WATER QUALITY OF CORYDON RESERVOIR BEFORE IMPLEMENTATION OF AGRICULTURAL BEST-MANAGEMENT PRACTICES IN THE BASIN, WAYNE COUNTY, IOWA, SEPTEMBER 1990 TO SEPTEMBER 1991

By Stephen J. Kalkhoff

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CONTENTS

Page

ILLUSTRATIONS

Page

ILLUSTRATIONS--Continued

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	*By*	*To obtain*
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
acre	0.4047	hectare
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
	Rate	
pound per acre (lb/acre)	1.121	kilogram per hectare
	Mass	
pound (lb)	453.6	gram
ton, short	.9072	megagram
ton per day (ton/d)	.9072	megagram per day

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water Year: A water year is a 12-month period, from October 1 through September 30, designated by the calendar year in which it ends. Years are water years in this report unless otherwise stated.

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ABSTRACT

A hydrologic investigation to define the water quality of Corydon Reservoir before implementation of agricultural best-management practices in the basin was conducted from September 1990 to September 1991. Runoff from the 1,680-acre basin is the primary source of water to the 58-acre reservoir. Current water quality of the reservoir is affected substantially by runoff from the agricultural basin. Total-solids, total-nitrogen, and total-phosphorus concentrations were largest during April through July 1991, the months of greatest rainfall. Herbicide concentrations increased substantially in June after application. The sum of the concentrations of all triazines was greater than 50 micrograms per liter in one sample, with the predominant herbicides being atrazine and cyanazine. Atrazine concentrations, estimated from immunoassay, were greater than 8.0 micrograms per liter from June through September 1991 as a result of reservoir storage. Atrazine concentrations commonly were less at the surface than at depth. Algal populations remained constant even though nutrient concentrations increased during the summer months. This may be due to the presence of suspended sediment that reduces light penetration and herbicides that inhibit photosynthesis.

INTRODUCTION

Agricultural chemicals have been used in increasing quantities during the past 20 years to enhance crop production but also have affected the water quality of lakes and reservoirs in Iowa (Kennedy, 1978; Leung and others, 1982; Soballe and Bachmann, 1984). In Iowa, several common herbicides used to control competing vegetation are the triazines (atrazine, cyanazine, simazine, and propazine) and the acetanilides (alachlor and metolachlor). Granular fertilizers and anhydrous ammonia are common sources of nutrients applied to enhance crop production. The use of chemicals has increased crop yields substantially, but chemical residuals have been transported to Iowa reservoirs (Wnuk and others, 1987; Kennedy and Miller, 1987, 1988; Miller and Kennedy, 1990, 1991). Additional nutrients in reservoirs may cause excessive growth of algae and aquatic plants. The presence of agricultural chemicals in surface water also may adversely affect municipal water supplies. Use of water containing chemical concentrations that exceed Maximum Contaminant Levels established by the U.S. Environmental Protection Agency for drinking water poses a health risk, and treatment of the water to meet water-quality regulations may be costly. In addition, some tillage practices tend to increase the amount of soil erosion. The soil that is washed into streams and surface impoundments affects the aquatic environment and causes the water to become esthetically unsuitable for some uses. The soil also prematurely fills reservoirs and reduces the storage capacity needed for water supply and flood control.

The Iowa Department of Natural Resources and the University of Iowa Hygienic Laboratory conducted a study during 1986 to investigate the occurrence of herbicides in water supplies from surface-water sources in Iowa. Wnuk and others (1987) report that detectable concentrations of one or more pesticides were found in 30 of 33 sampled water supplies and that the concentrations in 21 of 33 supplies exceeded preliminary lifetime health advisory concentrations. Some of the largest concentrations of the most commonly used herbicides (atrazine, 21 μg/L (micrograms per liter) and metolachlor, 21 μg/L) were in samples obtained from treated water from Corydon Reservoir.

Because Corydon Reservoir is used for public water supply, there is a need to reduce the input of agricultural chemicals into the reservoir. One method to accomplish the reduction of chemical input is through prescribed land use and management procedures termed "best-management practices." These best-management practices, as defined by the U.S. Department of Agriculture, include the installation of conservation structures to control soil erosion and runoff and management assistance to make optimal use of nutrients and pesticides. The Iowa Department of Natural Resources, in cooperation with the U.S. Department of Agriculture, Iowa State University Extension, and the City of Corydon are working with farmers to implement best-management practices in the Corydon Reservoir watershed.

To determine changes over time in the water quality of Corydon Reservoir caused by the implementation of chemical application and land-use practices called "best-management practices," there is a need to document the water quality before these practices are initiated. The U.S. Geological Survey, in cooperation with the Iowa Department of Natural Resources, Geological Survey Bureau, is conducting an investigation of water-quality in the Corydon Reservoir to determine the effects of implementing "best-management practices" in the basin.

Purpose and Scope

This report documents the areal and seasonal variation in water quality of Corydon Reservoir before "best-management practices" were initiated. This baseline information will be used to evaluate the effects of best-management practices on the water quality of Corydon Reservoir. Although terraces were constructed in a small part of the basin (150 acres) during 1991 (Douglas Bahl, U.S. Soil Conservation Service, oral commun., 1992), data collected during this initial study were considered representative of conditions before the initiation of best-management practices.

To document the quality of water in the reservoir, both historical information and data collected during the first year of the study were used. Historical water-quality data from Corydon Reservoir are available from as early as 1934. Additional water samples were collected in the 1950's, 60's, and 70's. Water-quality data presented in this report covers the period from September 1990 through September 1991. Precipitation, the source of water and some agricultural chemicals, also was measured. Monthly water-quality conditions in Corydon Reservoir and their relation to runoff are described.

Study Area

Location

Corydon Reservoir basin is located in the headwaters of an unnamed tributary of Jackson Creek, a tributary of the South Fork Chariton River, in Wayne County, Iowa (fig. 1). Wayne County is located in south-central Iowa adjacent to the Missouri border. The basin includes about 2.63 mi^2 or about 1,680 acres. The topography of the area is relatively flat on the ridges near the basin boundary and steepens near the intermittent streams. The basin relief is 80 ft. Several small, intermittent streams drain the basin and flow into Corydon Reservoir. Density of these streams is 2.3 mi of streams per square mile of basin. The main channel slopes 15.5 ft/mi from the basin boundary to the outlet of Corydon Reservoir. The reservoir comprises about 58 acres, has a mean depth of 5.9 ft, and is divided into two parts. The main part of the reservoir has an area of about 52 acres when the level of the lake is at the crest of the spillway. A railroad embankment divides the upper end of the lake resulting in a 6-acre section of the reservoir west of the embankment. When the water level is at the top of the spillway, the reservoir contains almost 15 million ft^3 (344 acre-ft).

Geology and Soils

The surficial geologic materials in the basin consist of unconsolidated glacial drift, loess, and alluvium. The glacial drift is composed predominantly of sandy, pebbly clay of varying thickness and extent. Glacial drift is relatively thick, greater than 100 ft, in the basin. Overlying the glacial drift on the uplands is a 5- to 10-ft layer of loess. Loess is windblown silt and clay-sized material. Streams have cut valleys into the drift and deposited alluvium along the principal streams (Cagle, 1969). Alluvium is composed of clay, silt, sand, and gravel and underlies the flood plains and terraces.

Upland soils in Corydon Reservoir basin developed from loess and are characterized as slightly to poorly drained (Lockridge,1971). The texture of the soil grades from a silt loam at the surface to silty-clay loam with depth. Soils on

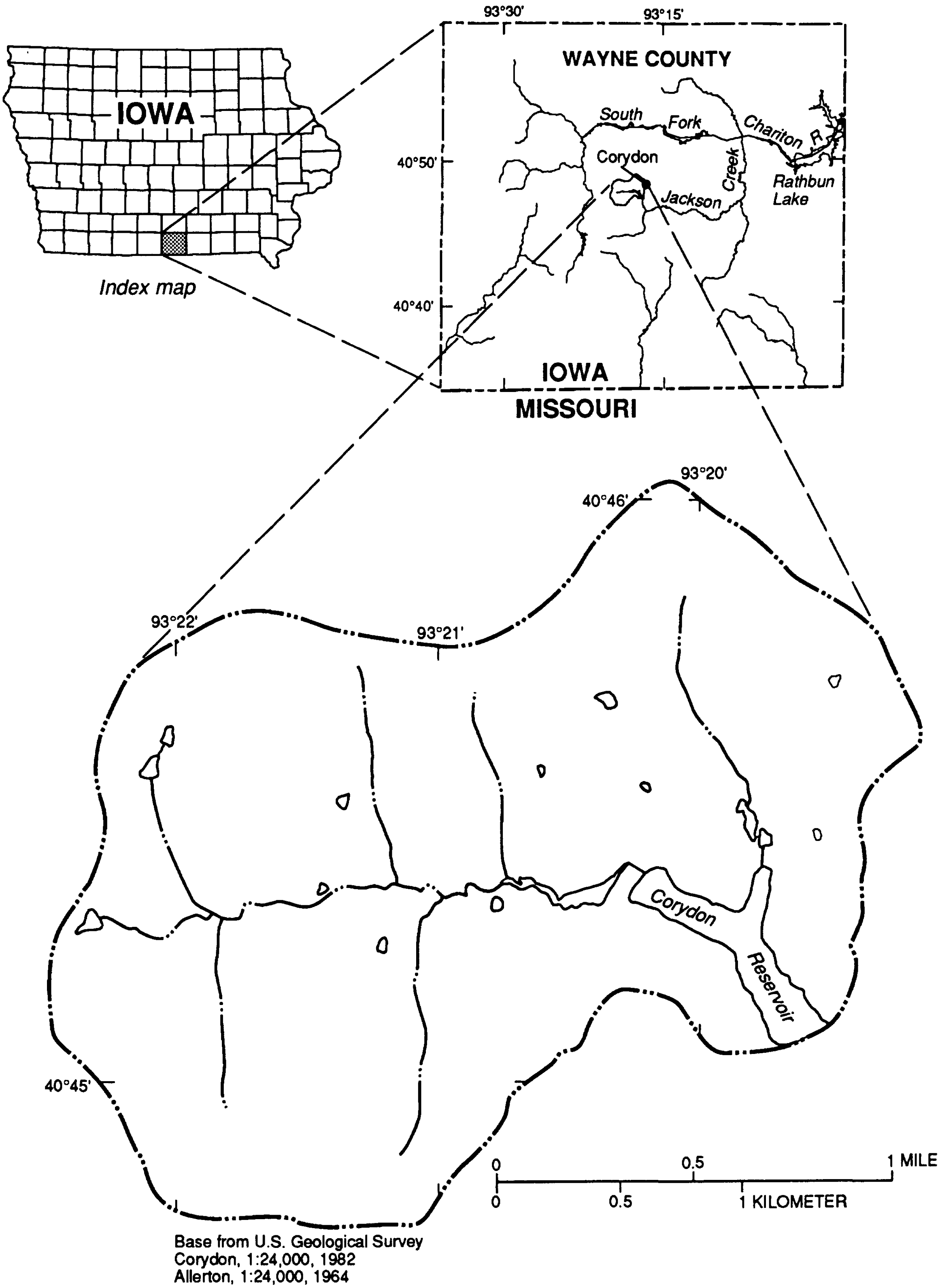

Figure 1. Location of the Corydon Reservoir basin, Wayne County, Iowa.

the slopes are derived from till and are moderately to poorly drained. Soils near the intermittent streams are a complex of soils developed on alluvium and of soils developed from materials washed from adjoining slopes (Lockridge, 1971). These soils are moderately well drained to poorly drained.

Land Use

Abundant rainfall and the type of soil in the Corydon Reservoir basin provide suitable conditions for agricultural activities. Agriculture is the major land use in the basin, and corn and soybeans are the major crops. To enhance the yield of corn, seven of the nine farm operators in the basin applied an average of 128 lb/acre of nitrogen during 1991. To control competing vegetation, pre- and post-emergent herbicides were applied to all corn and soybeans during 1991 (Gerald Miller, Iowa State Extension, written commun., 1992). Several minor crops, oats, wheat, and hay, were raised for local livestock use.

Historical Water Quality

Total solids, dissolved solids plus suspended material, an indicator of soil erosion in the basin, ranged from 248 mg/L (milligrams per liter) on October 19, 1955, to 404 mg/L on July 11, 1934 (table 1). Nitrite plus nitrate as nitrogen ranged from less than 0.01 mg/L on April 18, 1972, to 1.8 mg/L on April 8, 1976. Atrazine and metolachlor, two herbicides used to control competing vegetation, were detected in concentrations that exceeded 20 µg/L (micrograms per liter) on June 3, 1986 (Wnuk and others, 1987). Concentrations of atrazine and metolachlor decreased to 0.90 and 0.33 µg/L, respectively, in March 1987.

Soil that eroded from the basin and was subsequently transported to the reservoir has had a substantial effect on Corydon Reservoir. Resulting siltation has reduced the storage capacity of the water-supply reservoir, and the water level was raised in 1974 to compensate for the reduced storage (Donald McGee, Water Superintendent, City of Corydon, oral commun., 1992). Evidence of the siltation is seen on the

Table 1. *Selected water-quality constituents in water from Corydon Reservoir, Wayne County, Iowa, 1934-76*

[Data from U.S. Geological Survey files; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data; <, less than]

Date	Specific-conductance (µS/cm)	pH (units)	Total solids (mg/L)	Total solids, volatile on ignition (mg/L)	Nitrogen: Nitrite plus nitrate (mg/L)	Nitrogen: Ammonia (mg/L)	Nitrogen: Organic (mg/L)
07-11-34	--	7.6	404	--	0.09	--	--
10-19-55	348	8.2	248	--	.60	--	--
07-30-56	--	7.6	398	91	.20	0.19	1.1
11-13-56	357	8.1	260	74	.20	.03	1.1
03-11-57	326	8.0	252	74	.16	.04	1.1
06-29-65	279	8.0	264	--	1.2	--	--
04-25-66	442	7.5	--	--	.56	--	--
08-07-67	470	7.1	--	--	.41	--	--
04-18-72	440	7.8	319	69	<.10	0.11	1.8
04-08-76	320	7.6	--	--	1.8	--	--

bathymetric map of the reservoir (fig. 2). Lines of equal water depth show the presence of a delta-like formation just downstream of the inlet under the railroad embankment. This type of formation would be expected to form where the velocity of an inflowing stream decreases when emptying into a larger body of water. The reduced velocities would result in suspended sediment being deposited.

Methodology

To define the effects of agricultural activities on the water quality of Corydon Reservoir, areal and seasonal water-quality data were collected. An initial water-quality appraisal was made to determine areal variability and to select representative monthly sampling sites. Concurrently, the shoreline was surveyed, and depth data were collected to calculate morphometric characteristics of the reservoir. Physical, chemical, and biological data were collected monthly at representative sites in the reservoir to define seasonal water-quality variation.

Data Collection

The water quality in Corydon Reservoir was initially appraised on September 19-20, 1990. Measurements of water temperature and specific conductance were made onsite, and water samples were collected for analyses of selected chemical and biological constituents. Depth profiles of the water temperature and specific conductance were made from measurements taken at 2-ft intervals every 100 ft at eight cross sections in the reservoir. Thirteen water samples were collected from eight sites (table 1) for analyses of nitrogen species, total phosphorus, total organic carbon, and triazine herbicides.

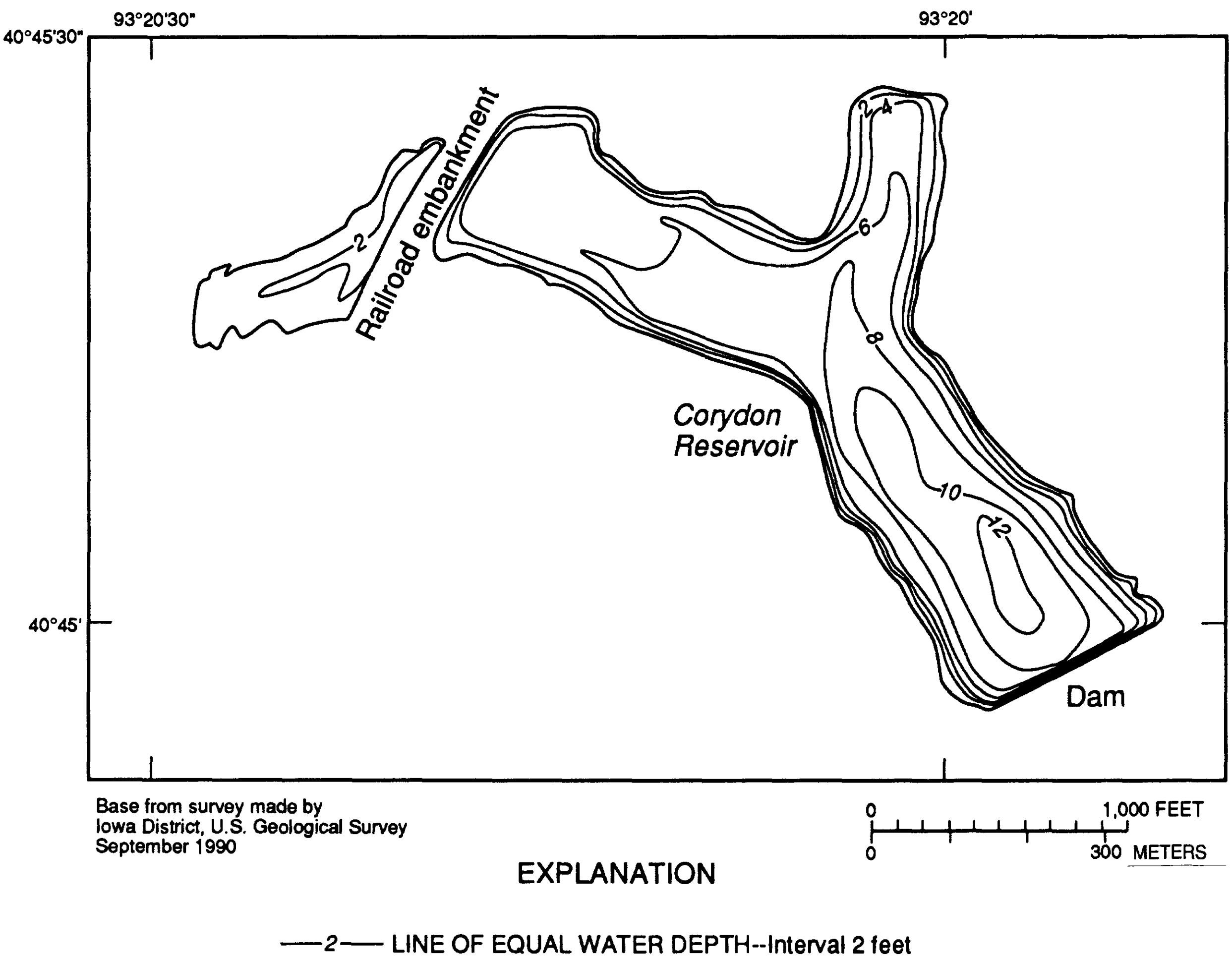

Figure 2. Water depth in Corydon Reservoir, September 1990.

Morphometric characteristics of the reservoir (area, volume, and mean depth) were determined by developing a bathymetric map (fig. 2). Standard survey methods (Rayner and Schmidt, 1963) were used to map the shoreline, and lines of equal depth were drawn on the basis of fathometer soundings at 18 cross sections. Surface area was determined by planimetering a plot of the shoreline from the surveyed points. Similarly, the area of each 1-ft line of equal water depth was planimetered. The reservoir volume then was estimated by summing the volume of each 1-ft truncated cone using the following equation (Wetzel, 1983, p. 31)

$$V = \frac{h}{3}(A1 + A2 + \sqrt{A1A2})$$

where V is the volume in cubic feet, h is the vertical depth of the stratum in feet, $A1$ is the area of the upper stratum in square feet, and $A2$ is the area of the lower stratum in square feet. The maximum depth was determined from fathometer readings and the mean depth is calculated by dividing the reservoir volume by the surface area.

The seasonal variation in water quality of the reservoir and water discharged from the reservoir were determined from monthly measurements of water temperature, specific conductance, pH, and dissolved oxygen onsite and monthly water samples for analyses of selected chemical and biological constituents from four sites (fig. 3 and table 2). When water was discharging from the reservoir, onsite measurements and samples also were collected just downstream of the spillway. Water temperature, specific conductance, and dissolved oxygen were measured in situ using portable meters. The pH was measured by pumping a sample with a peristaltic pump from the selected depth and measuring at the surface. Specific conductance and pH meters were calibrated with standard reference solutions. Temperature values were calibrated with a mercury thermometer. Reservoir transparency was determined as the average of the depth at which a standard secchi disk disappeared from view when lowered into the reservoir and the depth at which it reappeared when raised (Lind, 1974). Water discharged from the reservoir was measured monthly using standard current meter methods (Buchanan and Somers, 1969).

Samples for chemical analyses were collected using two techniques. When onsite water-quality characteristics (water temperature and specific conductance) were uniform from top to bottom of the reservoir, depth-integrated samples were collected. Water was pumped from the reservoir by lowering and then raising the intake hose of a peristaltic pump at a uniform rate through the vertical section. When the field parameters indicated that the reservoir was stratified, separate samples were collected from the surface and at a point midway to the reservoir bottom. Upon return to the shore, within 2 hours of sample collection, samples to be analyzed for the nitrogen species and total phosphorus were preserved with mercuric chloride and chilled for shipment to the laboratory.

Biological samples were collected and preserved at the three reservoir sampling sites using techniques described by Britton and Greeson (1987). Samples were collected at the surface in sterile bottles for the determination of fecal coliform and fecal streptococcal bacteria. The water sample was chilled until it could be filtered and incubated (within 6 hours of sample collection). Samples for the analyses of chlorophyll-*a* in the phytoplankton were collected at the surface, chilled, filtered within 6 hours, and shipped chilled to the laboratory.

Precipitation was measured using a Belfort[1] weighing bucket rain gage located near the reservoir dam (fig. 3). Data were supplemented with National Weather Service precipitation data from a site 8 mi west of Corydon (not shown) during periods of instrument malfunction. Precipitation-quality samples were collected automatically at the Corydon Reservoir rain gage with a wet/dry precipitation collector. Samples were removed weekly from the sampler and mailed to the U.S. Geological Survey office in Iowa City, Iowa.

[1] The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

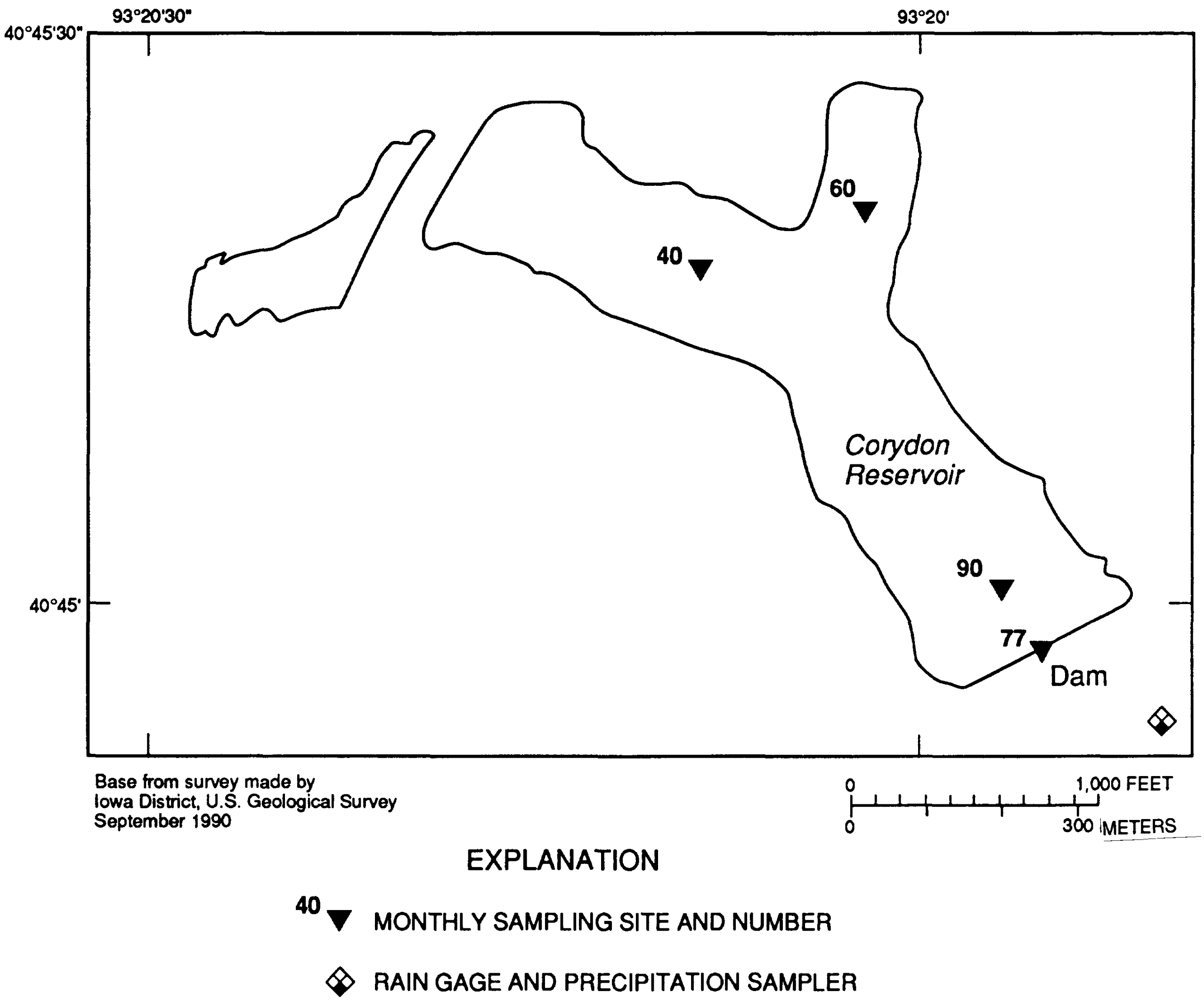

Figure 3. Location of monthly sampling sites and rain gage at Corydon Reservoir.

Analytical Methods

Water samples were analyzed by the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colorado, using techniques described by Fishman and Friedman (1989). Enumeration of fecal coliform and fecal streptococcal bacteria and the determination of chlorophyll-*a* concentrations were made using methods described by Britton and Greeson (1987). Triazines were analyzed by the author using enzyme-linked immunosorbent assay (ELISA) techniques described by Thurman and others (1990). About 20 percent of the herbicide samples were sent to the U.S. Geological Survey National Water-Quality Laboratory for confirmation using gas chromatograph/mass spectrometry (GC/MS) methods (Sandstrom and others, 1991). The reporting level for all herbicides except cyanazine using the GC/MS technique is 0.05 μg/L (microgram per liter).The detection level for cyanazine is 0.20 μg/L.

Atrazine concentrations were estimated in samples not analyzed by GC/MS techniques using a least-squares regression of the relation between ELISA and GC/MS analyses (fig. 4). Data points from samples having larger concentrations were more scattered than data points from samples having lower concentrations. Part of the scatter may be due to differences in the response of the ELISA method to various triazine herbicides (Thurman and others, 1990). The data were transformed to log base-10 values to obtain an improved regression. Because of the limited number of samples, the data are clustered into two groups and thus may provide a misleading relation. However,

Table 2. *Description of the Corydon Reservoir sampling sites*

[*, monthly sampling site; --, not applicable]

Site number	Site identification number	Site name	Cross-sectional location, looking upstream (feet from right bank)
30	0690367630	Corydon Reservoir 2,550 feet upstream of the dam at Corydon, Iowa	200
*40	0690367640	Corydon Reservoir 2,150 feet upstream of the dam at Corydon, Iowa	300
*60	0690367660	Corydon Reservoir, north arm, at Corydon, Iowa	200
70	0690367670	Corydon Reservoir 1,550 feet upstream of the dam at Corydon, Iowa	200
80	0690367680	Corydon Reservoir 950 feet upstream of the dam at Corydon, Iowa	200
*90	0690367690	Corydon Reservoir 350 feet upstream of the dam at Corydon, Iowa	300
90.2	0690367690	Corydon Reservior 350 feet upstream of the dam at Corydon, Iowa	200
90.4	0690367690	Corydon Reservior 350 feet usptream of the dam at Corydon, Iowa	400
*77	06903677	Corydon Reservoir at the spillway, Corydon, Iowa	--

other researchers (Thurman and others, 1990) have found a similar significant relation between ELISA and GC/MS results, and thus the regression line shown in figure 4 was used to estimate the atrazine concentrations in water from Corydon Reservoir from measurements from ELISA.

Calculation of Reservoir Storage

The water level in the reservoir was recorded hourly, and the amount of reservoir storage was calculated from the reservoir water level and the volume of the reservoir determined from the bathymetric map. Data on the amount of water withdrawn from the reservoir for municipal usage were provided by the City of Corydon.

Acknowledgments

The U.S. Environmental Protection Agency provided assistance to numerous Federal, State, and local agencies to initiate agricultural best-management practices. The study was substantially assisted by Douglas Bahl of the U.S. Soil Conservation Service in Corydon and officials of the city of Corydon; Bahl coordinated activities between cooperating agencies. Donald MaGee, water superintendent for Corydon, and his staff made water-quality measurements and helped maintain the rain gage.

AREAL VARIATION IN WATER QUALITY, SEPTEMBER 1990

The results of an initial appraisal of Corydon Reservoir in September 1990 indicate that, with the exception of atrazine, there was little areal variation in the water quality of the reservoir (table 3). Nearly constant water temperatures (19.1 to 20.2 °C) indicated that the reservoir was not thermally stratified. Nitrite plus nitrate concentrations as nitrogen were less than the detection level (0.10 mg/L),

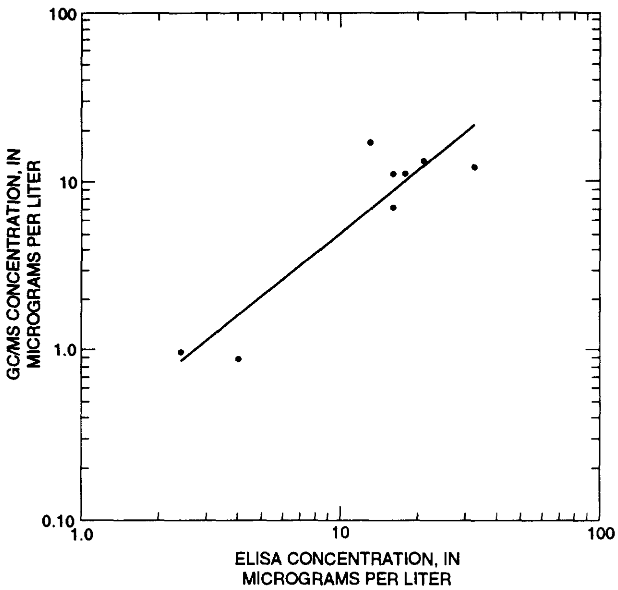

Figure 4. Relation between total-atrazine concentrations analyzed by gas chromatograph/mass spectrometry (GC/MS) and total-triazine concentrations analyzed by enzyme-linked immunosorbent assay (ELISA).

and total-phosphorus concentrations were less than 0.20 mg/L. However, the estimated-atrazine concentrations, determined by ELISA, were more variable. Estimated-atrazine concentrations tended to decrease towards the dam and increase with depth (fig. 5). Estimated-atrazine concentrations decreased from 2.7 µg/L in the north arm of the reservoir (site 60) to about 0.85 µg/L near the dam (site 90.2). The difference between the concentrations at the surface and near the bottom ranged from 0.20 to 0.60 µg/L, with the greater atrazine concentrations near the bottom of the reservoir.

SEASONAL VARIATION IN WATER QUALITY, SEPTEMBER 1990 TO SEPTEMBER 1991

In previously collected samples, concentrations of chemical constituents varied in Corydon Reservoir. However, results of this study better define the seasonal variability of physical properties and chemical and biological constituents and show that much of the variability is related to runoff from the agricultural basin. In addition to seasonal variability, seasonal vertical water-quality stratification was also noted. Persistence of the herbicides in the reservoir through the summer might be due, in part, to storage in the reservoir.

Physical Properties

Runoff from the basin was measured indirectly by recording the water level of the reservoir. A rise in the reservoir water level was assumed to be related primarily to surface-water inflow from intermittent streams that drain the basin. A small amount of input likely is from ground-water inflow. The reservoir water level remained below the level of the spillway during October and most of November 1990 (fig. 6). Several rains (table 4) in November caused the water levels to rise to the spillway by the end of the month. When ice was present (December to the first part of March), the reservoir water level remained relatively constant. Daytime air temperatures greater than 0 °C during February caused snowmelt which entered the reservoir with a subsequent increase in water levels and discharge from the reservoir. Greater than or near average rainfall (National Oceanic and Atmospheric Administration, 1991) in south-central Iowa during March through June caused inflow to exceed the reservoir-storage capacity and excess water to discharge over the spillway. Reservoir water levels generally declined the remainder of the year because of the less-than-average rainfall (National Oceanic and Atmospheric Administration, 1991). One exception occurred when precipitation runoff caused substantial rises in the reservoir water level on July 9 to 11.

Climatic changes caused seasonal variability in the water temperature (fig. 6 and table 5). Monthly mean reservoir water temperatures ranged from 25.4 °C in August 1991 to 2.2 °C in January 1991 (fig. 6). Although the monthly mean water temperatures remained greater than 0 °C, ice was present from December 1990 to February 1991.

Specific conductance, an indicator of the dissolved-solids concentration, generally was largest during the winter and early spring. The monthly mean specific conductance ranged from 333 µS/cm (microsiemens per centimeter at 25 °C) in January to 189 µS/cm in May. Generally the largest specific-conductance values occurred when the reservoir was covered

Table 3. *Summary of selected water-quality constituents in water from Corydon Reservoir, Wayne County, Iowa, September 19-20, 1990*

[*, Median value: nitrogen species reported as nitrogen; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, not determined]

Constituent	Number of samples	Mean	Standard deviation	Minimum	Maximum
Temperature (°C)	131	19.8	0.4	19.1	20.2
Conductance (µS/cm)	131	224	1.6	221	227
*pH (standard units)	13	8.8	.04	8.7	8.8
Total organic carbon (mg/L)	13	10.3	.8	8.9	12
Nitrite plus nitrate (mg/L)	13	<.10	--	<.10	<.10
Ammonia (mg/L)	13	.03	.004	.02	.04
Organic nitrogen (mg/L)	13	.72	.15	.57	1.1
Total phosphorus (mg/L)	13	.16	.04	.03	.19
Atrazine (µg/L)[1]	13	1.5	.50	.85	2.7

[1] Estimated concentrations using enzyme-linked immunosorbent assay techniques (Thurman and others, 1990).

with ice. This was similar to the conditions in several Minnesota prairie reservoirs (Smith and others, 1990).

Particulate matter, sediment originating from soil erosion in the basin, was a major factor in reducing reservoir transparency. The reservoir transparency and thus the ability of light to penetrate the water varied seasonally and was significantly ($p<0.05$) related to the total-solids concentration. Reservoir transparency, as indicated by the secchi-disk depth, was greatest during the months of January and February when there was little inflow to the reservoir and the water was calm because of the ice cover (fig. 7). Monthly mean secchi-disk depths were about 50 in. during both January and February. Monthly mean total-solids concentrations were 186 and 52 mg/L in January and February, respectively. In contrast, the secchi-disk depths decreased during April through June to less than 10 in. during the period of greatest inflow to the reservoir. The largest monthly mean total-solids concentrations were observed during these 4 months.

Chemical Constituents

Nutrients

Nitrogen and phosphorus in basin runoff originates from the natural cycling by chemical and biological processes and from agricultural sources (animal manure and chemical fertilizers). Agriculture probably provides the largest source of nitrogen to runoff. Farm surveys by Iowa State University Extension (Gerald Miller, written commun., 1991) indicate that in 1991 farmers applied an average of 128 lb/acre of nitrogen to corn in the Corydon Reservoir basin. Nitrogen from precipitation contributed an additional 6 lb/acre as calculated from the mean precipitation-weighted nitrogen concentration (O'Connell and others, 1992) collected by the U.S. Geological Survey for the National Atmospheric Deposition Program and National Trends Network at the McNay research site in Lucas County (not shown) and precipitation measured in the basin (table 4). Nitrogen and phosphorus concentrations are listed in table 6.

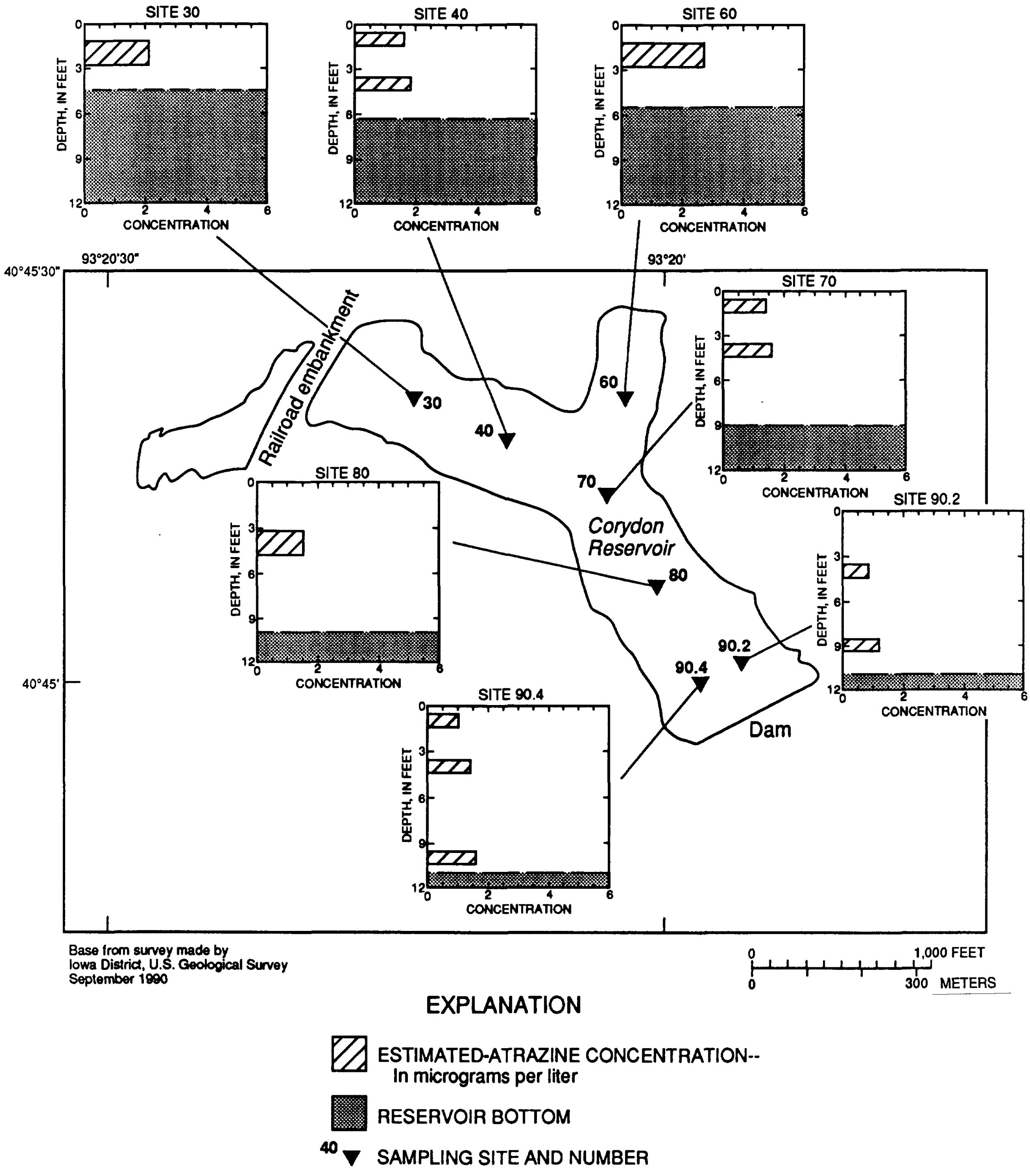

Figure 5. Estimated-atrazine concentrations in Corydon Reservoir, September 1990.

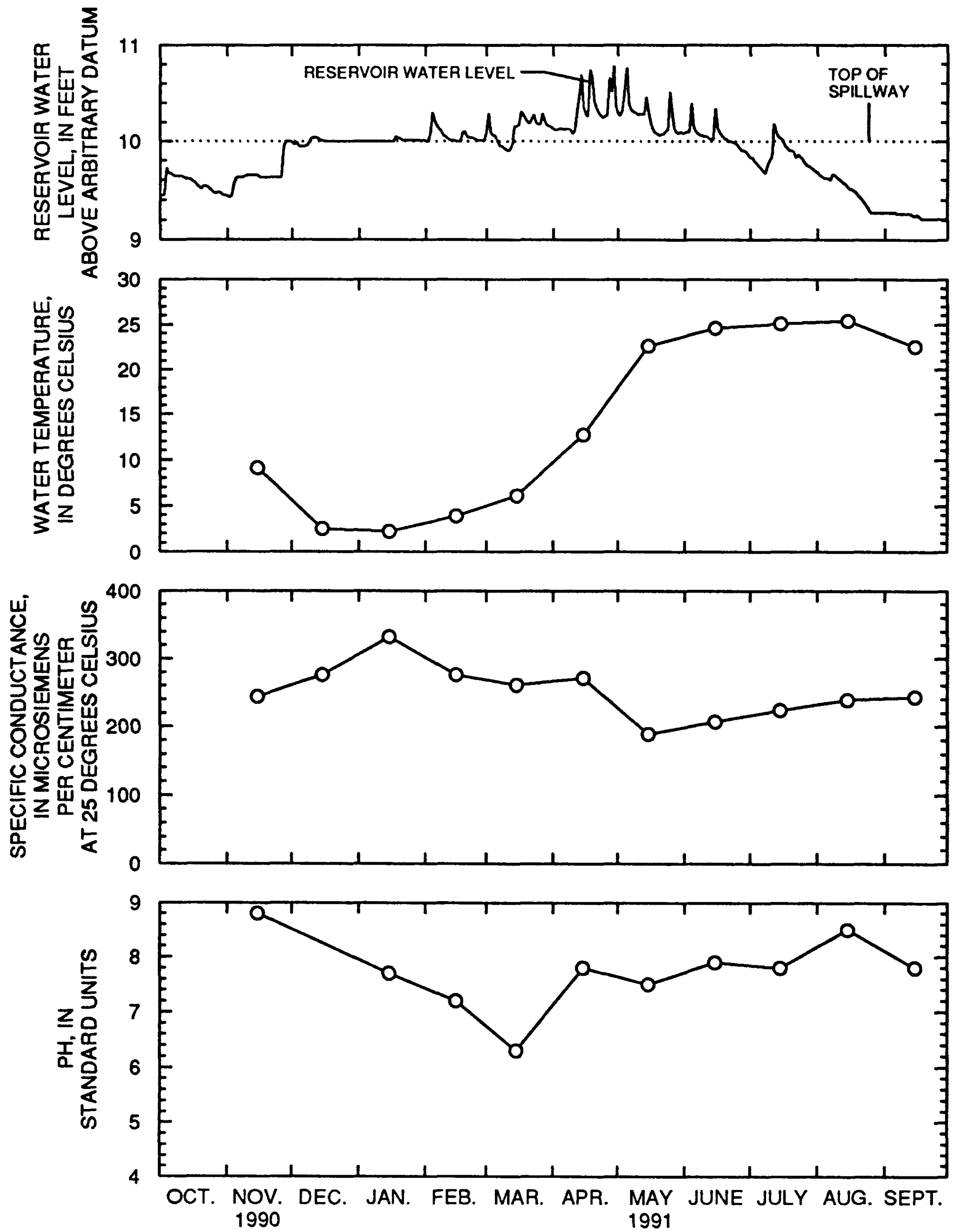

Figure 6. Daily mean reservoir level and monthly mean water temperature, specific conductance, and pH in Corydon Reservoir, water year 1991.

Table 4. *Daily precipitation in Corydon Reservoir basin, Wayne County, Iowa, water year 1991*

[Precipitation in inches]

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July.	Aug.	Sept.
1	0	0	0	0	0	1.00	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	.52	0	0	0
3	.70	0	.66	0	0	0	.04	.35	0	0	.11	1.32
4	1.04	1.26	0	0	0	0	.01	.61	0	0	0	0
5	0	.32	0	.28	0	0	0	1.18	.04	0	.32	0
6	0	0	0	0	.02	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	.01	.02	0	0	0
8	0	.27	0	0	.03	0	.33	0	0	0	.68	.22
9	.48	.02	0	0	.02	0	0	0	0	1.90	0	0
10	.09	0	0	.18	.03	0	0	0	0	.21	0	0
11	0	.03	0	.12	0	.22	0	.01	0	1.62	0	0
12	.03	0	0	.04	0	.18	.64	0	0	0	0	0
13	0	.03	0	.01	0	.04	1.00	1.39	0	0	0	0
14	.04	0	.12	0	0	.05	.76	.46	.11	0	0	.13
15	0	0	.10	.29	0	.53	.01	.12	1.02	0	0	.64
16	.02	.02	.13	.31	0	.09	0	.15	0	0	.12	0
17	.02	.01	.08	.02	0	.11	.02	.05	0	0	0	0
18	.04	.03	.23	.02	.43	.33	2.05	.01	0	0	.10	.26
19	0	.02	0	.06	0	.02	.19	0	0	0	0	0
20	.03	.20	.02	0	0	.04	.19	.05	0	0	0	0
21	.55	.04	.15	.01	.01	0	0	.04	0	0	0	0
22	0	0	0	.01	0	0	0	.02	.03	0	0	0
23	0	0	0	.02	0	.52	.03	.37	0	.31	0	0
24	.03	0	0	.02	0	0	.17	.09	0	.05	0	0
25	0	0	0	.03	0	0	0	2.18	0	0	0	0
26	0	0	0	.03	0	.62	.06	.04	0	0	0	0
27	0	.78	0	0	0	0	.77	0	0	0	0	0
28	0	0	0	0	.36	0	0	0	0	.23	0	0
29	0	0	.34	0	---	0	1.87	0	0	0	0	0
30	0	0	.05	0	---	0	.05	0	0	0	.55	0
31	0	---	0	0	---	0	---	0	---	.09	0	---
Total	3.07	3.03	1.88	1.45	0.90	3.75	8.19	7.13	1.74	4.41	1.88	2.57

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; in., inches; <, less than; --, no data]

Date	Time (24-hour)	Sampling depth (feet)	Temperature, water (°C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Transparency, secchi disk (in.)
Corydon Reservoir, 2,150 feet upstream from dam (site 40, fig. 3)								
11-16-90	1417	1.0	9.0	244	8.3	10.9	96	--
11-16-90	1358	2.0	9.0	242	8.3	10.8	95	--
11-16-90	1415	4.0	9.0	244	8.3	10.7	94	--
11-16-90	1400	5.5	9.0	244	8.3	10.5	92	--
12-17-90	1300	1.0	2.5	275	--	12.4	94	22.8
12-17-90	1301	2.0	2.5	276	--	12.4	93	22.8
12-17-90	1302	4.0	2.5	276	--	12.4	93	22.8
12-17-90	1303	6.0	2.5	277	--	12.4	93	22.8
01-17-91	1305	1.0	0.5	334	7.8	--	--	48.6
01-17-91	1306	2.0	1.5	332	7.8	--	--	48.6
01-17-91	1307	4.0	3.0	332	7.8	--	--	48.6
01-17-91	1308	6.0	3.5	331	7.7	--	--	48.6
02-11-91	1400	1.0	3.0	135	7.4	7.6	--	51.8
02-11-91	1401	2.0	4.0	226	7.5	5.6	--	51.8
02-11-91	1402	4.0	4.0	328	7.3	5.8	--	51.8
02-11-91	1403	5.0	4.0	340	7.2	5.8	--	51.8
03-14-91	1525	1.0	7.0	258	6.9	12.4	106	16.2
03-14-91	1526	2.0	6.5	260	6.4	12.7	107	16.2
03-14-91	1527	4.0	6.5	264	6.5	12.7	106	16.2
03-14-91	1528	6.0	5.5	262	6.8	12.8	105	16.2
04-15-91	1300	1.0	12.5	268	7.8	9.6	93	6.7
04-15-91	1301	2.0	12.0	273	7.9	9.3	89	6.8
04-15-91	1302	4.0	12.0	272	7.8	9.2	88	6.8
04-15-91	1303	6.0	11.5	270	7.8	9.0	85	6.8
05-13-91	1520	1.0	28.0	192	--	6.9	90	4.0
05-13-91	1521	2.0	24.0	189	--	6.4	78	4.0
05-13-91	1522	4.0	22.0	188	--	6.4	75	4.0
05-13-91	1523	5.0	21.0	186	--	6.2	71	4.0

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time (24-hour)	Sampling depth (feet)	Temperature, water (°C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Transparency, secchi disk (in.)
Corydon Reservoir, 2,150 feet upstream from dam (site 40, fig. 3)--Continued								
06-18-91	845	1.0	25.0	200	8.1	5.6	70	4.5
06-18-91	826	2.0	25.0	199	7.6	5.1	64	4.5
06-18-91	840	4.0	25.0	199	7.9	5.1	64	4.5
06-18-91	828	6.0	24.0	218	7.7	5.0	62	4.5
07-16-91	923	1.0	25.5	226	7.7	5.5	69	8.7
07-16-91	924	2.0	25.5	225	7.8	5.4	68	8.7
07-16-91	925	4.0	25.5	225	7.8	5.3	67	8.7
07-16-91	926	5.0	25.5	224	7.8	5.1	64	8.7
08-13-91	1330	1.0	26.0	239	8.3	8.2	104	26.7
08-13-91	1328	2.0	25.5	239	8.4	7.9	100	26.7
08-13-91	1319	4.0	25.5	239	8.4	7.6	95	26.7
08-13-91	1325	4.0	25.5	239	--	7.6	95	26.7
08-13-91	1318	5.0	24.0	241	8.4	6.4	78	26.7
09-17-91	823	1.0	22.0	244	6.9	5.2	62	15.3
09-17-91	821	2.0	22.0	244	7.1	5.0	59	15.3
09-17-91	820	4.0	22.5	244	7.2	5.1	61	15.3
09-17-91	819	5.0	22.5	244	7.3	5.0	60	15.3
Corydon Reservoir, north arm (site 60, fig. 3)								
11-16-90	1350	1.0	10.0	245	8.3	10.7	96	--
11-16-90	1331	2.0	9.5	245	8.3	10.7	95	--
11-16-90	1345	4.0	9.0	244	8.3	10.2	90	--
11-16-90	1333	6.0	9.0	--	8.3	9.9	--	--
12-17-90	1250	1.0	2.5	275	--	12.6	95	21.9
12-17-90	1251	2.0	2.5	276	--	12.4	93	21.9
12-17-90	1252	4.0	2.5	276	--	12.4	93	21.9
12-17-90	1253	6.0	2.5	277	--	12.3	93	21.9
01-17-91	1230	1.0	1.0	331	7.7	--	--	52.0
01-17-91	1231	2.0	1.5	332	7.8	--	--	52.0
01-17-91	1232	4.0	3.0	328	7.6	--	--	52.0
01-17-91	1233	6.0	3.5	329	7.7	--	--	52.0

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time (24-hour)	Sampling depth (feet)	Temperature, water (°C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Transparency, secchi disk (in.)
			Corydon Reservoir, north arm (site 60, fig. 3)--Continued					
02-11-91	1430	1.0	4.5	153	7.5	7.4	--	48.3
02-11-91	1431	2.0	4.0	239	7.5	6.6	--	48.3
02-11-91	1432	4.0	3.5	334	7.4	6.0	--	48.3
02-11-91	1433	6.0	4.0	344	7.5	6.3	--	48.3
03-14-91	1550	1.0	6.0	263	5.9	12.8	106	18.6
03-14-91	1551	2.0	6.0	264	5.9	12.6	104	18.6
03-14-91	1552	4.0	5.5	264	5.9	12.7	104	18.6
03-14-91	1553	6.0	5.5	265	5.9	12.2	100	18.6
04-15-91	1337	1.0	13.5	280	7.8	9.5	94	7.6
04-15-91	1338	2.0	13.0	277	7.8	9.4	92	7.6
04-15-91	1339	4.0	12.5	277	7.8	9.5	92	7.6
04-15-91	1340	6.0	12.5	276	7.8	9.0	87	7.6
05-13-91	1454	1.0	28.0	191	--	7.3	96	4.0
05-13-91	1455	2.0	23.0	189	--	7.0	84	4.0
05-13-91	1456	4.0	22.5	190	--	6.7	79	4.0
05-13-91	1457	6.0	21.5	188	--	5.8	67	4.0
06-18-91	913	1.0	25.5	199	8.2	5.0	63	4.5
06-18-91	901	2.0	25.5	199	8.0	4.8	61	4.5
06-18-91	908	4.0	25.0	218	7.9	3.9	49	4.5
06-18-91	903	6.0	24.0	221	7.6	1.8	22	4.5
07-16-91	1012	1.0	25.5	225	7.9	5.1	64	7.6
07-16-91	1013	2.0	25.5	224	7.8	5.1	64	7.6
07-16-91	1014	4.0	25.5	224	7.8	5.0	63	7.6
07-16-91	1015	6.0	25.5	225	7.8	5.0	63	7.6
08-13-91	1403	1.0	26.0	237	8.6	8.6	109	33.9
08-13-91	1405	1.0	26.0	237	8.6	8.6	109	33.9
08-13-91	1402	2.0	26.0	237	8.6	8.2	104	33.9
08-13-91	1400	4.0	25.0	239	8.4	7.4	92	33.9
08-13-91	1401	6.0	24.5	241	8.2	5.8	--	33.9

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time (24-hour)	Sampling depth (feet)	Temperature, water (°C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Transparency, secchi disk (in.)
Corydon Reservoir, north arm (site 60, fig. 3)--Continued								
09-17-91	850	1.0	22.0	244	7.8	6.0	71	16.5
09-17-91	848	2.0	22.0	243	7.8	5.8	69	16.5
09-17-91	847	4.0	22.0	243	7.8	5.7	67	16.5
09-17-91	845	5.0	22.0	243	7.8	5.6	66	16.5
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)								
11-16-90	1239	2.0	9.0	245	8.3	10.8	95	--
11-16-90	1240	4.0	9.0	244	8.3	10.9	96	--
11-16-90	1330	6.0	9.0	244	8.3	10.8	95	--
11-16-90	1242	8.0	9.0	242	8.3	10.9	96	--
11-16-90	1243	10.0	9.0	242	8.3	10.8	95	--
11-16-90	1244	12.0	9.0	242	8.3	1.2	11	--
12-17-90	1200	1.0	2.5	274	--	12.3	93	21.5
12-17-90	1201	2.0	2.5	274	--	12.4	93	21.5
12-17-90	1202	4.0	2.5	275	--	12.2	92	21.5
12-17-90	1203	6.0	2.5	275	--	12.4	93	21.5
12-17-90	1204	8.0	2.5	275	--	12.3	92	21.5
12-17-90	1205	10.0	2.5	276	--	12.2	92	21.5
12-17-90	1206	12.0	2.5	277	--	10.0	75	21.5
01-17-91	1200	1.0	0.5	333	6.9	--	--	50.4
01-17-91	1201	2.0	1.5	333	6.8	--	--	50.4
01-17-91	1202	4.0	3.0	330	6.9	--	--	50.4
01-17-91	1203	6.0	3.5	337	6.9	--	--	50.4
01-17-91	1204	8.0	4.0	336	6.9	--	--	50.4
01-17-91	1205	10.0	4.0	339	6.9	--	--	50.4
02-11-91	1530	1.0	1.5	124	6.4	7.4	--	48.5
02-11-91	1531	2.0	4.0	236	5.9	6.0	--	48.5
02-11-91	1532	4.0	4.0	336	5.8	5.2	--	48.5
02-11-91	1533	6.0	4.0	345	5.9	5.6	--	48.5
02-11-91	1534	8.0	4.5	351	6.1	4.8	--	48.5
02-11-91	1535	10.0	5.0	369	6.0	4.0	--	48.5

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time (24-hour)	Sampling depth (feet)	Temper-ature, water (°C)	Specific conduct-ance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satura-tion)	Trans-parency, secchi disk (in.)
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)--Continued								
03-14-91	1606	1.0	6.5	259	5.8	12.7	106	17.4
03-14-91	1607	2.0	6.5	259	6.3	12.5	105	17.4
03-14-91	1608	4.0	6.5	259	6.4	12.0	100	17.4
03-14-91	1609	6.0	5.5	259	6.4	11.8	97	17.4
03-14-91	1610	8.0	5.5	260	6.3	11.8	97	17.4
03-14-91	1611	10.0	5.0	260	6.3	11.7	95	17.4
04-15-91	1402	1.0	14.0	279	7.9	9.7	97	5.5
04-15-91	1403	2.0	13.5	280	7.8	9.6	95	5.5
04-15-91	1404	4.0	13.0	273	7.8	9.6	94	5.5
04-15-91	1405	6.0	11.0	266	7.8	9.5	89	5.5
04-15-91	1406	8.0	12.5	262	7.7	9.1	87	5.5
04-15-91	1407	10.0	11.0	244	7.7	9.0	84	5.5
05-13-91	1422	1.0	29.0	192	7.7	7.5	100	3.3
05-13-91	1423	2.0	24.0	192	7.6	7.5	91	3.3
05-13-91	1424	4.0	22.5	188	7.6	6.6	78	3.3
05-13-91	1425	6.0	16.5	185	7.4	5.0	53	3.3
05-13-91	1426	8.0	14.0	187	7.4	4.1	41	3.3
05-13-91	1427	9.0	12.5	188	7.3	4.0	39	3.3
06-18-91	954	1.0	25.0	198	8.6	4.5	57	4.6
06-18-91	931	2.0	25.0	199	7.9	3.9	49	4.6
06-18-91	932	4.0	24.5	202	7.8	2.7	34	4.6
06-18-91	944	6.0	24.0	210	7.5	<.1	< 1	4.6
06-18-91	934	8.0	22.5	212	7.5	.2	2	4.6
06-18-91	935	10.0	20.0	226	7.4	.1	1	4.6
07-16-91	1045	1.0	25.5	223	7.8	5.0	63	8.7
07-16-91	1046	2.0	25.5	223	7.8	4.8	60	8.7
07-16-91	1047	4.0	25.0	224	7.8	4.3	54	8.7
07-16-91	1048	6.0	24.5	224	7.7	3.4	42	8.7
07-16-91	1049	8.0	24.0	228	7.6	2.4	29	8.7
07-16-91	1050	10.0	24.0	228	7.8	1.4	17	8.7

Table 5. *Selected physical properties and chemical constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time (24-hour)	Sampling depth (feet)	Temper-ature, water (°C)	Specific conduct-ance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satura-tion)	Trans-parency, secchi disk (in.)
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)--Continued								
08-13-91	1445	1.0	26.5	235	8.6	9.3	119	36.0
08-13-91	1446	2.0	26.5	235	8.8	9.5	121	36.0
08-13-91	1447	4.0	26.0	236	8.8	9.3	118	36.0
08-13-91	1448	6.0	26.0	237	8.7	8.8	112	36.0
08-13-91	1450	8.0	25.0	239	8.7	8.3	103	36.0
08-13-91	1451	10.0	24.0	246	7.9	3.3	40	36.0
08-13-91	1452	11.0	23.5	248	7.7	.8	10	36.0
09-17-91	927	1.0	23.0	244	7.9	5.4	65	13.8
09-17-91	926	2.0	23.0	244	7.9	5.3	64	13.8
09-17-91	925	4.0	23.0	243	7.9	5.2	63	13.8
09-17-91	924	6.0	23.0	243	7.9	5.3	64	13.8
09-17-91	923	8.0	23.0	243	7.9	5.2	63	13.8
09-17-91	922	10.0	23.0	243	7.9	5.1	62	13.8
Corydon Reservoir at the spillway (site 77, fig. 3)								
12-17-90	1345	1.0	3.0	288	--	12.4	94	--
01-17-91	1345	1.0	0	337	7.7	--	--	--
03-14-91	1639	1.0	7.5	261	6.4	12.8	110	--
04-15-91	1518	1.0	15.0	280	8.0	10.8	109	--
05-13-91	1630	1.0	30.0	192	--	9.0	123	--
06-18-91	1130	1.0	29.0	209	7.9	5.1	69	--

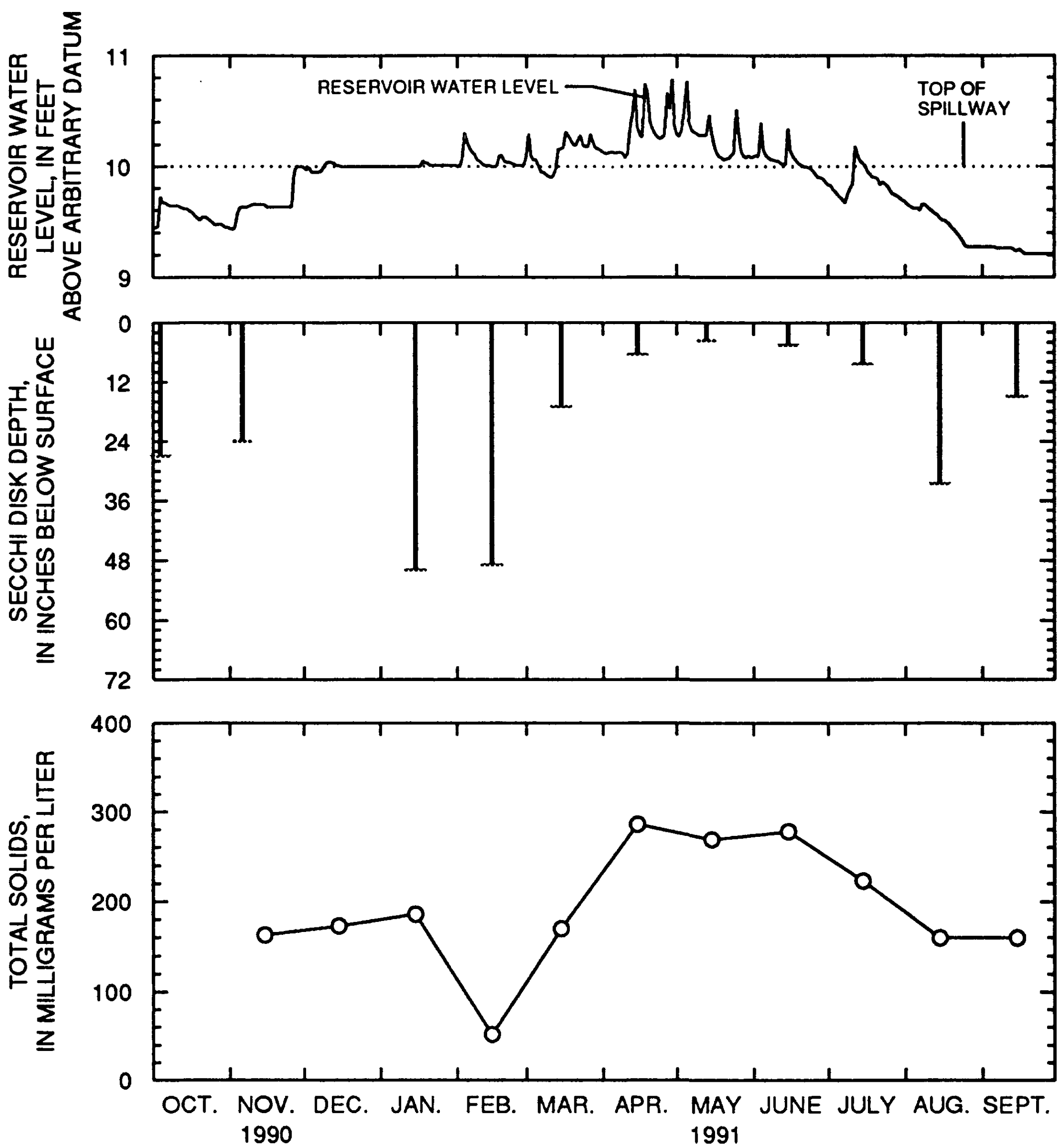

Figure 7. Daily mean reservoir level and monthly mean secchi depth and total-solids concentration in Corydon Reservoir, water year 1991.

The monthly mean total-nitrogen concentrations (nitrite plus nitrate nitrogen plus ammonia nitrogen plus organic nitrogen) increased from 0.80 mg/L in December 1990 to 3.5 mg/L in July 1991 and then decreased to 1.6 mg/L in August. Organic nitrogen was the predominant nitrogen species in 9 of the 11 sampling periods (fig. 8). Nitrite plus nitrate predominated in June and July after spring fertilizer applications. Peak ammonia nitrogen concentrations, which generally originate from the decomposition of organic matter, occurred in April and May.

The monthly mean total-phosphorus concentration increased from 0.05 mg/L in January 1991 to 0.34 mg/L in May 1991. Total-phosphorus concentrations were correlated with total-solids concentrations (r=0.74). This agrees with the findings of many researchers, including Meybeck (1982), who found that the particulate form of phosphorus constituted about 95 percent of the total phosphorus carried by streams.

Herbicides

Concentrations of herbicides in water from Corydon Reservoir were dependent on the time

Table 6. *Selected chemical and biological constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*

[deg. C, degrees Celsius; mg/ L, milligrams per liter; N, nitrogen; µg/L, micrograms per liter; cols./100 mL, colonies per 100 milliliters; <, less than detection level indicated; --, no data]

Date	Time	Sampling depth (feet)	Solids, residue at 105 deg. C, total (mg/L)	Solids, volatile on ignition, total (mg/L)	Nitrogen, NO_2+ NO_3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Phosphorus total (mg/L as P)	Chlorophyll-*a*, plankton (µg/L)	Coliform, fecal, bacteria (cols./ 100 mL)	Streptococci, fecal, bacteria (cols./ 100 mL)
Corydon Reservoir, 2,150 feet upstream from dam (site 40, fig. 3)											
11-16-90	1417	1.0	167	71	0.10	0.07	0.73	0.05	--	9	6
11-16-90	1415	4.0	151	45	.10	.07	.63	.05	--	--	--
12-17-90	1300	1.0	168	49	.20	.03	--	.08	7.4	--	21
01-17-91	1305	1.0	177	128	.30	.09	.91	.05	2.1	2	--
02-11-91	1400	1.0	58	54	.40	.40	1.0	.20	.30	15	76
03-14-91	1525	1.0	182	78	.58	.07	1.4	.16	18.0	--	80
04-15-91	1300	1.0	298	67	1.0	.41	1.2	.29	1.9	5,500	1,400
05-13-91	1520	1.0	274	66	.93	.42	1.4	.34	2.4	39	110
05-13-91	1522	4.0	261	98	.94	.44	1.2	.35	--	--	--
06-18-91	0845	1.0	292	88	1.70	.15	1.2	.28	3.4	6,000	200
06-18-91	0840	4.0	293	90	1.80	.12	1.1	.27	--	--	--
07-16-91	0923	1.0	222	77	2.0	.17	1.3	.20	2.9	40	77
07-16-91	0925	4.0	219	78	2.0	.14	1.1	.19	--	--	--
08-13-91	1319	4.0	153	65	.71	.02	.78	.09	--	--	--
08-13-91	1325	4.0	165	47	.72	.04	.66	.09	--	--	--
08-13-91	1330	1.0	158	85	.72	.02	--	.08	1.0	37	70
09-17-91	0823	1.0	169	82	.06	.34	.96	.20	1.6	37	70
09-17-91	0820	4.0	153	99	< .05	.31	.99	.15	--	--	--
Corydon Reservoir, north arm (site 60, fig. 3)											
11-16-90	1350	1.0	162	70	<0.10	0.08	0.82	0.06	--	8	8
11-16-90	1345	4.0	163	50	< .10	.08	.92	.05	--	--	--
12-17-90	1250	1.0	174	45	.20	.03	.57	.07	8.3	--	23
01-17-91	1230	1.0	191	134	.30	.08	.82	.05	4.7	3	7
02-11-91	1430	1.0	--	--	.30	.35	.45	.26	.50	3	30
03-14-91	1550	1.0	176	83	.53	.09	1.4	.17	16	--	27
04-15-91	1337	1.0	283	74	.92	.39	.61	.24	1.5	5,100	1,200
05-13-91	1454	1.0	262	82	.93	.41	1.2	.33	3.0	93	100
05-13-91	1456	4.0	269	92	.92	.43	1.3	.34	--	--	--
06-18-91	0913	1.0	276	116	1.8	.15	1.1	.28	3.4	6,000	83

Table 6. *Selected chemical and biological constituents in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time	Sampling depth (feet)	Solids, residue at 105 deg. C, total (mg/L)	Solids, volatile on ignition, total (mg/L)	Nitrogen, NO_2+ NO_3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Phosphorus total (mg/L as P)	Chlorophyll-*a*, plankton (µg/L)	Coliform, fecal, bacteria (cols./ 100 mL)	Streptococci, fecal, bacteria (cols./ 100 mL)
Corydon Reservoir, north arm (site 60, fig. 3)--Continued											
06-18-91	0908	4.0	183	58	1.7	0.18	1.0	0.29	--	--	--
07-16-91	1012	1.0	225	66	2.0	.15	1.2	.22	2.4	70	29
07-16-91	1014	4.0	227	75	2.1	.15	1.2	.23	--	--	--
08-13-91	1403	1.0	155	45	.73	.02	.88	.08	7.0	53	63
08-13-91	1400	4.0	168	44	.75	.03	.87	.09	--	--	--
08-13-91	1405	1.0	160	51	.73	.01	--	.08	8.6	59	69
09-17-91	0850	1.0	163	107	< .05	.27	.93	.17	3.0	63	59
09-17-91	0847	4.0	138	81	< .05	.27	.93	.14	--	--	--
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)											
11-16-90	1316	--	172	63	<0.10	0.09	0.81	0.06	--	31	8
11-16-90	1330	6.0	164	57	.10	.08	.82	.05	--	--	--
12-17-90	1200	1.0	178	81	.20	.04	--	.08	3.8	--	10
01-17-91	1200	1.0	190	124	.30	.07	.73	.04	2.1	4	7
02-11-91	1530	1.0	47	35	.30	.26	.54	.13	.30	7	52
03-14-91	1606	1.0	153	72	.52	.10	1.4	.15	23	--	23
04-15-91	1402	1.0	302	72	1.0	.41	1.1	.28	2.8	4,500	1,400
05-13-91	1422	1.0	261	87	.94	.42	1.5	.34	2.4	56	110
05-13-91	1426	8.0	292	82	.85	.55	1.2	.35	--	--	--
06-18-91	0954	1.0	293	110	1.8	.15	1.1	.26	2.1	6,000	200
06-18-91	0944	6.0	317	96	2.0	.40	1.6	.29	--	--	--
07-16-91	1045	1.0	222	74	2.1	.14	1.5	.21	--	57	57
07-16-91	1048	6.0	224	65	2.0	.17	1.5	.20	--	--	--
08-13-91	1445	1.0	155	53	.73	.02	.98	.08	5.3	55	49
08-13-91	1450	8.0	165	51	.75	.02	.68	.07	--	--	--
09-17-91	0927	1.0	170	96	< .05	.30	.80	.15	2.4	55	49
09-17-91	0924	6.0	165	93	< .05	.30	1.0	.15	--	--	--
Corydon Reservoir at the spillway (site 77, fig. 3)											
12-17-90	1345	1.0	--	--	0.20	0.03	0.57	--	--	--	--
01-17-91	1345	1.0	--	--	.30	.08	.72	0.04	--	--	--
03-14-91	1639	1.0	--	--	.51	.15	1.3	.14	--	--	--
04-15-91	1518	1.0	263	86	.88	.36	1.2	.25	--	--	--
05-13-91	1630	1.0	263	100	.90	.20	1.2	.32	--	--	--
06-18-91	1130	1.0	292	77	1.7	.19	1.2	.29	--	--	--

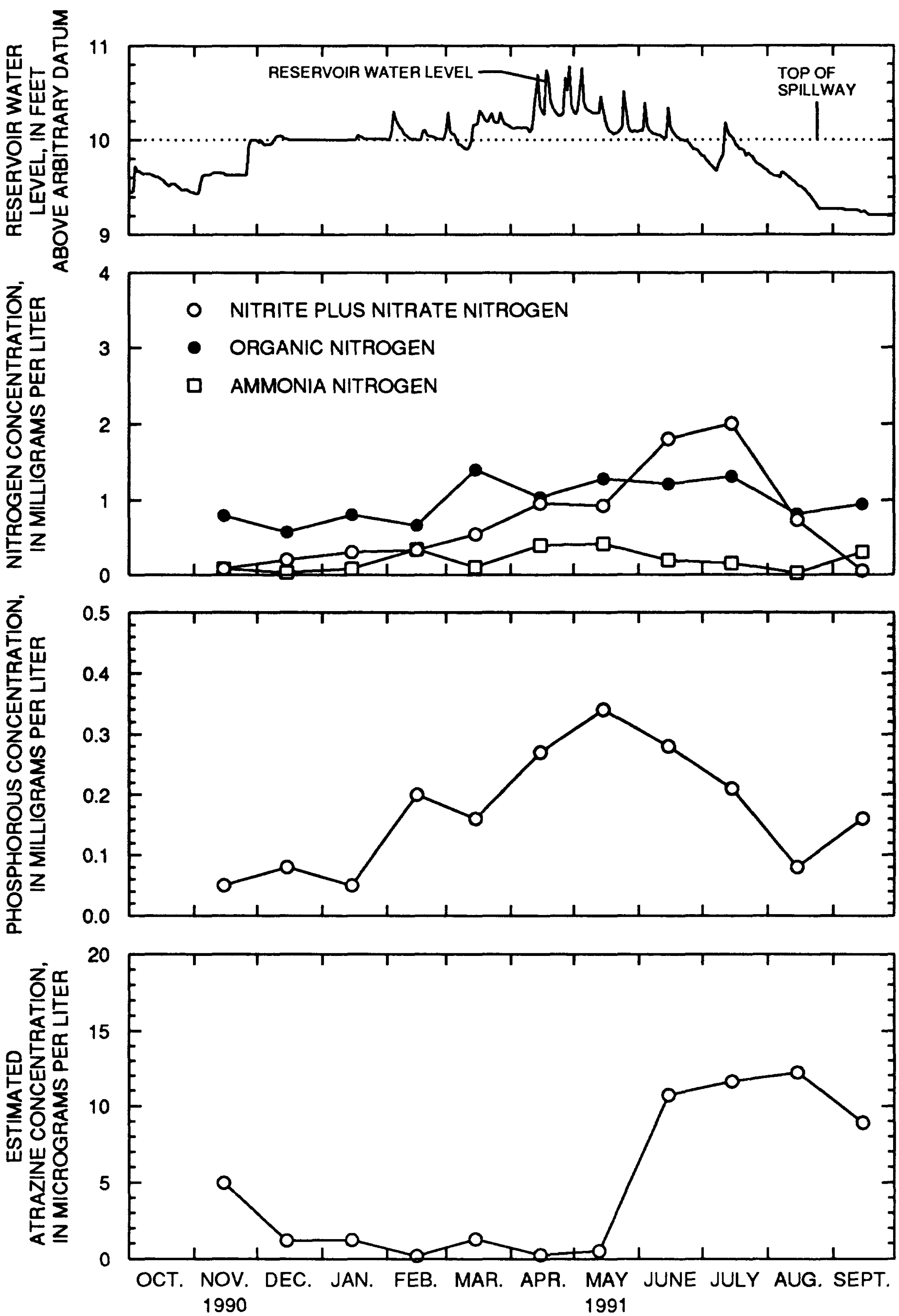

Figure 8. Daily mean reservoir level and mean monthly nitrogen, phosphorus, and estimated-atrazine concentrations in Corydon Reservoir, water year 1991.

of application in the basin rather than varying seasonally. Herbicide application data were not available, but precipitation contributed about 1.2 lb of triazine herbicides to the basin from the end of April through the first part of August 1991 (table 7). Estimated-atrazine concentrations were generally less than 2.0 µg/L from December 1990 until June 1991. Estimated-atrazine concentrations abruptly increased to more than 10 µg/L in June 1991 (fig. 8 and table 8). Most of the herbicide application probably occurred between the May and June sampling periods. Rainfall causing runoff then transported herbicides to the reservoir.

The results of the GC/MS analyses of samples from Corydon Reservoir indicate that atrazine and cyanazine were the predominant triazine herbicides in solution (table 9). Atrazine constituted about 45 percent of the total triazines in samples collected during March and from 28 to 36 percent of the triazines in samples collected during June, July, and August. Conversely, cyanazine constituted 30 percent of the triazines in March and from 59 to 65 percent of the triazines in the summer samples. The sum of all triazine herbicides and two atrazine degradation products (deethylatrazine and deisopropylatrazine) ranged from less than 2.0 µg/L in March to greater than 50 µg/L in one sample in August.

Two acetanilide herbicides (alachlor and metolachlor) were also detected in water samples by GC/MS analyses (table 9). Alachlor was detected in about 80 percent of the samples, and metolachlor was detected in all samples. Alachlor concentrations ranged from less than 0.05 to 0.39 µg/L, and metolachlor concentrations ranged from 0.09 to 0.43 µg/L.

The composition of the agricultural chemicals in Corydon Reservoir during 1991 was substantially different from the summer of 1986. During the summer of 1986, atrazine and metolachlor were the predominant herbicides in one sample (Wnuk and others, 1987). In contrast, the predominant herbicide in samples, collected in 1991 was cyanazine with lesser concentrations of atrazine. The maximum metolachlor concentration found in Corydon Reservoir during the summer of 1991 was 0.43 µg/L compared to the concentration of more than 20 µg/L in the summer of 1986. The reduction in metolachlor and the increase in cyanazine from 1986 to 1991 may be related to changing chemical usage or weather conditions.

Once applied and transported into the reservoir by precipitation runoff, atrazine remained stored in the reservoir through the end of the water year. Monthly mean atrazine concentrations, estimated from ELISA, remained greater than 10 µg/L during June, July, and August and decreased to 8.9 µg/L in September. During this period, the reservoir water level dropped below the top of the spillway and, except for 2 days in July, the only water leaving the reservoir was from municipal withdrawal by the City of Corydon.

Biological Constituents

Biological constituents are indicators of the physical and chemical conditions in Corydon Reservoir. Chlorophyll-*a*, the primary photosynthetic pigment of phytoplankton, was used to evaluate the algal population. Enumeration of fecal coliform and fecal streptococci bacteria was used to estimate the amount of animal and human wastes entering the reservoir. Total organic carbon was used to estimate the amount of all biologically derived material, living and dead, in the reservoir. Dissolved oxygen was included with the biological constituents because dissolved oxygen is closely related to the distribution, behavior, and physiological growth of aquatic organisms (Wetzel, 1983).

The phytoplankton population of Corydon Reservoir remained relatively constant through the year even though nutrient concentrations increased. The monthly mean chlorophyll-*a* concentrations generally ranged from 0.37 to 6.5 µg/L (table 6). One exception was in March when the monthly mean concentration was 19 µg/L (fig. 9). The peak chlorophyll-*a* concentration in March is probably indicative of the increase in phytoplankton population with the onset of improved light conditions and the circulation of nutrient-rich water (Wetzel, 1983, p. 371). Three factors may be important in controlling the algae population. The first factor may be the large concentrations of particulate material. As discussed previously, the solids transported to the reservoir by runoff reduced light penetration substantially in April through July. Thus algae production, dependent on sunlight for

Table 7. *Precipitation and triazine deposition in the Corydon Reservoir watershed, Wayne County, Iowa, March 19 to September 30, 1991*

[in., inches; µg/L, micrograms per liter; lb, pounds; <, less than detection level indicated; --, no data]

Beginning date	Ending date	Precipitation (in.)	Triazine concentration,[1] precipitation (µg/L)	Triazine deposition (lb)
03-19-91	03-27-91	1.14	<.10	<0.04
03-27-91	04-09-91	.38	<.10	< .01
04-09-91	04-16-91	2.45	<.10	< .09
04-16-91	04-23-91	2.39	<.10	< .09
04-23-91	04-30-91	2.32	.12	.11
04-30-91	05-07-91	2.01	<.10	< .08
05-07-91	05-14-91	1.39	.17	.09
05-14-91	05-21-91	.83	.20	.06
05-21-91	05-28-91	2.74	.35	.36
05-28-91	06-04-91	2.46	.27	.25
06-04-91	06-11-91	.11	.44	.02
06-11-91	06-18-91	1.13	.22	.09
06-18-91	06-25-91	.02	<.10	< .00
06-25-91	07-09-91	1.25	.15	.07
07-09-91	07-16-91	1.88	.13	.09
07-16-91	07-23-91	.31	.20	.02
07-23-91	07-30-91	.25	<.10	< .01
07-30-91	08-06-91	.52	<.10	< .02
08-06-91	08-13-91	.68	.10	.03
08-13-91	08-20-91	.22	<.10	< .01
08-20-91	08-27-91	0	--	--
08-27-91	09-03-91	.54	<.10	< .02
09-03-91	09-10-91	1.54	<.10	< .06
09-10-91	09-17-91	.77	<.10	< .03
09-17-91	09-24-91	.26	<.10	< .01
09-24-91	09-30-91	0	--	--

[1] Estimated using enzyme-linked immunosorbent assay techniques (Thurman and others, 1990).

Table 8. *Triazine concentrations in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*

[µg/L, micrograms per liter; >, greater than value indicated; --, no data]

Date	Time	Sampling depth (feet)	Triazine, enzyme-linked immuno-sorbent assay total (µg/L)	Estimated atrazine, total (µg/L)
Corydon Reservoir, 2,150 feet upstream from dam (site 40, fig. 3)				
11-16-90	1417	1.0	>10	> 4.9
11-16-90	1415	4.0	>10	> 4.9
12-17-90	1300	1.0	3.2	1.2
01-17-91	1305	1.0	2.8	1.0
02-11-91	1400	1.0	.63	.17
03-14-91	1525	1.0	2.4	.87
04-15-91	1300	1.0	.95	.28
05-13-91	1520	1.0	.86	.25
05-13-91	1522	4.0	.62	.17
06-18-91	0845	1.0	--	--
06-18-91	0840	4.0	19	11
07-16-91	0923	1.0	--	--
07-16-91	0925	4.0	--	--
08-13-91	1330	1.0	13	6.8
08-13-91	1325	4.0	21	12
09-17-91	0823	1.0	21	12
09-17-91	0820	4.0	21	12
Corydon Reservoir, north arm (site 60, fig. 3)				
11-16-90	1350	1.0	>10	> 4.9
11-16-90	1345	4.0	>10	> 4.9
12-17-90	1250	1.0	3.1	1.2
01-17-91	1230	1.0	3.4	1.3
02-11-91	1430	1.0	.70	.19
03-14-91	1550	1.0	3.6	1.4
04-15-91	1337	1.0	.72	.20
05-13-91	1454	1.0	.82	.23
05-13-91	1456	4.0	1.2	.37
06-18-91	0913	1.0	18	10

Table 8. *Triazine concentrations in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*--Continued

Date	Time	Sampling depth (feet)	Triazine, enzyme-linked immuno-sorbent assay total (µg/L)	Estimated atrazine, total (µg/L)
Corydon Reservoir, north arm (site 60, fig. 3)--Continued				
06-18-91	0908	4.0	16	11
07-16-91	1012	1.0	--	--
07-16-91	1014	4.0	--	--
08-13-91	1403	1.0	--	--
08-13-91	1405	1.0	--	--
08-13-91	1400	4.0	15	8.1
09-17-91	0850	1.0	23	14
09-17-91	0847	4.0	26	16
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)				
11-16-90	1316	--	>10	> 4.9
11-16-90	1330	6.0	>10	> 4.9
12-17-90	1200	1.0	3.0	1.1
01-17-91	1200	1.0	3.2	1.2
02-11-91	1530	1.0	.43	.11
03-14-91	1606	1.0	4.0	1.6
04-15-91	1402	1.0	.64	.17
05-13-91	1422	1.0	--	--
05-13-91	1426	8.0	1.4	.45
06-18-91	0954	1.0	--	--
06-18-91	0944	6.0	--	--
07-16-91	1045	1.0	16	8.8
07-16-91	1048	6.0	24	14
08-13-91	1445	1.0	21	12
08-13-91	1450	8.0	33	21
09-17-91	0927	1.0	25	15
09-17-91	0924	6.0	33	21
Corydon Reservoir at the spillway (site 77, fig. 3)				
12-17-90	1345	1.0	3.1	1.2
01-17-91	1345	1.0	--	--
03-14-91	1639	1.0	3.0	1.1
04-15-91	1518	1.0	1.1	.33
05-13-91	1630	1.0	3.8	1.5
06-18-91	1130	1.0	22	13

Table 9. *Selected herbicides in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*

[Herbicide concentrations in micrograms per liter; <, less than detection level indicated]

Date	Sampling depth (feet)	Alachlor, dissolved	Ametryn, dissolved	Atrazine, dissolved	Cyanazine, dissolved	Deethylatrazine, dissolved	Deisopropylatrazine, dissolved	Metolachlor, dissolved	Metribuzin, dissolved	Prometon, dissolved	Prometryn, dissolved	Propazine, dissolved	Simazine, dissolved
Corydon Reservoir, 2,150 feet upstream from dam (site 40, fig. 3)													
03-14-91	1.0	<0.05	<0.05	0.99	0.65	0.37	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.17
06-18-91	1.0	.10	< .05	12	20	.86	.70	.31	< .05	.05	< .05	.10	.10
08-13-91	1.0	.28	.09	17	33	1.6	1.1	.43	< .05	< .05	< .05	.14	.15
08-13-91	4.0	.21	.13	13	26	1.4	1.5	.30	< .05	.20	< .05	.11	.14
Corydon Reservoir, north arm at Corydon (site 60, fig. 3)													
06-18-91	4.0	0.06	<0.05	11	21	0.68	0.59	0.19	<0.05	0.05	<0.05	0.07	0.08
08-13-91	1.0	.22	.13	12	26	1.4	1.4	.32	< .05	.21	< .05	.11	.13
08-13-91	1.0	.21	.13	12	27	1.4	1.4	.32	< .05	.20	< .05	.11	.13
Corydon Reservoir, 350 feet upstream from dam (site 90, fig. 3)													
03-14-91	1.0	<0.05	<0.05	0.89	0.58	0.30	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.15
06-18-91	6.0	.11	< .05	14	26	.88	.71	.31	< .05	.06	< .05	.10	.11
07-16-91	1.0	.39	.07	7.0	16	1.2	< .05	.38	.10	.09	.05	.12	.13
08-13-91	8.0	.21	.13	12	25	1.3	1.3	.30	< .05	.20	< .05	.11	.12

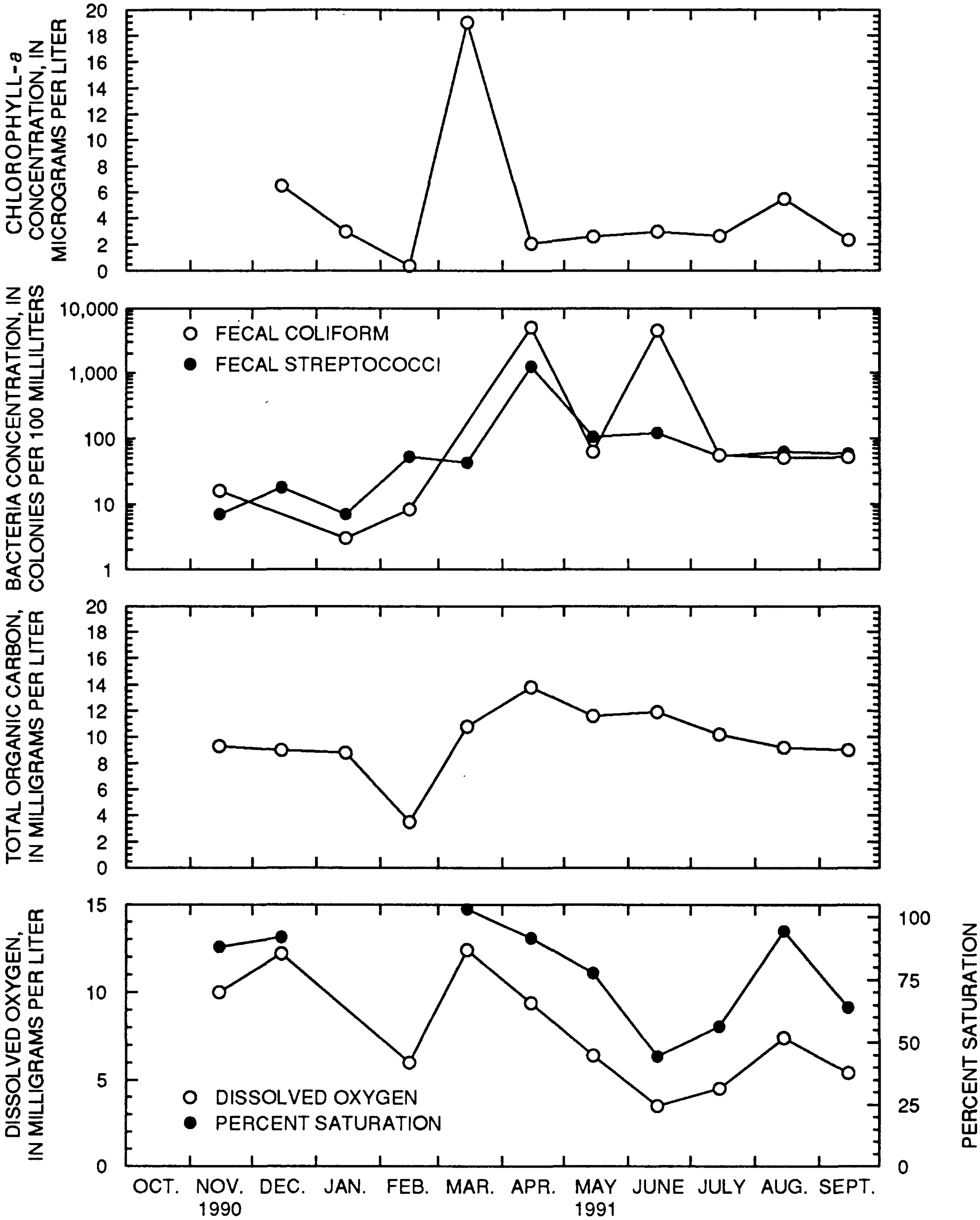

Figure 9. Monthly mean chlorophyll-*a*, bacteria, total organic carbon, and dissolved-oxygen concentrations in Corydon Reservoir, water year 1991.

photosynthesis, was limited to the uppermost part of the water column. A second factor may be the presence of herbicides. Estimated-atrazine concentrations exceeded 8.0 µg/L from June through September. Atrazine, one of the triazine herbicides detected in Corydon Reservoir, inhibits the process of photosynthesis (Esser and others, 1975) and thus may limit algal production. Atrazine concentrations from 1.0 to 5.0 µg/L have been found to affect algae populations (DeNoyelles and others, 1982). Conversely, research has shown that some species are resistent to the effects of triazine herbicides and that these algae species may become established and flourish (Hersh and Crumpton, 1987; DeNoyelles and others, 1982). Late in summer, algal populations were reduced through the application of an algicide (copper sulfate). Algicide was applied to the reservoir on August 18 and September 3, 1991, to control the algae population (Don MaGee, Water Superintendent, City of Corydon, oral commun., 1992).

In contrast to the algal population, the concentrations of fecal coliform and fecal streptococci, organisms that normally live in the intestines of animals and humans, varied seasonally in relation to runoff. The greatest populations of both fecal coliform and fecal streptococci bacteria occurred during April and June, months when the reservoir level was variable because of precipitation runoff. The monthly mean population of fecal coliform was more than 5,000 and 4,500 col/100 mL (colonies per 100 milliliters) in April and June, respectively. The mean fecal streptococci population was 1,250 and 122 col/100 mL during April and June, respectively. The smallest bacterial populations (less than 10 col/100 mL) occurred in January when the reservoir was ice covered, the reservoir water level was constant, and runoff was minimal.

Seasonally, concentrations of total organic carbon varied slightly (table 10). Concentrations were largest during months when the largest volume of runoff entered the reservoir (fig. 9). Total-organic-carbon concentrations increased from less than 10 mg/L during the winter months to about 14 mg/L in April. Although organic carbon in the reservoir originates from several sources each with a different C:N (organic carbon to organic nitrogen) ratio, runoff from animal production may be a major source. Organic matter from animal wastes has a relatively high organic nitrogen content, and thus the C:N ratios are probably less than 10. Cropland residues undergo decomposition in which much of the organic nitrogen can be utilized, and thus the C:N ratios range from 45:1 to 50:1 (Hutchinson, 1957). Organic matter produced by decomposition of plankton in the reservoir typically has a C:N ratio of about 12:1. The C:N ratio of samples collected during months where there was substantial inflow to the reservoir (April to June) from runoff had C:N ratios, with the exception of April, that were less than 10.

The monthly mean dissolved-oxygen concentrations ranged from 3.5 mg/L during June to 12.4 mg/L during March, which corresponds to monthly mean saturations of 44 and 103 percent, respectively (fig. 9 and table 5). The largest concentration was in March when light penetration was 17 in., and the smallest concentrations were in June when the light penetration was the least and the total-solids concentrations were the largest. Dissolved-oxygen concentrations in March exceeded 100-percent saturation, which indicates that oxygen input into the reservoir by diffusion and photosynthesis exceeded diffusion out of the reservoir and the metabolic and decomposition processes that consume oxygen. Dissolved-oxygen concentrations were less than 50-percent saturation in June. A combination of factors may have caused oxygen to be removed faster than it could be replenished. Increased particulate matter from runoff decreased light penetration, causing decreased oxygen production by photosynthesis, and increased organic decomposition, which caused increased oxygen consumption.

Water-Quality Stratification

The water quality of Corydon Reservoir varied not only seasonally but also varied vertically during water year 1991. Thermal and chemical stratification were observed at sampling site 90 during two periods (fig. 10 and table 5). During the winter, inverse stratification, colder temperatures at the surface, was observed in the deepest part of the reservoir. This pattern occurred in both January and February. In February, air temperature

Table 10. *Monthly mean organic-nitrogen and organic-carbon concentrations in water from Corydon Reservoir, Wayne County, Iowa, water year 1991*

[N, nitrogen; mg/L, milligrams per liter; C:N, organic carbon to organic nitrogen; --, no data]

Month	Carbon, organic total (mg/L)	Nitrogen, organic total (mg/L as N)	C:N ratio
		1990	
October	--	--	--
November	9.3	0.79	12
December	9.0	.57	16
		1991	
January	8.8	.80	11
February	3.5	.66	6.5
March	11	1.4	7.7
April	14	1.0	14
May	12	1.3	9.1
June	12	1.2	9.9
July	10	1.3	7.8
August	9.2	.81	12
September	9.8	.77	13

rose above freezing, and snowmelt occurred. The snowmelt produced runoff that entered the reservoir, as evidenced by the peaks in reservoir water level. Snowmelt water was cold (0 °C) and very dilute. Rather than mixing upon entering the reservoir, the less-dense snowmelt flowed along the top of the reservoir under the ice. The water temperature under the ice was 1.5 °C compared to about 4.0 °C in the rest of the water column. The specific conductance of the water near the surface was less (124 μS/cm), and the dissolved-oxygen was greater (7.4 mg/L) than in the deeper water (table 5). Therefore, the runoff from this snowmelt probably moved rapidly through the reservoir without mixing and did not have a great effect on the water quality of the reservoir.

The second period of stratification occurred as the water warmed in the spring. Stratification developed during the end of April and the first part of May. At site 90, the water temperature at the surface increased from 14.0 °C on April 15 to 29.0 °C on May 13. During the same period, water temperatures near the reservoir bottom remained nearly constant. On May 13, the dissolved-oxygen concentration decreased from 100-percent saturation at the surface to about 40-percent saturation near the bottom. Specific conductance and pH were nearly constant through the water column (fig. 10). Stratification also was evident in the shallower parts of the reservoir in May. Water temperatures at site 40 decreased from 28.0°C at the surface to 21.0 °C near the bottom and at site 60 decreased from 28.0°C at the surface to 21.5 °C near the bottom. Stratification continued through the middle of June in the deeper parts of the reservoir. Slight temperature differences (1.5 to 3.0 °C) at site 90 were noted in July and August. The dissolved-oxygen concentration decreased substantially from the surface to the bottom in the deeper parts of the reservoir throughout the summer. Depletion of oxygen near the bottom indicates that biological decomposition of organic

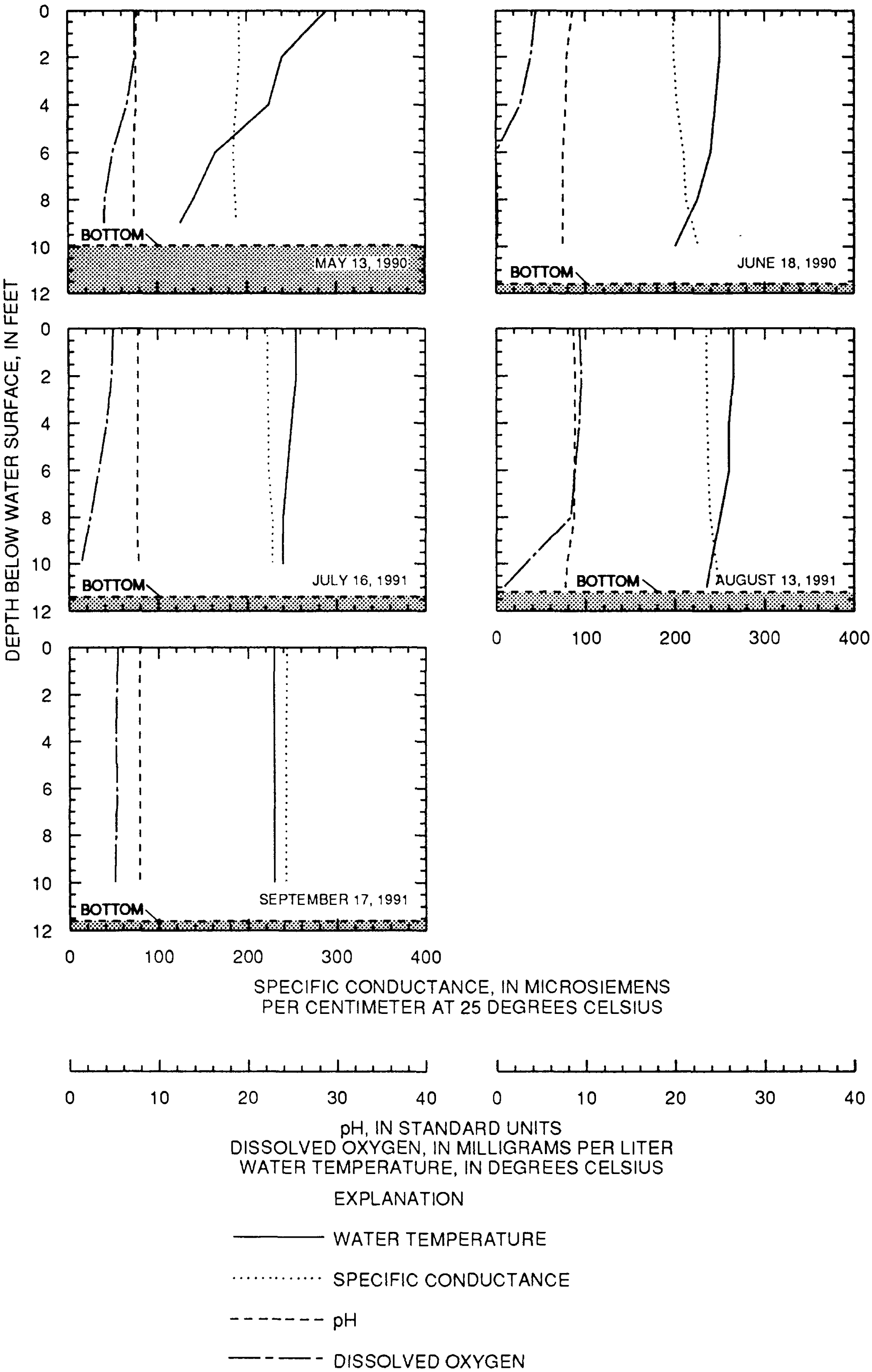

Figure 10. Vertical water temperature, specific conductance, pH, and dissolved-oxygen profiles at sampling site 90, Corydon Reservoir, water year 1991.

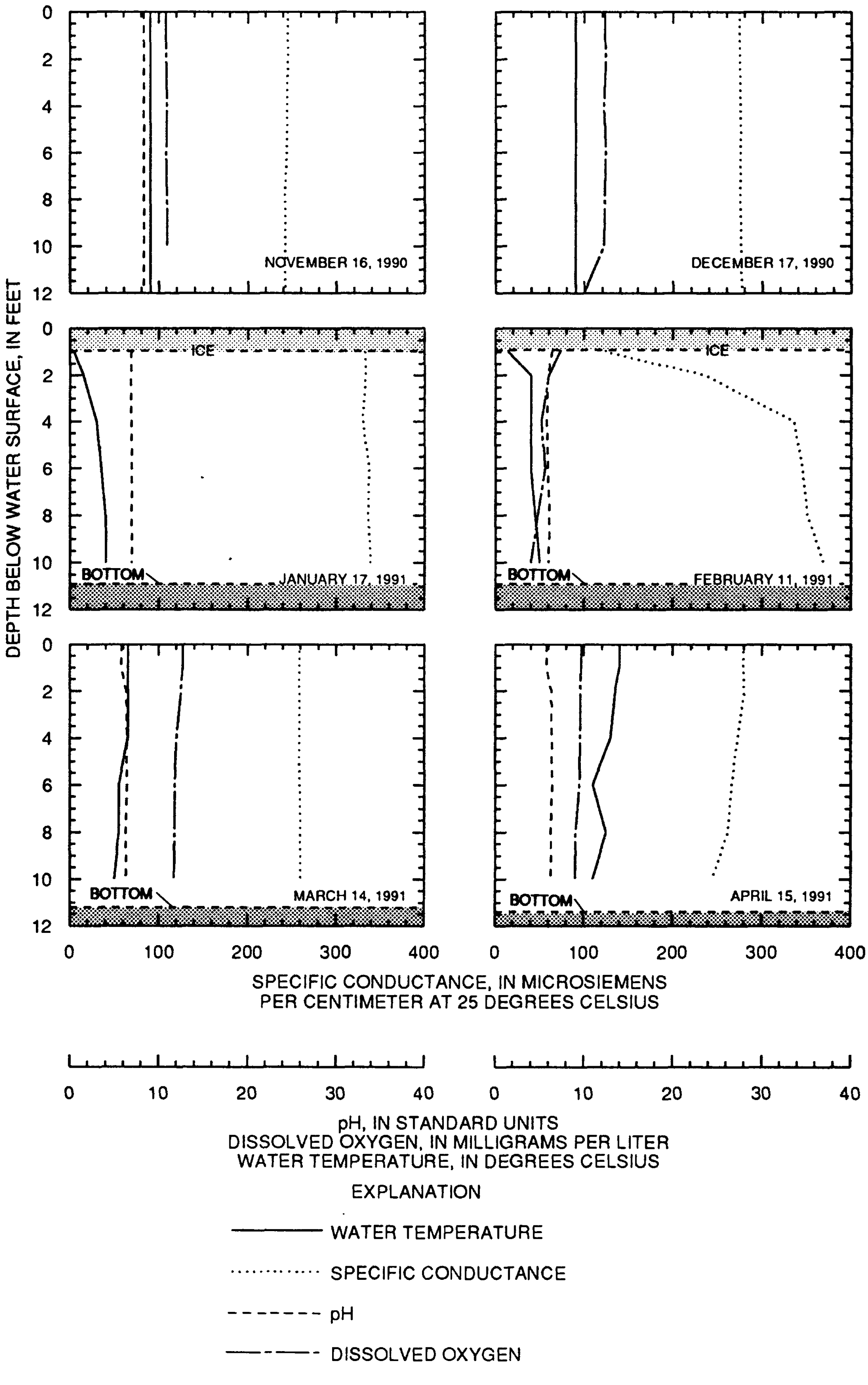

Figure 10. Vertical water temperature, specific conductance, pH, and dissolved-oxygen profiles at sampling site 90, Corydon Reservoir, water year 1991--Continued

material was occurring and that surficial waters, saturated with oxygen, were not mixing rapidly with the deeper waters. Temperature and oxygen stratification did not appear to be accompanied by large vertical differences in the concentration of nitrogen species (table 6), but atrazine concentrations commonly were greater at increased depths (table 8).

SUMMARY AND CONCLUSIONS

An investigation to document the effects of agricultural land-use practices before the initiation of best-management practices on the water quality of the Corydon water-supply reservoir was conducted from September 1990 to September 1991. Historical water-quality data, an initial reservoir appraisal, and 1 year of monthly sampling were used to document the water quality.

Corydon Reservoir is located in central Wayne County, Iowa; covers about 58 acres; and contains about 344 acre-ft of water. The source of water in the reservoir is primarily runoff from the 1,680-acre agricultural basin. Fertilizers and herbicides are used in the production of corn and soybeans, the two main crops grown in the basin.

Sediment eroded from the basin has filled part of the reservoir, which has required that the dam be raised to increase the reservoir storage capacity. Concentrations of two herbicides, atrazine and metolachlor, exceeded 20 μg/L in June 1986.

The results of an initial areal appraisal of the water quality of the reservoir on September 19 and 20, 1990, indicate that, with the exception of atrazine concentrations, there was little water-quality variation in the reservoir. The reservoir was not stratified, nitrite-plus-nitrate concentrations were less than 0.10 mg/L, and total-phosphorus concentrations were less than 0.20 mg/L. Estimated-atrazine concentrations decreased from 2.7 μg/L in the north arm of the reservoir to 0.85 μg/L near the dam.

The results of the monthly sampling indicated that runoff into the reservoir was greatest from April through July during the periods of greatest rainfall. Several physical, chemical, and biological constituents were related to runoff into the reservoir. Total-solids concentrations were largest and transparency of reservoir water was the least during months of largest runoff. Concentrations of nitrite-plus-nitrate and estimated triazines were largest after application in late May and early June. The concentrations of the sum of all triazines analyzed exceeded 50 μg/L in one sample in August. Atrazine and cyanazine were the predominant triazine herbicides in solution. The atrazine concentration was greater than 8.0 μg/L from June through September due to storage in the reservoir. Even though nutrient concentrations increased, the algae population remained relatively constant. Three factors may be controlling the algae population--light reduction due to suspended solids, the presence of herbicides, and the application of algicides. Concentrations of total organic carbon varied seasonally in relation to runoff. One source of the organic carbon, as indicated by C:N ratios, may be from animal wastes. Bacterial decomposition of this organic matter may cause decreased dissolved-oxygen concentrations during summer months.

The water quality in Corydon Reservoir not only varied seasonally but varied vertically at times during water year 1991. Inverse stratification occurred in February when snowmelt entered the reservoir and flowed along the top of the water column. Warming in the spring caused the reservoir to become thermally stratified in May and June. Dissolved-oxygen concentrations decreased from the surface to the bottom in the deeper parts of the reservoir. Temperature and oxygen stratification did not appear to be accompanied by large vertical differences in the concentration of nitrogen species, but atrazine concentrations commonly were greater at increased depths.

The data presented in this report will be useful in comparing 1991 reservoir water quality and discharge to water quality and discharge after the installation of conservation structures, such as terraces and grass waterways, to control runoff and after the initiation of agricultural best-management practices designed to make more efficient use of agricultural chemicals.

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