2	70.2	68.9	68.0	66.2
00076 TURB TRBIDMTR HACH FTU			10.2					
00094 CNDUCTVY FIELD MICROMHO			299					
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	3..4	0.8		0.3	0.2	0.2	0.2	0.2
00301 DO SATUR. PERCENT	39..1	9.2		3.4	2.2	2.2	2.2	2.1
00400 PH SU			8.10					
00410 T ALK CAC03 MG/L			153					
00515 RESIDUE DISS-105 C MG/L			196					
00530 RESIDUE TOT NFLT MG/L			20					
00535 RESIDUE VOL NFLT MG/L			11					
00608 NH3+NH4- N DISS MG/L			1.150					

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

	INITIAL DATE			81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18
	INITIAL TIME-DEPTH-BOTTOM			0830 0008	0830 0010	0830 0011	0830 0012	0830 0014	0830 0016	0830 0018	0830 0020
00610	NH3+NH4-	N TOTAL	MG/L			1.160					
00620	N03-N	TOTAL	MG/L			0.150					
00625	TOT KJEL	N	MG/L			2.020					
00665	PHOS-TOT		MG/L P			0.240					
00666	PHOS-DIS		MG/L P			0.160					
	INITIAL DATE			81/08/18	81/09/01	81/09/01	81/09/01	81/09/01	8.V09/01	81/09/01	81/09/01
	INITIAL TIME-DEPTH-BOTTOM			0830 0022	1000 0000	1000 0001	1000 0002	1000 0004	1000 0005	1000 0006	1000 0008
00010	WATER	TEMP	CENT	18.8	24,.9		24.9	24.9		24.6	24.2
00011	HATER	TEMP	FAHN	65.8	76..8		76.8	76.8		76.3	75.6
00020	AIR	TEMP	CENT			22.2					
00032	CLOUD	COVER	PERCENT			100					
00035	WIND	VELOCITY	MPH			0.0					
00045	FRECIP	TOT DAY	IN			0.00					
00076	TURB	TR3IDMTR	HACH FTU	37.8		2.8					
00077	TRANSP	SECCHI	INCHES			30					
00094	CNDUCTVY	FIELD	MICROMHO	311		285					
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	0.2	6 .7		6.7	6.5		5.7	1.7
00301	DO	SATUR	PERCENT	2.1	79,.8		79.8	77.4		67.9	20.0
00400	PH		SU	7.60		9.10					
00410	T ALK	CAC03	MG/L	183		151					
00515	RESIDUE	DISS-105	C MG/L	192		218					
00530	RESIDUE	TOT NFLT	MG/L	47		8					
00535	RESIDUE	VOL NFLT	MG/L	16		7					
00608	NH3+NH4-	N DISS	MG/L	2.720		0.080					
00610	NH3+NH4-	N TOTAL	MG/L	2.750		0.140					
00619	UN-IONZD	NH3-NH3	MG/L	0.048							
00620	N03-N	TOTAL	MG/L	0.180		0.030					
00625	TOT KJEL	N	MG/L	3.970		1.110					
00665	PHOS-TOT		MG/L P	0.610		0.080					
00666	PHOS-DIS		MG/L P	0.380		0.020					
32211	CHLRPHYL	A UG/L	CORRECTD						47.00		
60050	ALGAE	TOTAL	/ML						12080		
72025	DEPTH OF	POND	FEET			21.00					

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE	81/09/01	81/09/01	81/09/01	81/09/01	81/09/01	81/09/01	81/09/16	81/09/16
INITIAL TIME-DEPTH-BOTTOM	1000 0010	1000 0012	1000 0014	1000 0016	1000 0018	1000 0020	0945 0000	0945 0001
00010 WATER TEMP CENT	24.2	21.8	21.0	20.5	19.9	18.7	21.2	
00011 WATER TEMP FAHN	75.6	71.2	69.8	68.9	67.8	65.7	70.2	
00020 AIR TEMP CENT								18.0
00032 CLOUD COVER PERCENT								0
00035 WIND VELOCITY MFH								6.0
00045 PRECIP TOT DAY IN								0.00
00076 TURB TRBIDMTR HACH FTU	4.9					27.4		7.8
00077 TRANSP SECCHI INCHES								38
00094 CNDUCTVY FIELD MICROMHO	285					325		280
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	6.3	
00301 DO SATUR PERCENT	2.4	2.3	2.2	2.2	2.2	2.1	70.0	
00400 PH SU	8.90					7.80		8.90
00410 T ALK CAC03 MG/L	151					197		158
00515 RESIDUE DISS-105 C MG/L	230					244		214
00530 RESIDUE TOT NFLT MG/L	12					10		8
00535 RESIDUE VOL NFLT MG/L	10					6		7
00603 NH3+NH4- N DISS MG/L	0.150					2.720		0.120
00610 NH3+NH4- N TOTAL MG/L	0.270					3.320		0.130
00619 UN-IONZD NH3-NH3 MG/L	0.098					0.090		
00620 N03-N TOTAL MG/L	0.030					0.070		0.100
00625 TOT KJEL N MG/L	1.260					4.360		1.160
00665 PHOS-TOT MG/L P	0.120					0.610		0.090
00666 FHOS-DIS MG/L P	0.020					0.450		0.020
72025 DEPTH OF POND FEET								21.00

INITIAL DATE	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16
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	21.0	21.0	20.8	20.2
00011 WATER TEMP FAHN	70.2	70.2	70.2	70.2	69.8	69.8	69.4	68.4
00076 TURB TRBIDMTR HACH FTU					6.1			
00094 CNDUCTVY FIELD MICROMHO					275			
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	6.3	6.3	6.3	6.3	1.4	0.6	0.3	0.2
00301 DO SATUR PERCENT	70.0	70.0	70.0	70.0	15.6	6.7	3.3	2.2
00400 PH SU					8.90			
00410 T ALK CAC03 MG/L					158			
00515 RESIDUE DISS-105 C MG/L					220			
00530 RESIDUE TOT NFLT MG/L					8			
00535 RESIDUE VOL NFLT MG/L					7			
00608 NH3+NH4- N DISS MG/L					0.190			
00610 NH3+NH4- N TOTAL MG/L					0.260			
00619 UN-IONZD NH3-NH3 MG/L					0.080			
00620 N03-N TOTAL MG/L					0.080			
00625 TOT KJEL N MG/L					1.220			
00665 PHOS-TOT MG/L P					0.100			

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16	81/09/16
INITIAL TIME-DEPTH-BOTTOM	0945 0002	0945 0004	0945 0006	0945 0008	0945 0010	0945 0012	0945 0014	0945 0016
00666 PHOS-DIS MG/L P					0.030			
32211 CHLRFHYL A UG/L CORRECTD			40.00					
60050 ALGAE TOTAL /ML			16115					

INITIAL DATE	81/09/16	81/09/16	81/10/06	81/10/06	81/10/06	81/10/06	81/10/06	81/10/06
INITIAL TIME-DEPTH-BOTTOM	0945 0018	0945 0020	1030 0000	1030 0001	1030 0002	1030 0004	1030 0006	1030 0008
00010 WATER TEMP CENT	20..0	19.2	16.2		16.2	16.2	16.2	16.1
00011 WATER TEMP FAHN	68..0	66.6	61.2		61.2	61.2	61.2	61.0
00032 CLOUD COVER PERCENT				70				
00035 WIND VELOCITY MPH				10.0				
00036 WIND DIR.FROM NORTH-0				0				
00045 PRECIP TOT DAY IN				0.00				
00076 TURB TRBIDMTR HACH FTU		3.7		5.0				
00077 TRANSP SECCHI INCHES				43				
00094 CNDUCTVY FIELD MICROMHO		300		270				
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	0.2	0.2	9.1		9.1	9.1	9.0	9.0
00301 DO SATUR PERCENT	2.2	2.1	91.0		91.0	91.0	90.0	90.0
00400 PH SU		8.00		8.80				
00410 T ALK CAC03 MG/L		176		149				
00515 RESIDUE DISS-105 C MG/L		240		240				
00530 RESIDUE TOT NFLT MG/L		6		5				
00535 RESIDUE VOL NFLT MG/L		6		4				
00608 NH3+NH4- N DISS MG/L		0.860		0.160				
00610 NH3+NH4- N TOTAL MG/L		0.920		0.240				
00619 UN-IONZD NH3-NH3 MG/L		0.040.						
00620 N03-N TOTAL MG/L		0.100		0.080				
00625 TOT KJEL N MG/L		1.670		1.150				
00665 PHOS-TOT MG/L P		0.240		0.060				
00666 PHOS-DIS MG/L P		0.180		0.020				
72025 DEPTH OF POND FEET				19.00				

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE	81/10/06	81/10/06	81/10/06	81/10/06	81/10/06	81/10/06	81/11/03	81/11/03
INITIAL TIME-DEPTH-BOTTOM	1030 0009	1030 0010	1030 0012	1030 0014	1030 0016	1030 0018	1000 0000	1000 0001
00010 HATER TEMP CENT		16.1	7.9	16.0	16.0	16.0	12.0	
00011 WATER TEMP FAHN		61.0	46.2	60.8	60.8	60.8	53.6	
00020 AIR TEMP CENT								15.0
00032 CLOUD COVER PERCENT								75
00035 WIND VELOCITY MPH								6.0
00045 PRECIP TOT DAY IN								0.05
00076 TURB TRBIDMTR HACH FTU	5.0					5.7		1.7
00077 TRANSP SECCHI INCHES								90
00094 CNDUCTVY FIELD MICROMHO	270					270		260
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L		8.6	16.0	7.8	7.6	7.6	10.7	
00301 DO SATUR PERCENT		86.0	134.5	78.0	76.0	76.0	99.1	
00400 PH SU	8.70					8.60		8.80
00410 T ALK CAC03 MG/L	155					160		155
00515 RESIDUE DISS-105 C MG/L	238					222		262
00530 RESIDUE TOT NFLT MG/L	6					8		5
00535 RESIDUE VOL NFLT MG/L	5					6		3
00608 NH3+NH4- N DISS MG/L	0.230					0.260		0.130
00610 NH3+NH4- N TOTAL MG/L	0.280					0.280		0.160
00619 UN-IONZD NH3-NH3 MG/L						0.036		
00620 N03-N TOTAL MG/L	0.090					0.080		0.160
00625 TOT KJEL N MG/L	1.130					0.980		0.870
00665 PHOS-TOT MG/L P	0.070					0.080		0.060
00666 PHOS-DIS MG/L P	0.020					0.020		0.020
72025 DEPTH OF POND FEET								23.00

INITIAL DATE	81/11/03	81/11/03	81/11/03	81/11/03	81/11/03	81/11/03	81/11/03	81/11/03
INITIAL TIME-DEPTH-BOTTOM	1000 0002	1000 0004	1000 0006	1000 0008	1000 0010	1000 0011	1000 0012	1000 0014
00010 WATER TEMP CENT	12.0	12.0	11.9	11.9	11.9		11.0	10.9
00011 WATER TEMP FAHN	53.6	53.6	53.4	53.4	53.4		51.8	51.6
00076 TURB TRBIDMTR HACH FTU						1.4		
00094 CNDUCTVY FIELD MICROMHO						258		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	10.7	10.7	10.7	10.5	10.5		8.4	8.2
00301 DO SATUR PERCENT	99.1	99.1	99.1	97.2	97.2		75.7	73.9
00400 PH SU						8.80		
00410 T ALK CAC03 MG/L						155		
00515 RESIDUE DISS-105 C MG/L						228		
00530 RESIDUE TOT NFLT MG/L						6		
00535 RESIDUE VOL NFLT MG/L						5		
00608 NH3+NH4- N DISS MG/L						0.190		
00610 NH3+NH4- N TOTAL MG/L						0.200		
00620 N03-N TOTAL MG/L						0.170		
00625 TOT KJEL N MG/L						1.050		
00665 PHOS-TOT MG/L P						0.060		
00666 PHOS-DIS MG/L P						0.030		

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

INITIAL DATE	81/11/03	81/11/03	81/11/03	81/11/03	81/12/02	81/12/02	81/12/02	81/12/02
INITIAL TIME-DEPTH-BOTTOM	1000 0016	1000 0018	1000 0020	1000 0022	1100 0000	1100 0001	1100 0002	1100 0004
00010 WATER TEMP CENT	10 .9	10 .9	10.9	10.9	4.0		4.0	4.0
00011 WATER TEMP FAHN	51 .6	51 .6	51.6	51.6	39.2		39.2	39.2
00020 AIR TEMP CENT						6.5		
00032 CLOUD COVER PERCENT						0		
00035 WIND VELOCITY MPH						8.0		
00045 PRECIP TOT DAY IN						0.15		
00076 TURB TRBIDMTR HACH FTU				7.6		2.1		
00077 TRANSP SECCHI INCHES						96		
00094 CNDUCTVY FIELD MICROMHO				260		216		
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	7..9	7.,9	7.9	7.8	11.2		11.2	11.1
00301 DO SATUR PERCENT	71. 2	71. 2	71. 2	70.3	85.5		85.5	84.7
00400 PH SU				8.50		8.20		
00410 T ALK CAC03 MG/L				172		164		
00515 RESIDUE DISS-105 C MG/L				262		246		
00530 RESIDUE TOT NFLT MG/L				20		1		
00535 RESIDUE VOL NFLT MG/L				10		1		
00608 NH3+NH4- N DISS MG/L				0.190		0.170		
00610 NH3+NH4- N TOTAL MG/L				0.230		0.180		
00619 UN-IONZD NH3-NH3 MG/L				0.017				
00620 N03-N TOTAL MG/L				0.190		0.160		
00625 TOT KJEL N MG/L				0.990		0.700		
00665 PHOS-TOT MG/L P				0.060		0.030		
00666 PHOS-DIS MG/L P				0.020		0.010		
72025 DEPTH OF POND FEET						21.00		

INITIAL DATE	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02
INITIAL TIME-DEPTH-BOTTOM	1100 0006	1100 0008	1100 0010	1100 0012	1100 0014	1100 0016	1100 0018	1100 0020
00010 HATER TEMP CENT	4 .0	4 .0	4.0	4.0	4.0	4.0	4.0	4.0
00011 WATER TEMP FAHN	39 .2	39 .2	39.2	39.2	39.2	39.2	39.2	39.2
00076 TURB TRBIDMTR HACH FTU			3.4					1.7
00094 CNDUCTVY FIELD MICROMHO			216					214
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299 DO PROBE MG/L	11..1	11..1	11.1	11.1	11.1	11.1	11.1	11.1
00301 DO SATUR PERCENT	84..7	84..7	84.7	84.7	84.7	84.7	84.7	84.7
00400 PH SU			8.20					8.20
00410 ALK CAC03 MG/L			174					176
00515 RESIDUE DISS-105 C MG/L			242					240
00530 RESIDUE TOT NFLT MG/L			2					2
00535 RESIDUE VOL NFLT MG/L			1					1
00608 NH3+NH4- N DISS MG/L			0.170					0.170
00610 NH3+NH4- N TOTAL MG/L			0.170					0.180
00619 UN-IONZD NH3-NH3 MG/L			0.004					0.004
00620 N03-N TOTAL MG/L			0.160					0.150
00625 TOT KJEL N MG/L			0.740					0.750
00665 PHOS-TOT MG/L P			0.030					0.030

(SAMPLE CONTINUED ON NEXT PAGE)

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-1
41 20 04.0 089 52 49.0 4
JOHNSON SAUK TRAIL L SITE 1 NEAR DAM
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

(SAMPLE CONTINUED FROM PREVIOUS PAGE)

INITIAL DATE		81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02	81/12/02
INITIAL TIME-DEPTH-BOTTOM		1100 0006	1100 0008	1100 0010	1100 0012	1100 0014	1100 0016	1100 0018	1100 0020
00666 PHOS-DIS	MG/L P			0.020					0.020

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-3
41 19 34.0 089 53 05.0 4
JOHNSON SAUK TRAIL L SITE 3 660 FT SW SITE 2
17073 ILLINOIS HENRY
UPFER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20	81/01/20
	INITIAL TIME-DEPTH-BOTTOM			1000 0000	1000 0001	1000 0002	1000 0003	1000 0004	1000 0005	1000 0006	1000 0007
00010	WATER	TEMP	CENT	0.5	1.5	3.0	3.9	4.0	4.0	4.1	4.1
00011	WATER	TEMP	FAHN	32.9	34.7	37.4	39.0	39.2	39.2	39.4	39.4
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	14.6	15.4	15.4	15.2	15.2	12.8	12.2	12.0
00301	DO	SATUR	PERCENT	102.8	111.6	114.1	116.0	116.0	97.7	93.1	91.6
	INITIAL DATE			81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/02/17	81/02/17
	INITIAL TIME-DEPTH-BOTTOM			1120 0000	1120 0001	1120 0002	1120 0003	1120 0004	1120 0005	1120 0006	1120 0007
00010	WATER	TEMP	CENT	1.2	2.5	4.0	4.1	4.1	4.1	4.0	4.0
00011	WATER	TEMP	FAHN	34.2	36.5	39.2	39.4	39.4	39.4	39.2	39.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299.	DO	PROBE	MG/L	11.0	10.7	9.6	9.5	7.9	7.9	7.9	7.9
00301	DO	SATUR	PERCENT	77.5	79.3	73.3	72.5	60.3	60.3	60.3	60.3
	INITIAL DATE			81/02/17	81/02/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17	81/03/17
	INITIAL TIME-DEPTH--BOTTOM			1120 0008	1120 0009	1215 0000	1215 0001	1215 0002	1215 0003	1215 0004	1215 0005
00010	WATER	TEMP	CENT	4.0	4.0	7.0	6.9	6.8	6.5	6.5	6.3
00011	WATER	TEMP	FAHN	39.2	39.2	44.6	44.4	44.2	43.7	43.7	43.3
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.9	7.7	11.8	12.0	12.0	12.1	12.1	12.0
00301	DO	SATUR	PERCENT	60.3	58.8	96.7	98.4	98.4	99.2	99.2	96.0
	INITIAL DATE			81/03/17	81/03/17	81/03/17	81/04/14	81/04/14	81/04/14	81/04/14	81/04/14
	INITIAL TIME-DEPTH-BOTTOM			1215 0C06	1215 0007	1215 0008	1000 0000	1000 0001	1000 0002	1000 0003	1000 0004
00010	WATER	TEMP	CENT	6.2	6.2	6.1	14.6	14.6	14.6	14.4	14.2
00011	WATER	TEMP	FAHN	43.2	43.2	43.0	58.3	58.3	58.3	57.9	57.6
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	12.1	12.1	12.1	8.5	8.4	8.4	8.3	8.3
00301	DO	SATUR	PERCENT	96.8	96.8	96.8	83.3	82.4	82.4	79.8	79.8
	INITIAL DATE			81/04/14	81/04/14	81/04/14	81/04/14	81/04/14	81/05/12	81/05/12	81/05/12
	INITIAL TIME-DEPTH-BOTTOM			1000 0005	1000 0006	1000 0007	1000 0008	1000 0009	0945 0000	0945 0001	0945 0002
00010	WATER	TEMP	CENT	14.2	14.1	14.0	13.2	13.1	12.2	13.0	12.8
00011	WATER	TEMP	FAHN	57.6	57.4	57.2	55.8	55.6	54.0	55.4	55.0
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	8.3	8.3	8.3	7.9	7.9	9.6	9.5	9.5
00301	DO	SATUR	PERCENT	79.8	79.8	79.8	74.5	74.5	88.9	89.6	89.6

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-3
41 19 34.0 089 53 05.0 4
JOHNSON SAUK TRAIL L SITE 3 660 FT SW SITE 2
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/12	81/05/26
	INITIAL TIME-DEPTH-BOTTOM			0945 0003	0945 0004	0945 0005	0945 0006	0945 0007	0945 0008	0945 0009	1030 0000
00010	WATER	TEMP	CENT	12.7	12.5	12.5	12.5	12.5	12.4	12.4	19.2
00011	WATER	TEMP	FAHN	54.9	54.5	54.5	54.5	54.5	54.3	54.3	66.6
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.5	9.4	9.3	9.2	9.2	9.2	9.2	9.7
00301	DO	SATUR	PERCENT	89.6	88.7	87.7	86.8	86.8	85.2	85.2	103.2
	INITIAL DATE			81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26	81/05/26
	INITIAL TIME:-DEPTH-BOTTOM			1030 0001	1030 0002	1030 0003	1030 0004	1030 0005	1030 0006	1030 0007	1030 0008
00010	WATER	TEMP	CENT	19.2	19.0	19.0	18.8	18.1	18.0	18.0	18.0
00011	WATER	TEMP	FAHN	66.6	66.2	66.2	65.8	64.6	64.4	64.4	64.4
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.7	9.7	9.7	9.7	10.0	10.0	10.3	10.3
00301	DO	SATUR	PERCENT	103.2	103.2	103.2	103.2	105.3	105.3	108.4	108.4
	INITIAL DATE			81/05/26	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09	81/06/09
	INITIAL TIME-DEPTH-BOTTOM			1030 0009	1030 0000	1030 0001	1030 0002	1030 0003	1030 0004	1030 0005	1030 0006
00010	WATER	TEMP	CENT	17.9	24.2	24.0	24.0	23.8	23.8	23.8	23.5
00011	WATER	TEMP	FAHN	64.2	75.6	75.2	75.2	74.8	74.8	74.8	74.3
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	10.6	9.2	9.3	10.6	9.2	8.7	8.1	6.3
00301	DO	SATUR	PERCENT	111.6	108.2	109.4	124.7	108.2	102.4	95.3	74.1
	INITIAL DATE			81/06/09	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23	81/06/23
	INITIAL TIME-DEPTH-BOTTOM			1030 0007	1045 0000	1045 0001	1045 0002	1045 0003	1045 0004	1045 0005	1045 0006
00010	WATER	TEMP	CENT	23.2	25.0	24.2	24.0	23.8	23.3	23.2	23.1
00011	WATER	TEMP	FAHN	73.8	77.0	75.6	75.2	74.8	73.9	73.8	73.6
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	5.1	11.6	13.0	13.8	14.6	11.7	11.3	10.8
00301	DO	SATUR	PERCENT	58.6	138.1	152.9	162.4	171.8	134.5	129.9	124.1
	INITIAL DATE			81/06/23	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07
	INITIAL TIME-DEPTH-BOTTOM			1045 0007	1000 0000	1000 0001	1000 0002	1000 0003	1000 0004	1000 0005	1000 0006
00010	WATER	TEMP	CENT	23.0	28.0	28.0	27.1	27.1	26.9	26.0	26.0
00011	WATER	TEMP	FAHN	73.4	82.4	82.4	80.8	80.8	80.4	78.8	78.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.8	9.7	9.7	9.8	9.8	9.0	4.2	1.2
00301	DO	SATUR	PERCENT	112.6	122.8	122.8	121.0	121.0	111.1	51.2	14.6

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-3
41 19 34.0 089 53 05.0 4
JOHNSON SAUK TRAIL L SITE 3 660 FT SW SITE 2
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07	81/07/07
	INITIAL TIME-DEPTH-BOTTOM			1000 0007	1045 0000	1045 0001	1045 0002	1045 0003	1045 0004	1045 0005	1045 0006
00010	WATER	TEMP	CENT	25.2	28.0	28.0	27.1	27.1	26.9	26.0	26.0
00011	WATER	TEMP	FAHN	77.4	82.4	82.4	80.8	80.8	80.4	78.8	78.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	0.3	9.7	9.7	9.8	9.8	9.0	4.2	1.2
00301	DO	SATUR	PERCENT	3.6	122.8	122.8	121.0	121.0	111.1	51.2	14.6
	INITIAL DATE			81/07/07	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23	81/07/23
	INITIAL TIME>DEPTH-BOTTOM			1045 0007	1130 0000	1130 0001	1130 0002	1130 0003	1130 0004	1130 0005	1130 0006
00010	WATER	TEMP	CENT	25.2	25.8	25.8	25.6	25.6	25.6	25.6	25.5
00011	WATER	TEMP	FAHN	77.4	78.4	78.4	78.1	78.1	78.1	78.1	77.9
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	0.3	8.6	8.5	6.8	6.8	6.8	6.5	6.5
00301 '	DO	SATUR	PERCENT	3.6	104.9	103.7	82.9	82.9	82.9	79.3	79.3
	INITIAL DATE			81/07/23	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04	81/08/04
	INITIAL TIME[-DEPTH-BOTTOM			1130 0007	1030 0000	1030 0001	1030 0002	1030 0003	1030 0004	1030 0005	1030 0006
00010	WATER	TEMP	CENT	24.0	25.2	25.2	24.9	24.6	24.4	24.2	24.0
00011	WATER	TEMP	FAHN	75.2	77.4	77.4	76.8	76.3	75.9	75.6	75.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	FROBE	MG/L	2.6	6.1	5.9	4.3	2.4	1.7	0.9	0.3
00301	DO	SATUR	PERCENT	30.6	72.6	70.2	51.2	28.6	20.0	10.6	3.5
	INITIAL DATE			81/08/04	81/08/04	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18	81/08/18
	INITIAL TIME-DEPTH-BOTTOM			1030 0007	1030 0008	0915 0000	0915 0001	0915 0002	0915 0003	0915 0004	0915 0005
00010	WATER	TEMP	CENT	23.6	23.0	23.4	23.4	23.4	23.2	23.2	23.2
00011	WATER	TEMP	FAHN	74.5	73.4	74.1	74.1	74.1	73.8	73.8	73.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	0.2	0.1	8.0	8.0	7.9	7.9	7.9	7.9
00301	DO	SATUR	PERCENT	2.4	1.1	92.0	92.0	90.8	90.8	90.8	90.8
	INITIAL DATE			81/08/18	81/08/18	81/08/18	81/09/01	81/09/01	81/09/01	81/09/01	81/09/01
	INITIAL TIME-DEPTH-BOTTOM			0915 0006	0915 0007	0915 0008	1045 0000	1045 0001	1045 0002	1045 0003	1045 0004
00010	WATER	TEMP	CENT	23.2	23.2	23.1	24.8	24.8	24.8	24.8	24.6
00011	WATER	TEMP	FAHN	73.8	73.8	73.6	76.6	76.6	76.6	76.6	76.3
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.9	7.9	8.4	7.0	6.9	6.9	6.9	6.7
00301	DO	SATUR	PERCENT	90.8	90.8	96.6	83.3	82.1	82.1	82.1	79.8

STORET RETRIEVAL DATE 83/02/16
RP-A01-D-3
41 19 34.0 089 53 05.0 4
JOHNSON SAUK TRAIL L SITE 3 660 FT SW SITE 2
17073 ILLINOIS HENRY
UPPER MISSISSIPPI RIVER 070900
ROCK RIVER
21ILLAKE
791215 DEPTH 0
/TYPA/AMBNT/LAKE

	INITIAL DATE			81/09/01	81/09/01	81/09/01	81/09/01	81/09/16	81/09/16	81/09/16	81/09/16
	INITIAL TIME:-DEPTH-BOTTOM			1045 0005	1045 0006	1045 0007	1045 0008	1030 0000	1030 0001	1030 0002	1030 0003
00010	WATER	TEMP	CENT	24.6	24.6	24.4	24.2	21.0	21.2	21.2	21.2
00011	WATER	TEMP	FAHN	76.3	76.3	75.9	75.6	69.8	70.2	70.2	70.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	6.6	6.5	6.1	5.2	7.9	7.8	7.6	7.6
00301	DO	SATUR	PERCENT	78.6	77.4	71.8	61.2	87.8	86.7	84.4	84.4

	INITIAL DATE			81/09/16	81/09/16	81/09/16	81/09/16	81/10/06	81/10/06	81/10/06	81/10/06
	INITIAL TIME:-DEPTH-BOTTOM			1030 0004	1030 0005	1030 0006	1030 0007	1115 0000	1115 0001	1115 0002	1115 0003
00010	WATER	TEMP	CENT	21.2	21.2	21.2	21.0	16.2	16.2	16.2	16.2
00011	WATER	TEMP	FAHN	70.2	70.2	70.2	69.8	61.2	61.2	61.2	61.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	7.6	7.6	7.6	7.6	9.3	9.3	9.3	9.3
00301	DO	SATUR	PERCENT	84.4	84.4	84.4	84.4	93.0	93.0	93.0	93.0

	INITIAL DATE			81/10/06	81/10/06	81/10/06	81/10/06	81/11/03	81/11/03	81/11/03	81/11/03
	INITIAL TIME-DEPTH-BOTTOM			1115 0004	1115 0005	1115 0006	1115 0007	1045 0000	1045 0001	1045 0002	1045 0003
00010	WATER	TEMP	CENT	16.2	16.2	16.1	15.8	12.2	12.2	12.2	12.1
00011	WATER	TEMP	FAHN	61.2	61.2	61.0	60.4	54.0	54.0	54.0	53.8
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.3'	9.3	9.3	7.4	9.5	9.5	9.7	9.7
00301	DO	SATUR	PERCENT	93.0	93.0	93.0	74.0	88.0	88.0	89.8	89.8

	INITIAL DATE			81/11/03	81/11/03	81/11/03	81/11/03	81/12/02	81/12/02	81/12/02	81/12/02
	INITIAL TIME-DEPTH-BOTTOM			1045 0C04	1045 0005	1045 0006	1045 0007	1145 0000	1145 0001	1145 0002	1145 0003
00010	WATER	TEMP	CENT	12.1	12.0	12.0	12.0	4.0	4.0	4.0	4.0
00011	WATER	TEMP	FAHN	53.8	53.6	53.6	53.6	39.2	39.2	39.2	39.2
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00299	DO	PROBE	MG/L	9.6	9.6	9.4	9.4	11.0	11.0	11.0	11.0
00301	DO	SATUR	PERCENT	88.9	88.9	87.0	87.0	84.0	84.0	84.0	84.0
	INITIAL DATE			81/12/02	81/12/02	81/12/02	81/12/02				
	INITIAL TIME-DEPTH-BOTTOM			1145 0004	1145 0005	1145 0006	1145 0007				
00010	WATER	TEMP	CENT	4.0	4.0	4.0	4.0				
00011	WATER	TEMP	FAHN	39.2	39.2	39.2	39.2				
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705				
00299	DO	PROBE	MG/L	11.0	11.0	11.0	11.0				
00301	DO	SATUR	PERCENT	84.0	84.0	84.0	84.0				

STORET RETRIEVAL DATE 83/02/16
RPDA01
41 19 10.0 089 53 30.0 4
WEST TRIBUTARY TO JOHNSON SAUK TRAIL LAKE
17073 ILLINOIS HENRY
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

INITIAL DATE	81/01/20	81/02/17	81/03/17	81/04/14	81/05/12	81/05/26	81/06/09	81/06/23
INITIAL TIME-DEPTH-BOTTOM	1110 0000	1230 0000	1325 0000	1110 0000	1055 0000	1140 0000	1140 0000	1155 0000
00076 TURB TRBIDMTR HACH FTU	3.8	11.7	2.4	33.5	2.7	2.6	6.4	3.0
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	504	400	492	388	482	282	253	526
00530 RESIDUE TOT NFLT MG/L	0	30	6	164	8	7	22	12
00535 RESIDUE VOL NFLT MG/L	0	10	2	16	6	3	7	9
00608 NH3+NH4- N DISS MG/L	0.010	0.420	0.150	0.020	0.070	0.110	0.200	0.030
00610 NH3+NH4- N TOTAL MG/L	0.100	0.570	0.180	0.190	0.100	0.130	0.210	0.160
00615 N02-N TOTAL MG/L	'0.010		0.012	0.014	0.007	0.030	0.052	0.020
00620 N03-N TOTAL MG/L	0.650		0.412	2.200	0.705	0.680	0.850	0.856
00625 TOT KJEL N MG/L	0.100	1.340	0.330	0.750	0.230	0.530	0.430	0.330
00665.PHOS-TOT MG/L P	0.070	0.250	0.080	0.260	0.080	0.100	0.210	0.130
00666 PHOS-DIS MG/L P	0.040	0.120	0.040	0.120	0.060	0.060	0.130	0.080

INITIAL DATE	81/07/07	81/07/23	81/08/04	81/08/18	81/09/01	81/09/16	81/10/06	81/11/03
INITIAL TIME-DEPTH-BOTTOM	1145 0000	1230 0000	1125 0000	1015 0000	1145 0000	1130 0000	1215 0000	1145 0000
00076 TURB TRBIDMTR HACH FTU		6.3	4.2	1.0	1.4	4.1	3.5	2.4
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	508	504	508	482	500	500	520	550
00530 RESIDUE TOT NFLT MG/L	6	12	11	4	4	8	4	4
00535 RESIDUE VOL NFLT MG/L	3	5	7	2	3	2	4	2
00608 NH3+NH4- N DISS MG/L	0.050	0.050	0.110	0.040	0.030	0.040	0.010	0.040
00610 NH3+NH4- N TOTAL MG/L	0.080	0.070	0.110	0.050	0.060	0.050	0.010	0.090
00615 N02-N TOTAL MG/L	0.020		0.030	0.010	0.010	0.010	0.010	0.010
00620 N03-N TOTAL MG/L	0.770	0.810	0.830	1.020	0.870	0.970	0.690	0.480
00625 TOT KJEL N MG/L	0.510	0.260	0.520	0.460	0.300	0.230	0.250	0.230
00665 PHOS-TOT MG/L P	0.300	0.130	0.160	0.100	0.120	0.130	0.150	0.150
00666 PHOS-DIS MG/L P	0.090	0.100	0.120	0.070	0.100	0.090	0.100	0.090

INITIAL DATE	81/12/02
INITIAL TIME-DEPTH-BOTTOM	1245 0000
00076 TURB TRBIDMTR HACH FTU	4.0
00116 INTNSVE SURVEY IDENT	821705
00515 RESIDUE DISS-105 C MG/L	496
00530 RESIDUE TOT NFLT MG/L	3
00535 RESIDUE VOL NFLT MG/L	2
00608 NH3+NH4- N DISS MG/L	0.050
00610 NH3+HH4- N TOTAL MG/L	0.080
00615 N02-N TOTAL MG/L	0.010
00620 N03-N TOTAL MG/L	0.750
00625 TOT KJEL N MG/L	0.260
00665 PHOS-TOT MG/L P	0.100
00666 PHOS-DIS MG/L P	0.060

STORET RETRIEVAL DATE 83/02/16
RPDB01
41 18 57.0 089 53 10.0 4
MIDDLE TRIBUTARY TO JOHNSON SAUK TRAIL LAKE
17073 ILLINOIS HENRY
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

INITIAL DATE	81/01/20	81/02/17	81/03/17	81/04/14	81/05/12	81/05/26	81/06/09	81/06/23
INITIAL TIME-DEPTH-BOTTOM	1120 0000	1240 0000	1335 0000	1120 0000	1105 0000	1150 0000	1150 0000	1205 0000
00076 TURB TRBIDMTR HACH FTU	6.7	10.9	0.7	69.1	0.7	1.9	5.4	10.1
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	492	340	464	378	466	464	470	500
00530 RESIDUE TOT NFLT MG/L	48	40	4	158	6	3	19	23
00535 RESIDUE VOL NFLT MG/L	48	8	4	15	6	2	4	10
00608 NH3+NH4- N DISS MG/L	0.050	0.230	0.090	0.090	0.060	0.060	0.200	0.010
00610 NH3+NH4- N TOTAL MG/L	0.120	0.320	0.070	0.190	0.130	0.060	0.200	0.030
00615 N02-N TOTAL MG/L	0.010		0.005	0.014	0.006	0.030	0.041	0.023
00620 N03-N TOTAL MG/L	0.300		0.088	1.250	0.394	0.500	0.635	0.725
00625 TOT KJEL N MG/L	0.120	1.070	0.180	0.910	0.160	0.320	0.510	0.300
00665 PHOS-TOT MG/L P	0.070	0.260	0.080	0.480	0.080	0.070	0.150	0.130
00666 PHOS-DIS MG/L P	0.010	0.160	0.040	0.100	0.040	0.070	0.110	0.100

INITIAL DATE	81/07/07	81/07/23	81/08/04	81/08/18	81/09/01	81/09/16	81/10/06	81/11/03
INITIAL TIME-DEPTH-BOTTOM	1140 0000	1225 0000	1120 0000	1010 0000	1140 0000	1125 0000	1210 0000	1140 0000
00076 TURB TRBIDMTR HACH FTU		9.2	7.0	1.0	6.3	6.1	3.5	3.5
00116 INTHSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	249	474	500	450	470	472	468	512
00530 RESIDUE TOT NFLT MG/L	14	9	16	2	12	14	8	4
00535 RESIDUE VOL NFLT MG/L	5	4	4	2	3	3	3	4
00608 NH3+NH4- N DISS MG/L	0.040	0.100	0.060	0.090	0.080	0.030	0.100	0.020
00610 NH3+NH4- N TOTAL MG/L	0.080	0.100	0.060	0.110	0.090	0.040	0.200	0.040
00615 N02-N TOTAL MG/L	0.020		0.020	0.010	0.010	0.010	0.010	0.000
00620 N03-N TOTAL MG/L	0.750	0.740	0.620	0.760	0.650	0.750	0.410	0.140
00625 TOT KJEL N MG/L	0.360	0.480	0.340	0.290	0.260	0.250	0.200	0.360
00665 PHOS-TOT MG/L P	0.140	0.130	0.140	0.100	0.130	0.130	0.160	0.160
00666 PHOS-DIS MG/L P	0.090	0.090	0.090	0.080	0.110	0.100	0.130	0.090

INITIAL DATE	81/12/02
INITIAL TIME-DEPTH-BOTTOM	1240 0000
00076 TURB TRBIDMTR HACH FTU	5.9
00116 INTHSVE SURVEY IDENT	821705
00515 RESIDUE DISS-105 C MG/L	480
00530 RESIDUE TOT NFLT MG/L	6
00535 RESIDUE VOL NFLT MG/L	3
00603 NH3+NH4- N DISS MG/L	0.030
00610 NH3+NH4- N TOTAL MG/L	0.030
00615 N02-N TOTAL MG/L	0.010
00620 N03-N TOTAL MG/L	0.390
00625 TOT KJEL N MG/L	0.200
00665 PHOS-TOT MG/L P	0.090
00666 PHOS-DIS MG/L P	0.030

STORET RETRIEVAL DATE 83/02/16
RPDCOl
41 19 03.0 089 52 56.0 4
EAST TRIBUTARY TO JOHNSON SAUK TRAIL LAKE
17073 ILLINOIS HENRY
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

				81/01/20	81/02/17	81/03/17	81/04/14	81/05/12	81/05/26	81/06/09	81/06/23
INITIAL DATE				81/01/20	81/02/17	81/03/17	81/04/14	81/05/12	81/05/26	81/06/09	81/06/23
INITIAL TIME-DEPTH-BOTTOM				1130 0000	1250 0000	1345 0000	1130 0000	1115 0000	1200 0000	1200 0000	1215 0000
00076	TURB	TRBIDMTR	HACH FTU	9.6	14.2	4.5	43.4	4.1	2.6	4.7	2.0
00116	IHTNSVE	SURVEY	IDENT	821705	21705	821705	821705	821705	821705	821705	821705
00515	RESIDUE	DISS-105	C MG/L	456	324	486	324	486	484	478	490
00530	RESIDUE	TOT NFLT	MG/L	118	62	9	305	8	3	14	6
00535	RESIDUE	VOL NFLT	MG/L	8	10	6	21	6	2	6	6
00608	NH3+NH4-	N DISS	MG/L	0.110	0.160	0.100	0.000	0.060	0.030	0.170	0.070
00610	NH3+NH4-	N TOTAL	MG/L	0.120	0.170	0.100	0.140	0.100	0.030	0.170	0.100
00615	N02-N	TOTAL	MG/L	0.010		0.010	0.018	0.005	0.010	0.031	0.007
00620	N03-N	TOTAL	MG/L	0.240		0.054	1.140	0.131	0.070	0.571	0.228
00625	TOT KJEL	N	MG/L	0.230	0.800	0.130	0.730	0.210	0.190	0.260	0.210
00665	PHOS-TOT		MG/L P	0.110	0.190	0.070	0.230	0.060	0.060	0.100	0.100
00666	PHOS-DIS		MG/L P	0.020	0.040	0.020	0.060	0.030	0.040	0.060	0.060

INITIAL DATE				81/07/07	81/07/23	81/08/04	81/08/18	81/09/01	81/09/16	81/10/06	81/11/03
INITIAL TIME-DEPTH-BOTTOM				1135 0000	1220 0000	1115 0000	1005 0000	1135 0000	1120 0000	1205 0000	1135 0000
00076	TURB	TRBIDMTR	HACH FTU		5.3	1.8	1.0	4.2	6.8	5.7	8.0
00116	INTNSVE	SURVEY	IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515	RESIDUE	DISS-105	C MG/L	488	450	488	446	472	466	504	512
00530	RESIDUE	TOT NFLT	MP/L	13	4	1	3	3	6	4	4
00535	RESIDUE	VOL NFLT	MG/L	5	2	1	2	2	2	2	2
00608	NH3+NH4-	N DISS	MG/L	0.030	0.120	0.080	0.070	0.080	0.020	0.010	0.040
00610	NH3+NH4-	N TOTAL	MG/L	0.040	0.140	0.120	0.120	0.090	0.050	0.060	0.070
00615	N02-N	TOTAL	MG/L	0.010		0.020	0.010	0.100	0.000	0.010	0.000
00620	N03-N	TOTAL	MG/L	0.160	0.060	0.270	0.290	0.250	0.070	0.080	0.050
00625	TOT KJEL	N	MG/L		0.330	0.230	0.170		0.130	0.300	0.230
00665	PHOS-TOT		MG/L P	0.100	0.090	0.110	0.080	0.110	0.140	0.160	0.150
00666	PHOS-DIS		MG/L P	0.060	0.010	0.070	0.040	0.060	0.050	0.070	0.040

INITIAL DATE				81/12/02
INITIAL TIME-DEPTH-BOTTOM				1235 0000
00076	TURB	TRBIDMTR	HACH FTU	10.1
00116	INTNSVE	SURVEY	IDENT	821705
00515	RESIDUE	DISS-105	C MG/L	442
00530	RESIDUE	TOT NFLT	MG/L	5
00535	RESIDUE	VOL NFLT	MG/L	3
00608	NH3+NH4-	N DISS	MG/L	0.070
00610	NH3+NH4-	N TOTAL	MG/L	0.070
00615	N02-N	TOTAL	MG/L	0.010
00620	N03-N	TOTAL	MG/L	0.060
00625	TOT KJEL	N	MG/L	0.070
00665	PHOS-TOT		MG/L P	0.080
00666	PHOS-DIS		MG/L P	0.020

STORET RETRIEVAL DATE 83/02/16
RPDD01
41 20 10.0 089 52 52.0 4
KING CR OUTFALL FROM JOHNSON SAUK TRAIL LAKE
17073 ILLINOIS HENRY
UPPER MISSISSIPPI 070900
ROCK RIVER
21ILLAKE
821008 DEPTH 0
/TYPA/AMBNT/STREAM

INITIAL DATE	81/01/20	81/02/17	81/03/17	81/04/14	81/05/12	81/05/26	81/06/09	81/06/23
INITIAL TIME-DEPTH-BOTTOM	1240 0000	1300 0000	1355 0000	1140 0000	1225 0000	1210 0000	1210 0000	1225 0000
00076 TURB TRBIDMTR HACH FTU	1.3	2.5	3.7	90.3	4.1	3.2	6.1	3.4
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	388	260	386	242	306	324	288	362
00530 RESIDUE TOT NFLT MG/L	0	6	5	125	10	4	16	14
00535 RESIDUE VOL NFLT MG/L	0	6	5	19	8	3	7	14
00608 NH3+NH4- N DISS MG/L		0.300	0.110	0.180	0.110	0.090	0.260	0.290
00610 NH3+HH4- N TOTAL MG/L	0.020	0.300	0.120	0.230	0.140	0.090	0.320	0.300
00615 N02-N TOTAL MG/L	0.010			0.006	0.004	0.007	0.012	0.004
00620 N03-N TOTAL MG/L	0.070		0.068	0.240	0.118	0.100	0.021	0.121
00625 TOT KJEL N MG/L	0.060	0.650	0.140	0.810	0.620	0.440	0.910	0.870
00665. PHOS-TOT MG/L P	0.030	0.050	0.040	0.270	0.050	0.030	0.090	0.070
00666 PHOS-DIS MG/L P	0.010	0.030	0.020	0.040	0.020	0.010	0.020	0.020

INITIAL DATE	81/07/23	81/08/04	81/08/18	81/09/01	81/09/16	81/10/06	81/11/03	81/12/02
INITIAL TIME-DEPTH-BOTTOM	1215 0000	1110 0000	0830 0000	1130 0000	1115 0000	1200 0000	1130 0000	1230 0000
00076 TURB TRBIDMTR HACH FTU	3.0	3.2	5.5	2.8	2.4	3.5	2.1	3.4
00116 INTNSVE SURVEY IDENT	821705	821705	821705	821705	821705	821705	821705	821705
00515 RESIDUE DISS-105 C MG/L	406	262	212	254	408	382	306	260
00530 RESIDUE TOT NFLT MG/L	4	9	15	11	4	3	6	4
00535 RESIDUE VOL NFLT MG/L	2	5	3	7	1	3	3	2
00608 NH3+NH4- N DISS MG/L	0.050	0.170	0.140	0.220	0.130	0.110	0.090	0.130
00610 NH3+NH4- N TOTAL MG/L	0.050	0.200	0.170	0.230	0.130	0.130	0.100	0.150
00615 N02-N TOTAL MG/L		0.010	0.010	0.010	0.010	0.010	0.010	0.010
00620 N03-N TOTAL MG/L	0.060	0.070	0.140	0.090	0.140	0.110	0.130	0.140
00625 TOT KJEL N MG/L	0.340	1.090	1.010	1.020	0.020	0.360	0.580	0.600
00665 PHOS-TOT MG/L P	0.020	0.080	0.080	0.060	0.030	0.040	0.030	0.300
00666 PHOS-DIS MG/L P	0.010	0.020	0.020	0.020	0.010	0.010	0.020	0.200