Relations Between Quality of Urban Runoff and Quality of Lake Ellyn at Glen Ellyn, Illinois

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U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2301

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1987

For sale by the Books and Open-File Reports Section, U.S. Geological Survey,
Federal Center, Box 25425, Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Striegl, Robert G.
Relations between quality of urban runoff and quality of
Lake Ellyn at Glen Ellyn, Illinois.
(U.S. Geological Survey water-supply paper; 2301)
Bibliography: p.
Supt. of Docs. no.: I 19.13:2301
1. Water quality—Illinois—Ellyn, Lake. 2. Urban runoff—
Illinois—Ellyn, Lake. 3. Water chemistry.
I. Cowan, Ellen A. II. Title. III. Series.
TD225.E45S77 1986 363.7'39456'0977324 86–600044

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Abstract

Comparison of flow and chemical data collected at the principal inlet and at the outlets of Lake Ellyn—an urban lake in the Chicago metropolitan area—shows that detention storage alters the discharge and the quality of urban runoff. Peak water discharge and variation in the concentration of constituents transported by the runoff are usually reduced. Mass-balance relations based on comparison of measured constituent loads at the inlet and the outlets show that the lake is very efficient in trapping suspended solids, suspended sediment, and sediment-associated metals. Calculated trap efficiencies for many dissolved constituents were negative. However, negative efficiencies appear to be influenced mostly by insufficient sampling in winter. Trap efficiencies for nitrogen and phosphorus are intermediate to those determined for other constituents.

Solids accumulate on the lake bottom as organic-rich muds that reduce lake storage and cover potential habitat for aquatic organisms. Lake sediments, particularly fine-grained sediments, have elevated concentrations of metals associated with them. Several organic compounds, not detected in inlet- or outlet-water samples, were detected in a lake-sediment sample collected near the inlet.

Concentrations of many constituents dissolved in lake water are seasonally cyclic, with annual concentration peaks occurring during the winter. Establishment and maintenance of desirable benthic invertebrate and fish populations appear to be inhibited by sediment deposition.

INTRODUCTION

Properly managed lakes and ponds are assets to urban areas. They are pleasant visual features in the urban landscape, and they provide sites for recreational activity and attractive settings for homes and businesses. Areas with lakes and ponds generally have high real estate values, and many afford wildlife a refuge from the urban environment.

Lakes and ponds also have practical values of a hydrologic nature that often are not recognized by urban dwellers. Land managers and planners have long known that routing storm runoff through a lake or pond reduces flooding in downstream areas (Rutter and Engstrom, 1964; Dunne and Leopold, 1978; Nacht, 1981). This practice, commonly called "detention storage," has also been used to reduce the amount of sediment transported in runoff from construction sites. Scientists and engineers have become aware that detention storage may also play an important role in changing the chemical characteristics of runoff (Cherkauer, 1977; McCuen, 1980; Oliver and Grigoropoulos, 1981).

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92–500) set a national goal of restoring the quality of polluted surface waters and maintaining them in a clean fishable and swimmable condition. Section 208 of that law provided funds for the development of regional water-quality management plans and for investigations to identify and quantify nonpoint sources of pollution to surface water. These studies indicated a need for further investigations addressing the problems of nonpoint-source pollution in urban areas. Consequently, the USEPA (U.S. Environmental Protection Agency) entered into an agreement with the U.S. Geological Survey in 1978 and established the Nationwide Urban Runoff Program. The study on which this report is based was conducted as part of that program.

Purpose and Scope

This report is based on data collected from January 1980 to August 1981, at Lake Ellyn, a small lake located in the western Chicago suburb of Glen Ellyn, Ill. (fig. 1). The objectives of the Lake Ellyn study were to identify and quantify water-quality constituents in runoff from a developed urban watershed, and to evaluate the effect of detention in Lake Ellyn on concentrations and loads of those constituents.

The purpose of this report is to describe the effects of detention storage on the quality of water in and downstream of Lake Ellyn. Changes in the chemical and sediment characteristics of runoff attributed to detention storage in the lake are set forth by comparing constituent concentrations and loads measured at the principal lake inlet with those measured at the lake outlets. Some effects of runoff on the physical, chemical, and biological properties of the lake are described.

This report incorporates relevant information and results from other studies of runoff detention with information

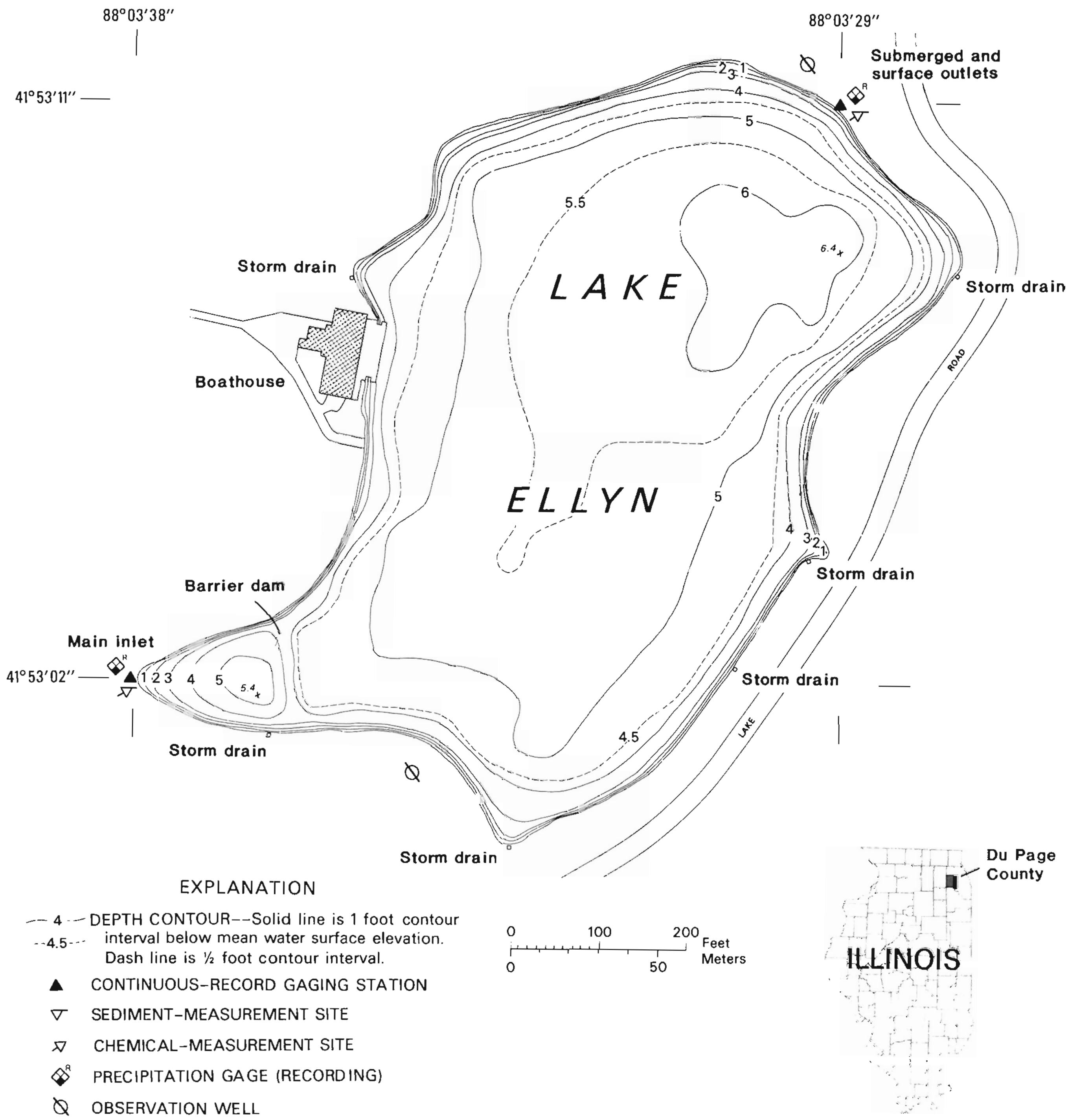

Figure 1. Location and depth contours of Lake Ellyn.

from Lake Ellyn. The concepts that are discussed are applicable to detention storage in similar physical and climatic settings.

The authors expect that readers of this report will represent a wide spectrum of backgrounds and professions. Therefore, the basic hydrologic concepts upon which data interpretations were based are explained or referenced as each topic is presented. Use of technical language and complex mathematics has been intentionally minimized. Many technical terms that appear in the text are defined in the glossary.

Hydrologic Setting

The Lake Ellyn watershed is located approximately 20 miles west of Chicago in Du Page County, Ill. (fig. 1). Lake Ellyn is a 10.2-acre impoundment constructed in 1889 by building a small earthen dam across a narrow valley and blocking a tributary to the East Branch Du Page River. The lake receives drainage from a 534-acre urban watershed comprising three smaller drainage areas (fig. 2). The main

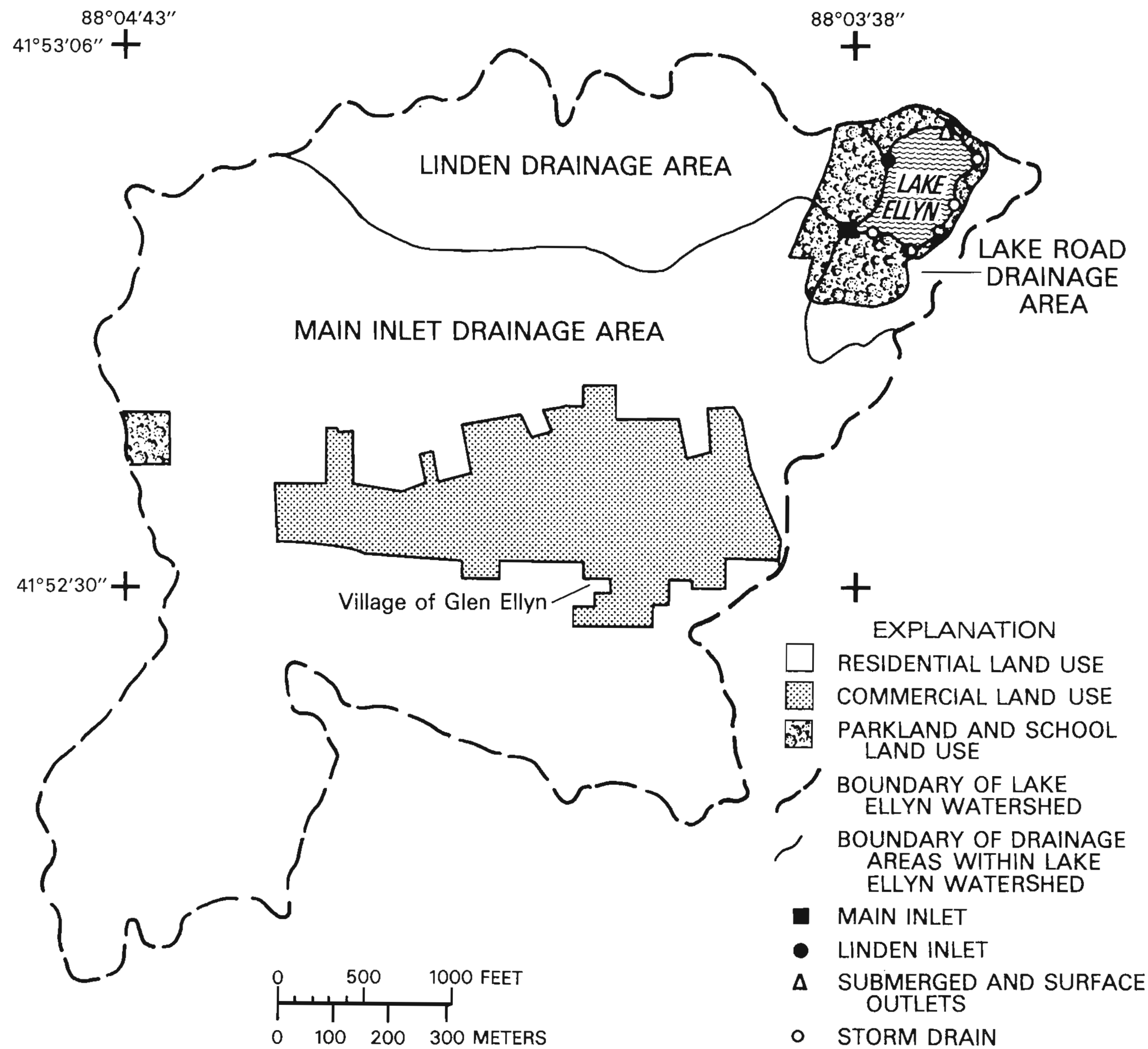

Figure 2. Drainage areas and land use in the Lake Ellyn watershed (modified from Hey and Schaefer, 1983).

Table 1. Physiographic and land-use characteristics of the Lake Ellyn watershed
[Modified from Hey and Schaefer, 1983]

Total drainage area, in acres	534
Impervious area, in percentage of drainage area	34
Average basin slope, in percent	4.2
Lake volume, in acre-feet	44.8
Inches of runoff required to fill lake	1.0
Land use as a percentage of drainage area:	
Single-family residential	80
Multiple-family residential	3
Commercial	5
Under construction (bare surface)	0
Parkland and open space	7
Institutional	5

inlet drainage area is 390 acres and includes downtown Glen Ellyn; inflow from this drainage area was gaged and sampled during the study. The Linden drainage area is 96 acres, and the Lake Road drainage area is 48 acres; both areas drain single-family residential neighborhoods and parkland. Physiographic and land-use characteristics for the watershed are summarized in table 1. Of the watershed area, 83 percent is used for residences, 5 percent is in commercial use, and the remaining 12 percent is in institutional use, parkland, or open space (Hey and Schaefer, 1983). There is no undeveloped land in the watershed.

Land-surface features near Lake Ellyn were formed about 14,000 years ago during the retreat of Wisconsinan glaciers from Illinois. The watershed is mostly underlain by glacial till consisting of clay and silt with few pebbles and boulders (Taylor and Gilkeson, 1972). Lake Ellyn is underlain by fine-grained glacial lake deposits. The most prominent topographic features of the watershed are kame deposits located immediately to the east and southeast of the lake. Kames are steeply sloping hills composed of stratified sand and gravel formed when crevasses in the glacier filled with water-deposited sediment. After the glacial ice melted, kames remained as areas of high relief on the land surface.

Lake Ellyn has a volume of 45 acre-ft, a maximum depth of 6.4 ft, and a mean depth of 5.0 ft (fig. 1), at a water-surface elevation of 707.6 ft above sea level. The lake is clay lined and has a subsurface barrier dam near the principal inlet (main inlet) that is designed to reduce sediment transport into the main lake basin (Harza Engineering Company, 1969). Runoff from 73 percent of the watershed flows to the lake from main inlet, a 4.0-ft by 4.5-ft rectangular concrete storm drain. Remaining runoff flows to the lake through six smaller storm drains (fig. 2) and by overland flow. Two weirs control the lake water-surface elevation and outflow (fig. 3). Surface outlet is a 5.25-ft-wide, fixed concrete weir at the entrance to a cistern that drains into a 2.0-ft-diam concrete pipe. Submerged outlet is a 6.0-ft-wide, adjustable metal-plate weir in a stilling well that receives water from a 2.5-ft-diam corrugated-metal pipe that originates at the lake bottom, near the point of maximum depth. Submerged outlet is located at the entrance to a cistern that drains into a 2.5-ft-diam concrete pipe.

The lake is located in a 25-acre park and is surrounded by grass-covered parkland. Principal benefits derived from the lake are runoff storage and noncontact recreation, including picnicking, fishing, and ice skating.

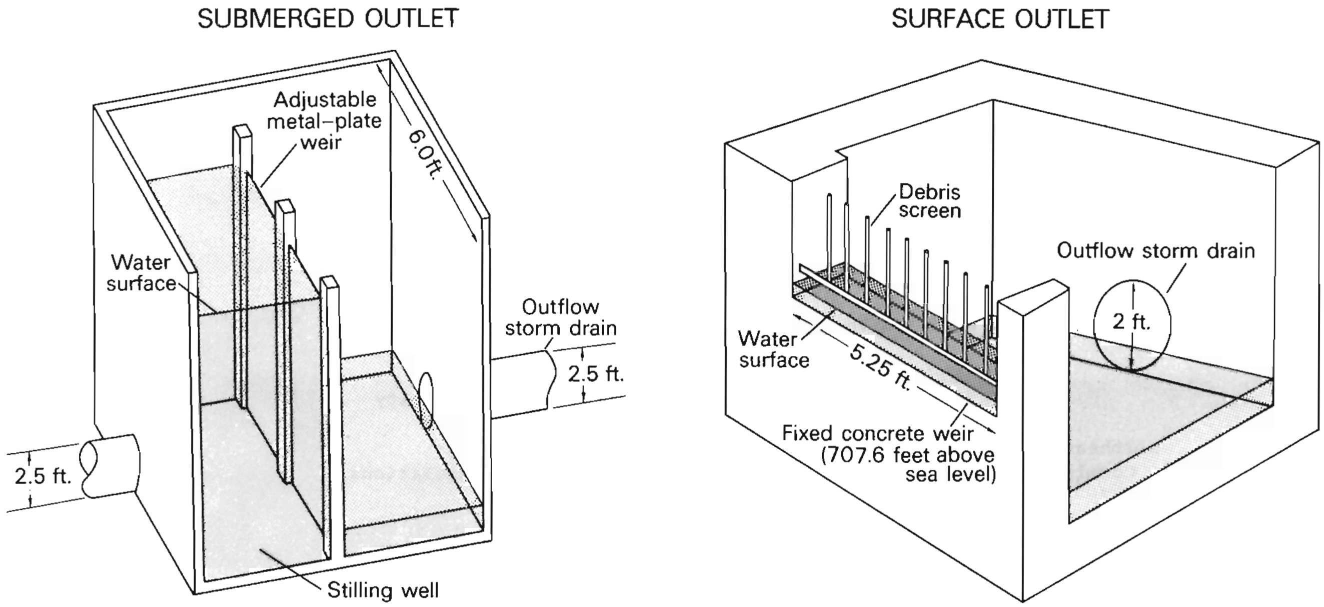

Figure 3. Outlet structures at Lake Ellyn.

Climate

The average annual precipitation at Chicago Midway Airport (20 miles east of Glen Ellyn) for the period from 1928 through 1981 was 24.4 in (National Oceanic and Atmospheric Administration, 1981). Precipitation is distributed relatively evenly through the year, but there is less during the winter months. Much of the summer precipitation occurs as severe rainstorms of relatively short duration and high intensity. In northeastern Illinois, 75 percent of the severe rainstorms occur during June through September (Huff and Vogel, 1976).

Based on 13 yr of record at Wheaton, Ill., about 3 miles west of Lake Ellyn, the local average annual precipitation is 35.6 in deposited in an average of 100 precipitation periods (National Oceanic and Atmospheric Administration, 1981). The local, 13-yr average rainfall period had a duration of 4.6 hr and deposited 0.34 in of water. The average time between precipitation periods was 83.2 hr.

Precipitation characteristics during the period of study were similar to those defined by long-term records (Hey and Schaefer, 1983). Ninety-five rainfall and snowfall periods were recorded from July 1, 1980, through June 30, 1981, yielding a total of 39 in of precipitation. The mean precipitation period had a duration of 4.0 hr and deposited 0.4 in of water. The average time between precipitation periods was 87.1 hr.

The average annual temperature recorded at Chicago Midway Airport is 49°F (National Oceanic and Atmospheric Administration, 1981). Average monthly temperatures range from a low of 24°F in January to a high of 75°F in July. Lake Ellyn is usually covered with ice between December and March.

Methods of Study

This report is based on information compiled during investigations by several agencies (table 2). Physical characteristics of Lake Ellyn, including size, shape, bathymetry, and depth of accumulated sediments were determined from aerial photographs and by direct measurement (Cowan, 1982).

Stages were recorded at 5-min intervals at main inlet, surface outlet, and submerged outlet from March 1980 to August 1981 (fig. 1). A servo-manometer was used to measure stages at main inlet, and float-type gages in stilling wells were used at the outlets (Buchanan and Somers, 1968). Stage-discharge relations were determined using methods from Hulsing (1967), Bodhaine (1968), and Buchanan and Somers (1968).

Inflow and outflow water samples were collected at preprogrammed intervals by stage-activated automatic pumping samplers. As many as 24 samples were collected at each station for each period of runoff. Specific conductance and pH were measured for all samples. Selected samples were analyzed for chemical constituents, sediment concentration, and particle-size distribution using methods from Guy (1969), Goerlitz and Brown (1972), and Skougstad and others (1979); and methods provided by USEPA to contract laboratories for priority pollutant analyses (Hey and Schaefer, 1983). Thirty-three runoff periods were sampled

Table 2. Agencies involved in data collection for the Lake Ellyn study

Agency	Data collected
Du Page County Regional Planning Commission	Land-use surveys
Illinois Department of Conservation	Fish census
Illinois State Water Survey	Atmospheric deposition Benthic invertebrates Lake-water quality Lake-sediment quality
Northeastern Illinois Planning Commission	Land-use surveys Road-dirt accumulations Snow survey Soil survey
Northern Illinois University	Lake morphology Lake-sediment quality and quantity
U.S. Environmental Protection Agency	Organic-compound analyses of water and sediments
U.S. Geological Survey	Lake-outflow quality and quantity Lake-sediment quality Phytoplankton enumeration Precipitation Runoff quality and quantity

for chemical constituents and sediment concentrations between February 1980 and July 1981. Chemical and sediment loads and mean constituent concentrations were computed for 18 runoff periods between April 3, 1980, and June 8, 1981. Equations used to compute storm loads and mean concentrations were derived from Heaney and Huber (1979).

Precipitation was recorded at 5-min intervals throughout the study period. Volumetric rain gages coupled with punched-papertape recorders were located at main inlet and at the outlets.

Samples of lake-bottom sediment were collected by coring (Cowan, 1982) and by Ekman grab sampler (Hill and Hullinger, 1981). Grab samples for biological analyses were washed through a 30-mesh-per-in sieve, and benthic invertebrates were picked from the residue. Methods used for the chemical and biological analyses of lake sediments are described in Skougstad and others (1979), Hill and Hullinger (1981), Cowan (1982), and Hey and Schaefer (1983).

Diversity and relative abundances of fish species were assessed in June 1980 using a boat-mounted electroshocker (Illinois Department of Conservation, written commun, 1980).

Acknowledgments

Funding for the Lake Ellyn study was provided by USEPA as part of the Nationwide Urban Runoff Program and by the Illinois Department of Energy and Natural Resources through the Northeastern Illinois Planning Commission. The Village of Glen Ellyn, the Glen Ellyn Park District, and Glenbard West High School made the study area accessible and provided logistic support.

CONCEPTS

The purpose of this section is to present the basic hydrologic concepts on which the Lake Ellyn study and data interpretations were based. These concepts are presented within a general hydrologic framework that contains specific examples using Lake Ellyn data.

Urban Runoff

Urban runoff is water that flows off the surfaces in urban areas. It is most commonly thought of as the runoff that follows rain showers or storms, but it also may include snowmelt runoff and water discharges from other sources such as fire-hydrant flushing, lawn watering, and automobile washing.

As water flows over surfaces in an urban watershed, it collects sediments and chemicals that have been deposited on or degraded from those surfaces. The number and concentration of constituents in the runoff are highly variable both within and between runoff periods; therefore, predictions of the constituent composition of runoff from urban areas are difficult to make. Factors that contribute to these variations include the magnitude, intensity, and duration of each rainfall; the amount of time that passes between runoff periods; and the season (Whipple and others, 1977). Intense rainfalls of long duration tend to wash watershed surfaces clean of deposited particles and chemicals, and the ensuing runoff transports them downstream and out of the watershed. Alternatively, rainfalls of low intensity or short duration may produce runoff with only enough energy to move constituents around within a watershed, resulting in little or no export of constituents to receiving streams. Increased time between runoff periods may result in a buildup of constituents on watershed surfaces. The season of the year often affects the kind and amount of constituents that are available for runoff. For example, fertilizers applied to lawns in spring may contribute to high concentrations of nitrogen and phosphorus in rainfall runoff. Road-deicing salt applications in winter contribute to high concentrations of chloride, sodium, and other dissolved ions in snowmelt runoff; also, frozen or snow-covered land surfaces in winter may delay the transport of some sediments and sediment-associated constituents until spring.

Concentrations of suspended and dissolved constituents respond differently to changes in water discharge during runoff. Concentrations of suspended constituents usually increase in response to an increase in discharge. Increased flow velocity and turbulence result in an increase in the ability of a stream to suspend and transport particles. Concentrations of dissolved constituents usually decrease with an increase in water discharge. Dilution by the increased water volume outweighs the input of dissolved constituents to the streamwater.

These responses are illustrated by rainfall, water-discharge, and constituent-concentration hydrographs for July 20–21, 1980, at main inlet (fig. 4). Rainfall occurred during two discrete periods producing a water-discharge hydrograph with two main peaks of similar maximum discharge. Suspended-sediment, total-lead, and total-phosphorus concentrations are used to illustrate relations for suspended constituents. Dissolved-solids, dissolved-lead, and chloride concentrations are used to illustrate relations for dissolved constituents.

Concentrations of suspended constituents were low in base flow prior to rainfall. As water discharge increased, the concentration of suspended constituents also increased. Changes in concentration are directly related to the changes in water discharge. Peak concentrations of lead and phosphorus occurred within 10 min after the start of rainfall. Similar peaks at the onset of runoff have been observed in other studies of urban runoff quality (Wilber and Hunter, 1977; Helsel and others, 1979). The second peak on the suspended-solids hydrograph is reduced approximately 300 mg/l from the first peak although the peak discharge is nearly the same. The reduction in suspended-solids concentrations is attributed to the accumulated particles having been washed off streets and other impervious surfaces during the first pulse of rainfall (Sartor and Boyd, 1972). During the second pulse of rainfall, fewer solids remain available to be removed.

Concentrations of dissolved constituents were high in base flow prior to rainfall. Concentrations decreased at the start of rainfall because of dilution of base-flow concentrations by rainfall and runoff. With the exception of lead, dissolved-constituent concentrations continued to decrease with time throughout the runoff period. The peak in dissolved-lead concentration at 0010 illustrates the unpredictable variability of constituent concentrations observed in urban runoff. Concentrations of dissolved lead in that sample represent the release of a confined source of dissolved lead from some point in the watershed. The flooding of a gas station parking lot could possibly cause a concentration of dissolved lead similar to the one observed.

Detention Storage

Detention storage is the temporary storage of runoff in a reservoir prior to release to a receiving stream. Water may drain to a detention lake or pond by way of natural channels, channelized streams, storm pipes, or overland flow. Detention reservoirs differ greatly in size and morphometry, and they range from completely designed and excavated depressions in the ground to natural lakes through which runoff is directed.

A detention reservoir acts as a widening in a stream channel, increasing the flow area and allowing incoming

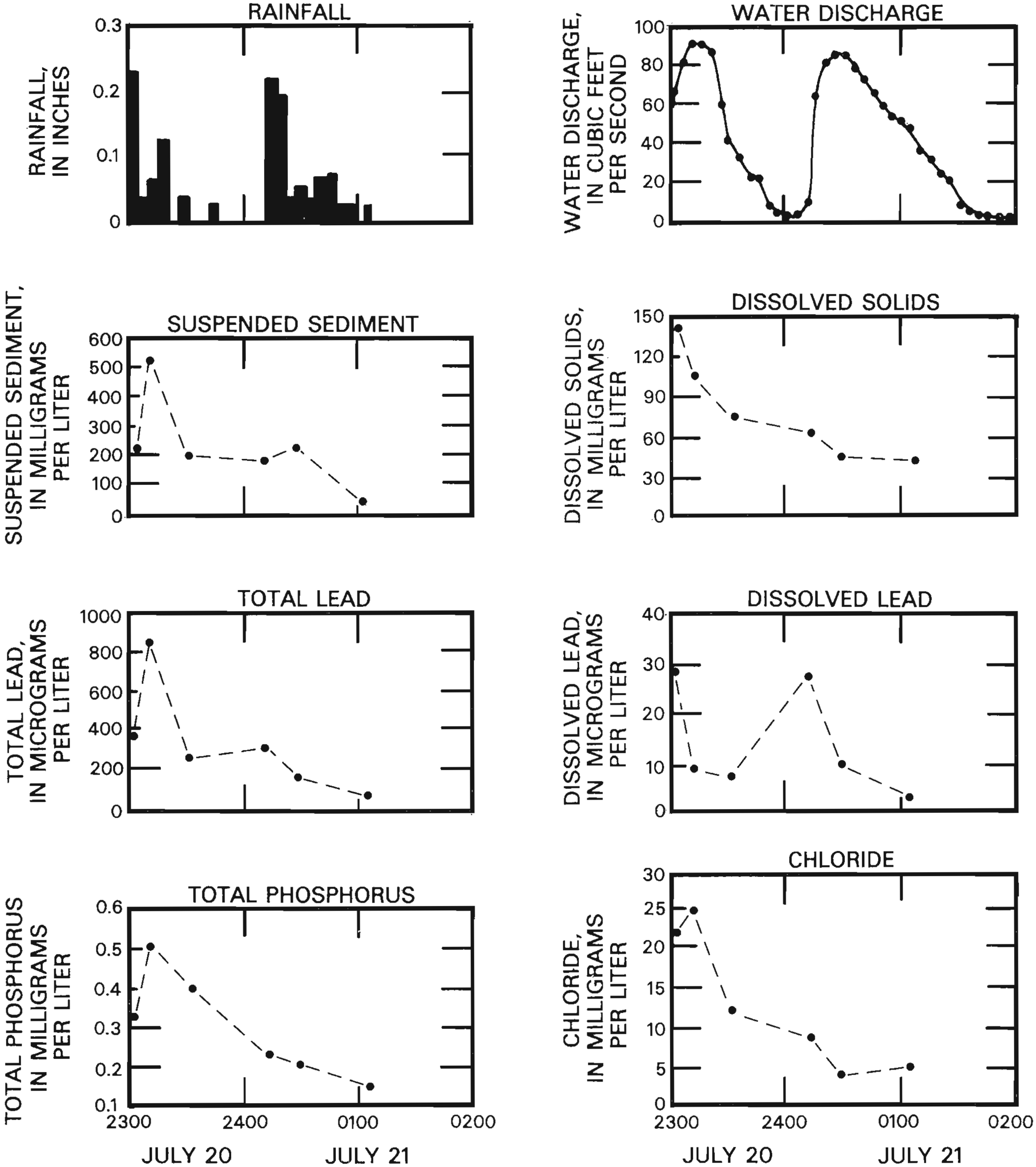

Figure 4. Rainfall, water discharge, and constituent concentrations with time, July 20–21, 1980, at main inlet.

runoff to lose velocity with relatively little change in stage. The flow of water out of detention reservoirs is commonly regulated by a hydraulic-control device such as a weir or a siphon. The net result is that the duration of runoff is increased and the magnitude of the peak discharge is decreased (fig. 5). For this reason, detention storage has been used extensively for flood-control purposes (Spieker, 1970). Because reduction in permeable watershed surface area by urbanization has the effect of decreasing the duration of runoff and increasing the magnitude of peak discharge, detention storage often serves to change flow patterns to resemble conditions before urbanization (Rutter and Engstrom, 1964).

Outflow from a detention reservoir during a runoff period consists mostly of water that has been displaced from the reservoir by the inflowing runoff. This outflow water is fairly homogeneous in concentrations of water-quality constituents when compared to the inflowing runoff. Concentrations of dissolved constituents in the outflow can be greater than or less than concentrations in the runoff. Figure 6 shows ranges in concentrations of chloride that were observed in main inlet and submerged outlet and surface outlet samples for 20 runoff periods during 1980–81. During winter, chloride from road salt is dissolved in snowmelt runoff (see fig. 6, Feb. 16, 1981) that flows to the lake and displaces the more dilute lake water. Chloride from the snowmelt runoff mixes with the water in the lake, increasing the chloride concentrations in the lake water. During spring and summer, rainfall runoff that has low concentrations of chloride displaces and mixes with the more concentrated lake water. Chloride concentrations in submerged outlet and surface outlet samples are consequently greater than those in main inlet samples, and concentrations tend to decrease throughout the summer as the lake water becomes more diluted by rainfall runoff. Outflow concentrations increase again in the winter with the advent of deicing-salt applications to road surfaces.

Concentrations of suspended constituents in outflow from detention reservoirs are generally less than concentrations of suspended constituents in inflowing runoff, depending on the amount of time that has been available for particle settling. Figure 7 shows that total-lead concentrations were less in submerged outlet and surface outlet samples than in main inlet samples for 20 runoff periods during 1980–81.

The hydraulics of reservoirs for detention of storm runoff are unique. Flows to and from the reservoirs are typically surface-water dominated, with little or no flow between the reservoir and ground water. More noticeably, inputs of water to detention reservoirs are commonly limited to relatively short periods of high flows followed by long periods of little or no flow. Many detention reservoirs receive water only during precipitation runoff. Inlet and outlet discharges at Lake Ellyn were typically about 0.1 ft^3/s except during precipitation runoff periods such as June 8, 1981, when main inlet flow reached 130 ft^3/s.

Constituent Loads and Mean Concentrations

The amount or mass of a constituent that is transported to or from a system, such as a detention reservoir, is termed "load." Loads may be calculated for a standard unit of time (second, day, year), or they may be calculated for a specific period, such as the period of runoff that follows a rainstorm.

Because detention reservoirs are surface-water dominated, and the greatest volume of flow to them occurs during precipitation runoff, estimates of constituent loads to and from a reservoir can be calculated from discharge and water-quality measurements made at reservoir inlets and outlets during runoff periods. Accurate estimates require that discharge be recorded continuously and that water-quality samples be collected near the beginning, on the rise, near the peak, and on the tail of the runoff hydrograph. Such measurements were made at main inlet, submerged outlet, and surface outlet at Lake Ellyn for 30 rainfall-runoff, 3 snowmelt-runoff, and 2 base-flow periods between February 1980 and August 1981.

Load of a constituent for a runoff period is calculated in a stepwise manner. First, the runoff period is subdivided into smaller time intervals, each representing a water-quality sample. Runoff volumes for each time interval are then determined. Next, concentrations of the constituent measured in each sample are multiplied by their representative runoff volumes. The products from the previous step are then summed, and the total is multiplied by a coefficient that converts load into the units desired. This is expressed mathematically by

$$L = \Sigma(C_i Q_i \Delta t_i)\, 10^{-4.55} , \qquad (1)$$

where L = load, in kilograms;

Σ = mathematical notation for a summation;

C_i = concentration of constituent in sample i (collected at time, t_i), in milligrams per liter;

Q_i = mean discharge during the time interval representing sample i, in cubic feet per second;

Δt_i = time interval that represents sample i, concentration C_i, and mean discharge Q_i, in seconds; and

$10^{-4.55}$ = coefficient for converting cubic feet to liters and milligrams to kilograms.

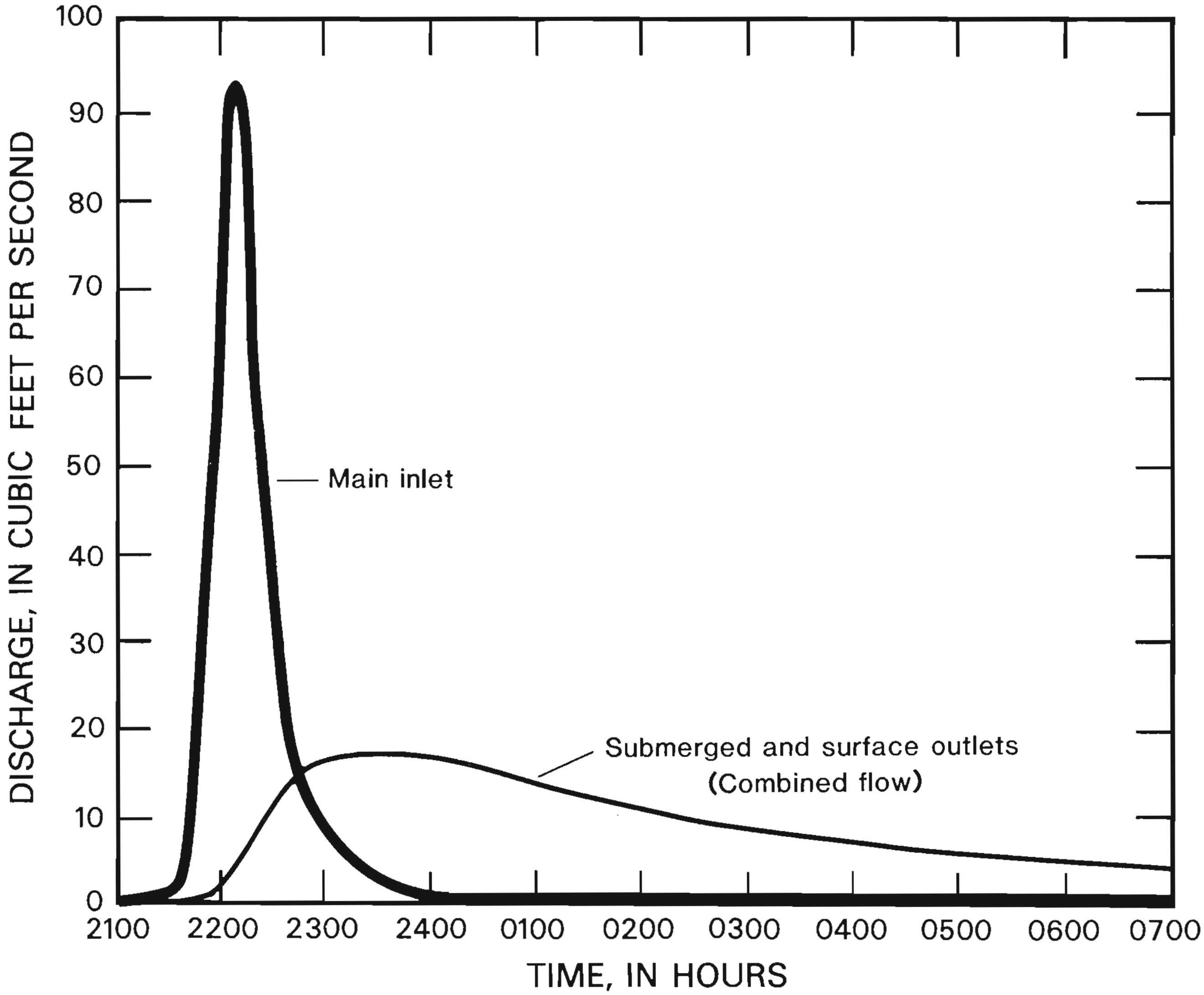

Figure 5. Water discharges at main inlet and at submerged outlet and surface outlet following rainfall, July 25–26, 1981.

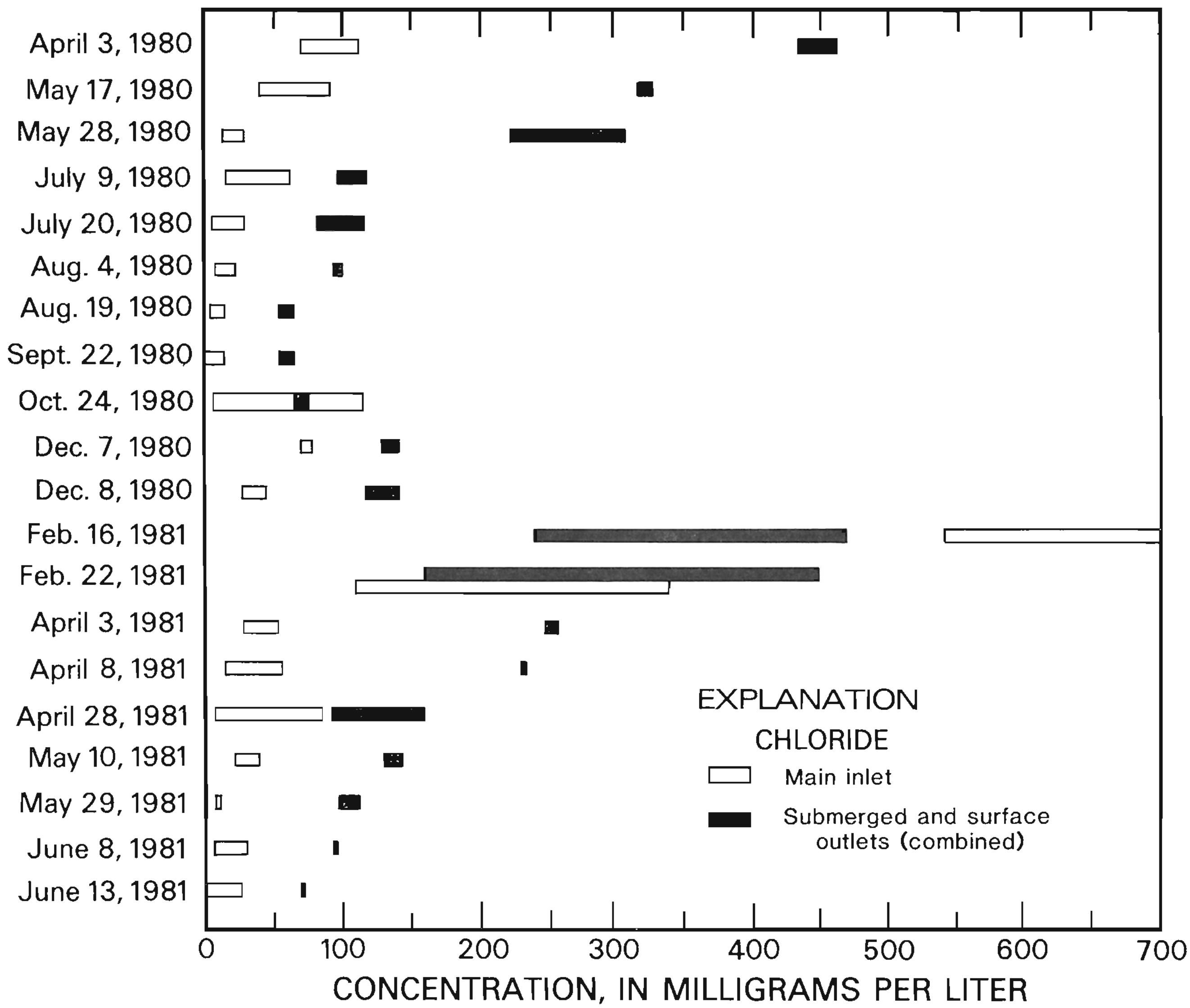

Figure 6. Ranges of chloride concentrations at main inlet and at submerged outlet and surface outlet for 20 periods of runoff at Lake Ellyn, 1980–81.

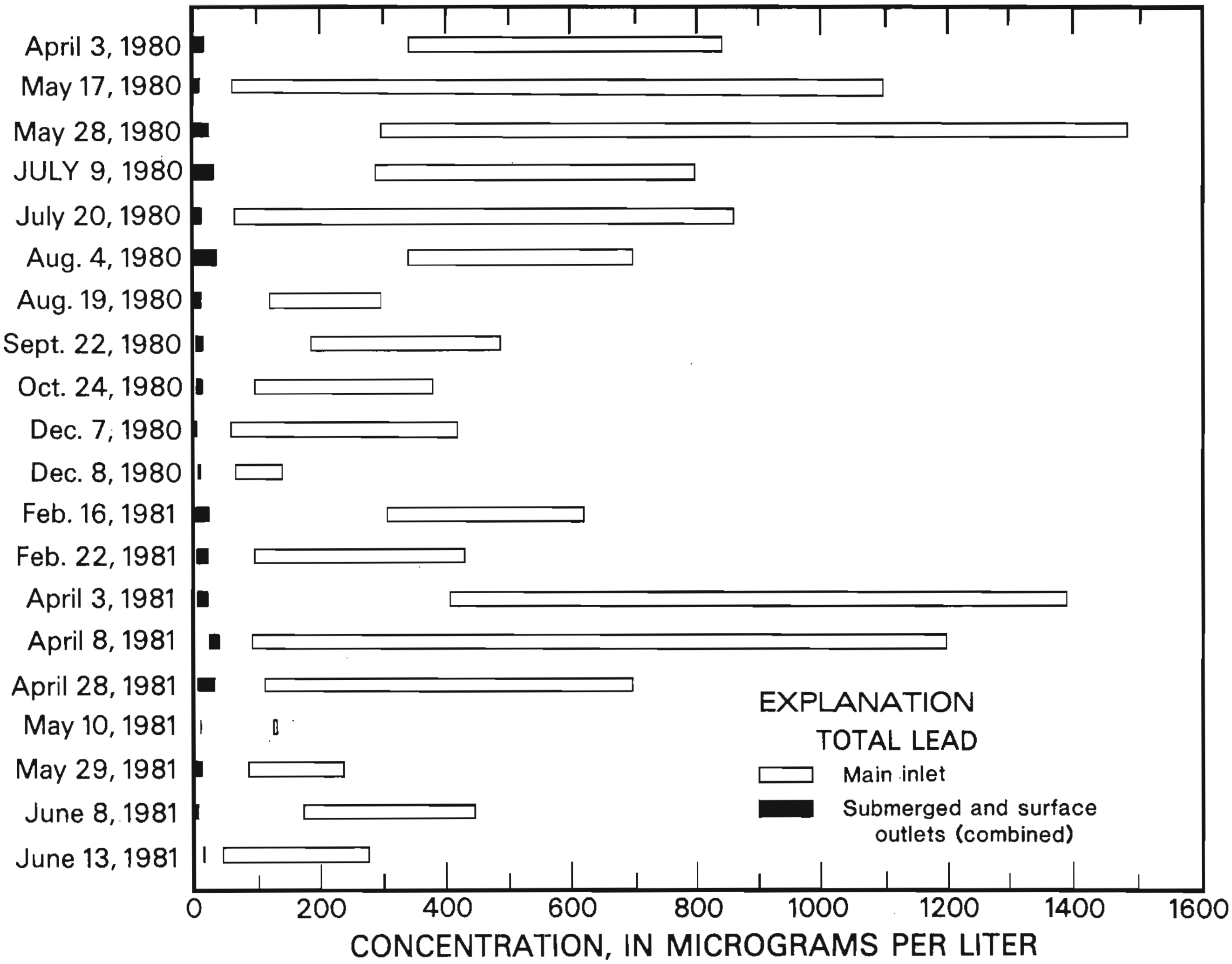

Figure 7. Ranges of total-lead concentrations at main inlet and at submerged outlet and surface outlet for 20 periods of runoff at Lake Ellyn, 1980–81.

The summation is calculated over the entire runoff period from the first sample, $i=1$, through the last sample, $i=n$. The time interval, Δt_i, that represents the measured concentration for a sample collected at time, t_i, is determined by adding the amount of time that has passed since the previous sample (or beginning of runoff) to the amount of time until the next sample (or end of runoff) and dividing by 2 (fig. 8). This is expressed by

$$\Delta t_i = \frac{(a+b)}{2} , \qquad (2)$$

where a = the amount of time since the previous sample (or beginning of runoff), in seconds; and

b = the amount of time until the next sample (or end of runoff), in seconds.

The time- and flow-weighted mean concentration, $\overline{C}$, of a constituent for a sampled runoff period may be determined by dividing the calculated load, L, by the product of the total runoff volume and a coefficient to correct for changes in units of expression

$$\overline{C} = \frac{L}{\Sigma(Q_i \Delta t_i)10^{-4.55}} . \qquad (3)$$

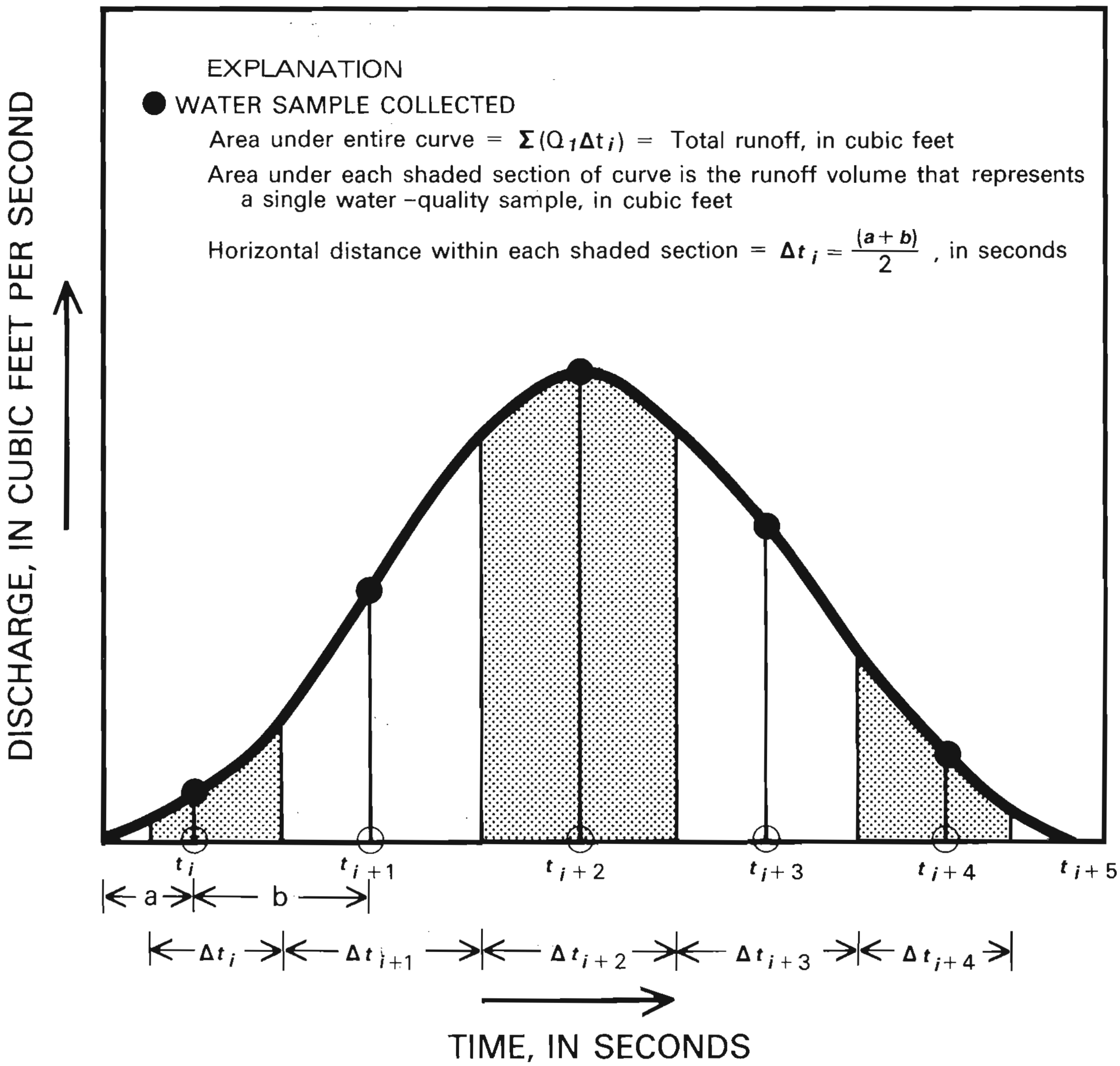

Figure 8. Hypothetical hydrograph showing volumes of runoff that represent individual water-quality samples for calculation of constituent loads.

If the goal of sampling is to determine only $\overline{C}$, water-quality analytical costs can be conserved by combining well-mixed aliquots of several samples collected over the period represented by a runoff hydrograph into a single time- and flow-weighted composite sample, from which $\overline{C}$ is measured directly. The volume of an individual aliquot, v_i, in the composite sample is equal to the fraction of the total runoff volume that the aliquot is intended to represent, multiplied by the total volume of the desired composite sample, V_t,

$$v_i = \frac{Q_i \Delta t_i}{\Sigma(Q_i \Delta t_i)} V_t \ . \qquad (4)$$

When samples are composited by equation 4, the load for a runoff period can be calculated by rearrangement of equation 3,

$$L = \overline{C} \Sigma(Q_i \Delta t_i) 10^{-4.55} \ . \qquad (5)$$

Further explanations about the calculation of constituent loads and mean concentrations may be found in Guy (1969), Guy and Norman (1970), Porterfield (1972), and Heaney and Huber (1979).

Mass Balances

A comparison of the load of a constituent that enters into a system to the load of the same constituent that leaves the system is called "mass balance." The mass balance is a useful method for assessing the net changes of individual constituent loads in a detention reservoir. In assessing differences in loads of a constituent by a mass-balance approach, it is useful to understand the physical processes that control the movements of the constituent and to be able to conceptualize the relative importance of each process.

Water enters or leaves a reservoir or lake by three major ways: surface water (direct runoff and streamflow), ground water, and exchange with the atmosphere (precipitation and evaporation). In determining a lake water balance, all the water inputs to a lake (positive values) for a period of time are added to all the water outputs from the lake (negative values) for the same period (fig. 9). If there is no change in lake volume during that time period, the lake is in steady state (input equals output) with respect to water, and the water balance is zero.

Comprehensive water balances, the goals of which are to determine accurately all the water inputs and outputs of a lake, are very difficult to construct (Winter, 1981) and may not be needed to assess detention reservoirs for water-quality purposes. More approximate water balances, based only on surface-water data, are adequate in many cases. A general water balance for a lake is defined by

$$S_{ig} + S_{iu} + G_i + P - S_{og} - S_{ou} - G_o - E \mp \Delta v = 0 \ , \qquad (6)$$

where S_{ig} = gaged surface-water inflow volume,
S_{iu} = ungaged surface-water inflow volume,
G_i = ground-water inflow volume,
P = volume of precipitation that falls on the lake surface,
S_{og} = gaged surface-water outflow volume,
S_{ou} = ungaged surface-water outflow volume,
G_o = ground-water outflow volume,
E = volume of evaporation from the lake surface, and
Δv = change in volume of the lake during the time period for which the calculation is made.

For Lake Ellyn, ground-water interchange was assumed to be negligible, because the water-table surface at nearby observation wells (fig. 1) was measured to average about 20 ft below the deepest point in the lake; and because the lake is clay lined, and it overlies glacial lake deposits that have low hydraulic conductivities. Precipitation and evaporation were assumed to be nearly equal and, therefore, negligible relative to other lake water-balance terms. Change in lake volume was negligible because flow periods began when lake water-surface elevations exceeded the outlet-weir elevation and ended when lake water-surface elevations returned to the outlet-weir elevation. All surface-water outflow from Lake Ellyn was gaged. The water-balance (equation 6) therefore reduced to

$$S_{ig} + S_{iu} - S_{og} = 0 \ . \qquad (7)$$

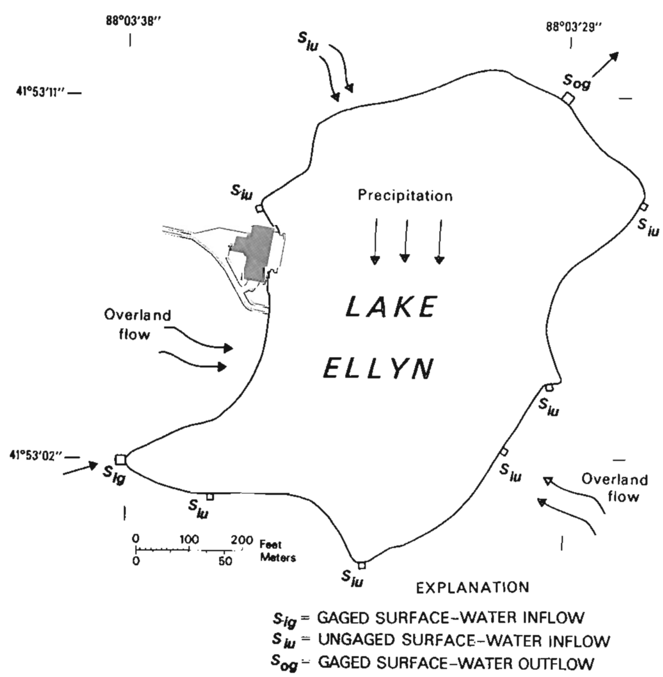

Figure 9. Water inputs and outputs for Lake Ellyn water balance.

The total runoff volume, $\Sigma(Q_i \Delta t_i)$, in equations 1, 3, and 5 is equal to $S_{ig}+S_{iu}$ for inflow to Lake Ellyn, and to S_{og} for outflow from the lake.

The movements of suspended solids and most chemicals into and out of a detention reservoir are determined mainly by the movements of surface water through the reservoir. Other sources of constituents such as direct deposition from the atmosphere or inputs from ground water are usually less important; however, these sources should not be discounted without justification. Contaminant spills may have considerable effects on constituent mass balances; however, such occurrences are unpredictable and, fortunately, rare. Therefore, volumes of surface water entering, leaving, and being stored in a detention reservoir and concentrations of constituents associated with those volumes must be measured in order to determine constituent mass balances at the reservoir.

Trap Efficiencies

The reason for calculating inflow-to-outflow mass balances at Lake Ellyn was to determine the trap efficiencies of the lake for retaining constituents measured in runoff. A trap efficiency is a ratio of the outflow load to the inflow load of a constituent and is commonly expressed as a percentage. A trap efficiency of 0 percent indicates that inflow loads are equal to outflow loads and that none of the measured inflow load is being trapped in the reservoir. A trap efficiency of 100 percent indicates that all of a particular constituent measured in inflow is being trapped in the reservoir. Negative trap efficiencies may also be calculated; these indicate that the measured load of a constituent out of a reservoir is greater than the measured load of that constituent into the reservoir. Since mass must always be conserved, the probable cause of a calculated negative efficiency must be determined. For several dissolved constituents in Lake Ellyn runoff, the cause of calculated negative efficiencies can be traced to inadequate measurement of the inflow load, either because of hydrologic error in the water balance or because of insufficient water-quality sampling during low flow and winter. In some instances, calculation of a negative trap efficiency can be attributed to desorption or dissolution of a constituent from sediments deposited in the reservoir. Trap efficiency, in percent, may be calculated by

$$R=\left[1-\frac{L_o}{L_i}\right]\times 100 \qquad (8)$$

where R = trap efficiency, in percent;
L_o = load of a constituent in outflow; and
L_i = load of a constituent in inflow.

Since all the outflow from Lake Ellyn was gaged, total outflow load, L_o, was measured. However, only inflow at main inlet was gaged, and runoff to the lake from other drainage areas in the watershed was unmeasured. To account for the uncertainty in total inflow load, L_i, that may be attributed to the unmeasured runoff, minimum and maximum possible inflow loads were determined and used to calculate minimum and maximum possible trap efficiencies, R_{min} and R_{max}.

Minimum inflow load, L_{min}, to Lake Ellyn was considered equal to the load measured at main inlet. Therefore, R_{min} was calculated by substituting L_{min} for L_i in equation 8.

Calculation of maximum inflow load, L_{max}, was based on two assumptions. First, the total volume of inflow to Lake Ellyn, $S_{ig}+S_{iu}$, is assumed to be equal to the measured outflow from the lake, S_{og}. This is an assumption of steady state. Second, the concentrations of constituents in main inlet samples are assumed to be equal to or greater than constituent concentrations in runoff from ungaged areas (recall that downtown Glen Ellyn drains to main inlet). Based on these assumptions, L_{max} was calculated from equation 5 using the time- and flow-weighted concentration at main inlet, $\overline{C}_{main}$, and substituting S_{og} for $\Sigma(Q_i \Delta t_i)$,

$$L_{max}=\overline{C}_{main} S_{og}\, 10^{-4.55} \qquad (9)$$

R_{max} was then calculated by substituting L_{max} for L_i in equation 8.

R_{min} and R_{max} give a range within which the actual trap efficiency of a detention reservoir will probably lie. They are reliable estimates for relatively nonreactive constituents that are input predominantly by surface runoff.

EFFECTS OF LAKE ELLYN ON RUNOFF QUALITY

Water-quality constituents analyzed in runoff (inflow and outflow) samples collected at Lake Ellyn have been grouped into five categories according to similarities in constituent behavior or chemistry (table 3). Discussion of each category includes description of the constituents, their sources, and ranges in constituent concentrations between inlet and outlet samples. Linear regressions are presented to help quantify relations between constituents that exhibit close interdependence. Mass balances between inflow and outflow, and ranges of trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, are summarized in table 20 (at the end of this report). The last entries for each water-quality constituent in the table include the total runoff volume, total load, runoff-weighted mean concentration, and the overall minimum and maximum trap efficiencies for the 18 runoff periods. Sampled runoff periods for which trap efficiency calculations were made represent a variety of flow conditions and all seasons. Only periods for which measurements were available were

Table 3. Categories of water-quality constituents for Lake Ellyn data

Particles in suspension	
Solids, suspended	Sediment, suspended
Metals and arsenic	
Arsenic, total	Iron, total
Arsenic, dissolved	Iron, dissolved
Cadmium, total	Lead, total
Cadmium, dissolved	Lead, dissolved
Chromium, total	Mercury, total
Chromium, dissolved	Mercury, dissolved
Copper, total	Zinc, total
Copper, dissolved	Zinc, dissolved
Dissolved solids and major ions	
Solids, dissolved	Potassium
Calcium	Sodium
Chloride	Sulfate
Magnesium	
Nitrogen and phosphorus	
Nitrogen, total	Nitrogen, total ammonia
Nitrogen, dissolved	Nitrogen, nitrate plus nitrite
Nitrogen, total organic	Phosphorus, total
Nitrogen, dissolved organic	Phosphorus, dissolved
Organic compounds	
Organic pesticides	Other organic compounds
Solvents	

used in the calculations. Attempts by others to simulate data for unsampled flow periods indicated similar results (Hey and Schaefer, 1983).

Particles in Suspension

Suspended solids and suspended sediments are mineral and organic particles in water that are maintained in suspension by the upward components of turbulent currents, or that exist in suspension as colloids. The major difference between the two constituents is analytical (Skougstad and others, 1979; and Guy, 1969). Suspended-solids concentrations are determined by filtering an aliquot of a larger sample through a glass-fiber filter and weighing the dried residue. The analysis does not account for any colloids that may pass through the filter (Skougstad and others, 1979, p. 573).

Suspended-sediment concentrations are also determined by filtration methods. However, the laboratory technique for the analysis requires that an entire sample be filtered and that colloids that pass through the filter be accounted for by refiltration, adsorption, or flocculation (Guy, 1969, p. 13). The suspended-sediment determination is quantitatively more accurate, and measured suspended-sediment concentrations are often greater than measured suspended-solids concentrations.

The relation between suspended-sediment concentrations and suspended-solids concentrations in Lake Ellyn inflow and outflow samples is shown by the linear regression line in figure 10. This relation was used to estimate suspended-sediment concentrations from suspended-solids concentrations for periods when only suspended-solids data were available.

Naturally occurring suspended sediment results from the weathering of rocks and erosion, commonly caused by running water. Rates of erosion are often accelerated by construction in urban areas (Wolman and Schick, 1967; Walling and Gregory, 1970). Exposed soil without protective cover is easily eroded and transported to streams during rainfall. In urban watersheds like the Lake Ellyn watershed, soil erosion may be below natural levels because vegetation and pavement provide protective cover. However, suspended sediments from urban areas may include particles that are not found naturally in streams. Water samples collected at main inlet, as well as samples of sediment deposited in Lake Ellyn, commonly included pieces of glass, metal, and construction and packaging materials.

Suspended sediments can affect the chemical quality of streams by functioning as transport surfaces for heavy metals and organic molecules. Chemicals adsorb most strongly to sediment particles that have high surface area to mass ratios, such as clays. Surfaces of clay particles commonly possess a negative charge for the range in pH found in natural waters, and electrostatic forces cause metal ions with high positive valences to adsorb to them. Additionally, surface-tension forces may enhance the adsorption of large organic molecules to particle surfaces (Stumm and Morgan, 1981, chapter 10).

In areas where flow velocities decrease, sediment particles settle out of suspension and accumulate on stream bottoms. In addition to chemical quality effects that may be caused by adsorbed constituents, these accumulations may physically bury aquatic organisms, destroy habitat, or cause stream channels to clog with deposited sediment and debris.

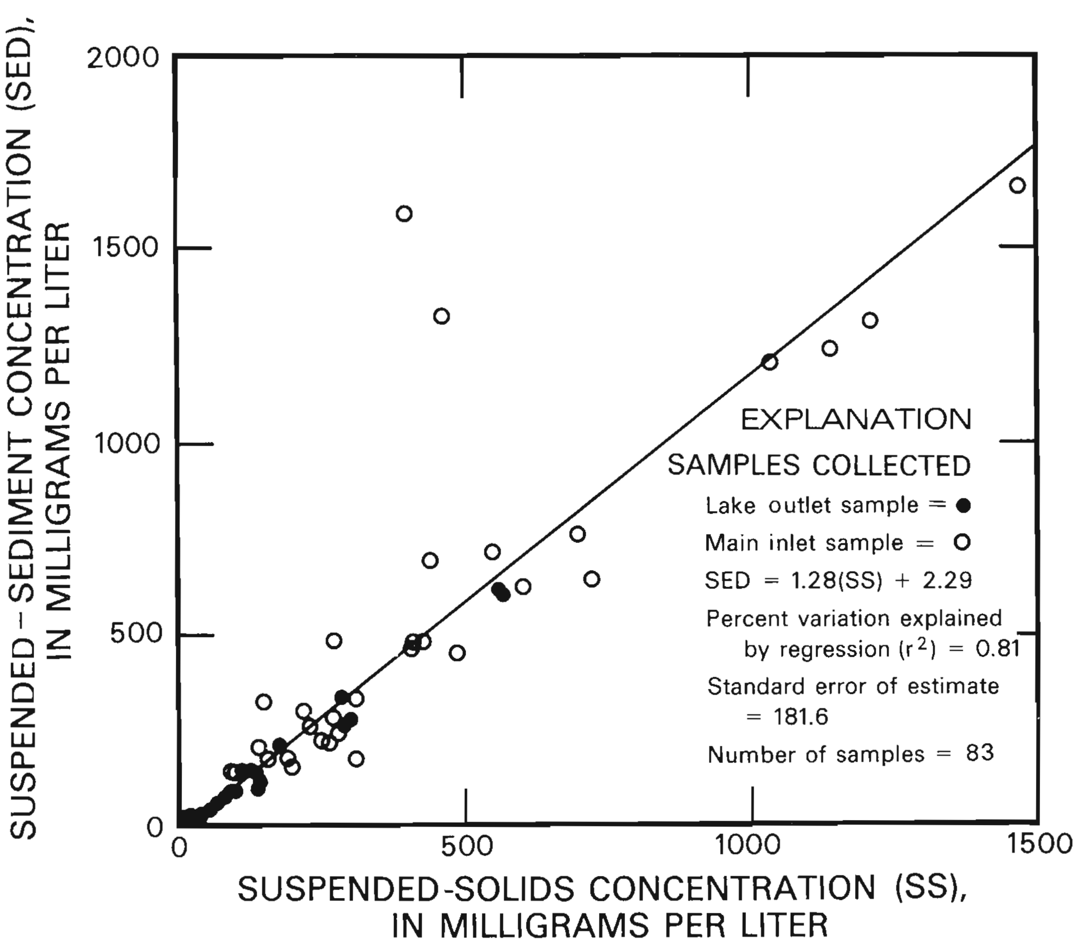

Figure 10. Relation between suspended-sediment concentrations and suspended-solids concentrations in samples collected at main inlet and lake outlets.

Suspended sediments are usually classified by particle sizes (table 4). A particle-size distribution is a list of the arelative mass of sediments of different sizes in a water or sediment sample. Particle-size distributions for water samples collected at Lake Ellyn are shown in table 5. Sediment particles in inlet and outlet samples are mainly silt and clay size, and many may originate from decomposition of asphalt and concrete street surfaces (Sartor and others, 1974; Hey and Schaefer, 1983).

Impervious surfaces, including parking lots, streets, and driveways, accumulate particles deposited from the atmosphere and surrounding land. Atmospheric particles may originate from industrial areas outside the watershed and from vehicle exhaust. The particles are transported readily by suspension in storm runoff.

The rate of settling of particles in suspension may be theoretically calculated by Stokes' Law or may be measured directly in a settling column. Figure 11 compares theoretical rates of settling of suspended solids to measured rates of settling for two 40-L samples collected at main inlet and placed in a 6-ft-tall settling column. The lower envelope of figure 11 defines the theoretical range of the rates of settling that was estimated by particle-size distributions. It shows that, after 4 hr, about 45 percent of the solids could be expected to settle from the water column. Measured rates showed that about 95 percent of the solids settled in 4 hr. This suggests flocculation of the particles, probably due to high concentrations of clay-size sediment and colloidal organic material. Particles cohere as chains or clumps that settle more rapidly than discrete particles.

Settling-column experiments for runoff samples collected from five urban areas in New Jersey (Whipple and Hunter, 1981) showed that suspended water-quality constituents settled at varying rates that were not proportional to their concentrations. After a 32-hr period, 50 to 80 percent of suspended solids, hydrocarbons, and total lead, 20 to 80 percent of total copper and total nickel, and 17 to 36 percent of total zinc settled from a 76-L sample placed in a 6-ft-tall by 0.75-ft-diam settling column. Their results support chemical theory for particle settling (Stumm and Morgan, 1981, chapter 10) by showing that settling rates are related not only to the concentrations of individual constituents, but also to the overall constituent composition of the runoff.

Table 4. Particle-size classification for sediments
[Modified from Feltz, 1980]

Material	Size range (millimeters)
Boulders	More than 256
Cobbles	64-256
Gravel	2-64
Sand	0.062-2
Silt	0.004-.062
Clays and colloids	Less than 0.004

The relatively fast settling of solids in Lake Ellyn is manifested by reductions in concentrations of suspended solids and suspended sediments between the main inlet and the outlets (table 6), and by the trap efficiency of the lake for suspended solids and suspended sediments. Trap-efficiency calculations (table 20, sections 1 and 2) show Lake Ellyn to be 88- to 95-percent efficient in trapping suspended solids and suspended sediment from runoff. This compares to an 84-percent median trap efficiency for suspended sediments in normal-ponded reservoirs that would be determined for Lake Ellyn (fig. 12) based on the ratio of lake volume to annual outlet discharge (Brune, 1953; Gottschalk, 1964).

Metals

Seven metals (cadmium, chromium, copper, iron, lead, mercury, and zinc) were analyzed in water samples collected at Lake Ellyn. Minimum, maximum, and mean concentrations of these metals for sampled runoff periods are shown in table 7. Although not a metal, arsenic has also been listed with the metals group and is presented here for the sake of convenience and because it behaves like a metal under some chemical conditions.

Iron was the most abundant metal in stormwater entering Lake Ellyn. Iron in the water originates from weathering of iron-bearing minerals in the till and bedrock (Hem, 1970), and from urban sources. During low-flow periods, iron-oxide floccules of unknown origin were often observed in the main inlet channel. Rainfall-runoff samples often included rust particles, apparently originating from vehicles and debris on the streets. Metal particles too large to be sampled (75 mm) were transported to the lake as bedload. Although high, iron concentrations such as those observed in inflow are generally not detrimental to aquatic life.

Figure 13 shows sources of copper, lead, and zinc that are deposited on watershed surfaces and are available for transport by runoff to Lake Ellyn. They include atmospheric sources that originate from outside the watershed, such as from industrial areas near Chicago; and sources that originate from within the watershed including local traffic, disintegration of roads and buildings, chemicals applied to roads and lawns (road salt, fertilizer), vegetation, and soils. Airborne metals may be deposited by rain, snow, and dry deposition. Hey and Schaefer (1983) estimate that atmospheric deposition contributes 10 percent of the copper,

Table 5. Particle-size distributions of suspended sediment in main inlet, submerged outlet, and surface outlet samples, Lake Ellyn, Illinois, 1980–81

Date	Suspended-sediment concentration (mg/l)	Percent suspended sediment in size class		
		Sand	Silt	Clay
	Main Inlet			
May 16, 1980	60	0	8	92
May 17, 1980	14	0	12	88
May 17, 1980	16	0	5	95
May 17, 1980	477	3	67	30
May 28, 1980	1,080	22	57	21
May 28, 1980	568	15	57	28
May 28, 1980	385	10	61	29
May 28, 1980	342	16	53	31
May 28, 1980	264	3	59	38
July 20,21, 1980	261	31	41	28
Aug. 4, 1980	120	14	41	45
July 12, 1981	249	3	50	47
July 13, 1981	138	3	50	47
Aug. 2, 1981	146	2	50	48
	Submerged Outlet			
May 17, 1980	15	0	12	88
May 28, 1980	25	1	29	70
July 20, 1980	17	3	12	85
Aug. 4, 1980	8	3	18	79
	Surface Outlet			
May 16, 1980	16	3	15	82
May 17, 1980	11	0	12	88
May 17, 1980	14	0	14	86
May 28, 1980	24	3	43	54
July 20, 1980	25	3	17	80
Aug. 4, 1980	10	5	19	76

5 percent of the lead, and 23 percent of the zinc that is available for transport to the lake. Traffic and the disintegration of roads and buildings are the major sources of metals that originate from within the watershed. Hey and Schaefer (1983) also estimate that traffic-related sources contribute 62 percent of the available copper, 87 percent of the available lead, and 27 percent of the available zinc. Traffic-related sources include gasoline, motor oil, tires, and brake linings (Shaheen, 1975; Solomon and others, 1977; Pitt and Bozeman, 1980). Concentrations of copper, lead, and zinc in gasoline and vehicle parts are shown in table 8. The major source of zinc is attributed to disintegration of roads and buildings and probably originates from galvanized metal, nails, and painted surfaces. Chemicals applied to roads and lawns, vegetation, and soils introduce minor amounts of copper, lead, and zinc to the watershed.

Most of the metals transported in runoff to Lake Ellyn are associated with suspended sediments. Relations of total-copper, total-lead, and total-zinc concentrations to suspended-sediment concentrations as determined by least-squares linear regression calculations are shown in figures 14–16. For samples collected at main inlet, 83 percent of the variation of total-copper concentrations, 86 percent of the variation of the total-lead concentrations, and 90 percent of the variation of total-zinc concentrations can be explained by variation of suspended-sediment concentrations. As a

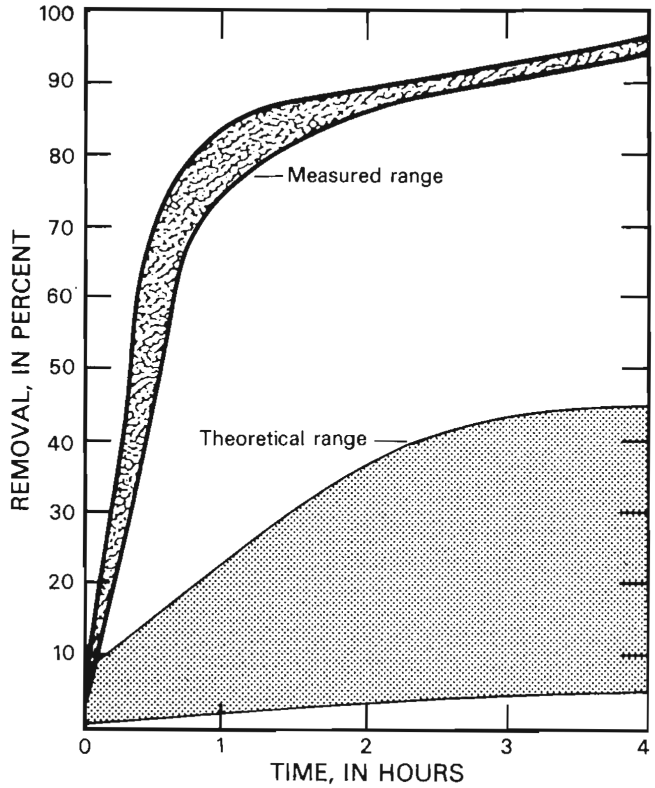

Figure 11. Ranges of measured and theoretical rates of settling for suspended solids in samples of runoff collected at main inlet.

consequence of high trap efficiencies for suspended sediment, trap efficiencies for total metals are also high (table 20, sections 3, 5, 7, 9). Trap efficiencies for dissolved metals (table 20, sections 4, 6, 8, 10) are less than those observed for total metals. The −290 to −650 percent trap efficiency for dissolved lead indicates that some lead that is adsorbed to deposited sediment particles may dissolve into the lake water, or that all of the source of dissolved lead was not accounted for by sampling at the main inlet.

Cadmium, chromium, arsenic, and mercury were detected in low concentrations in water samples (table 7). These constituents have been demonstrated to be toxic at concentrations much greater than those observed in the water samples from Lake Ellyn (Safe Drinking Water Committee, 1977).

Dissolved Solids and Major Ions

Ranges in concentrations of dissolved solids, calcium, chloride, magnesium, potassium, sodium, and sulfate in main inlet and outlet samples are listed in table 9. Specific-conductance measurements were made to estimate dissolved-solids concentrations in water samples and to select samples for additional chemical analyses. In all samples collected at main inlet and the outlets, 98 percent of the

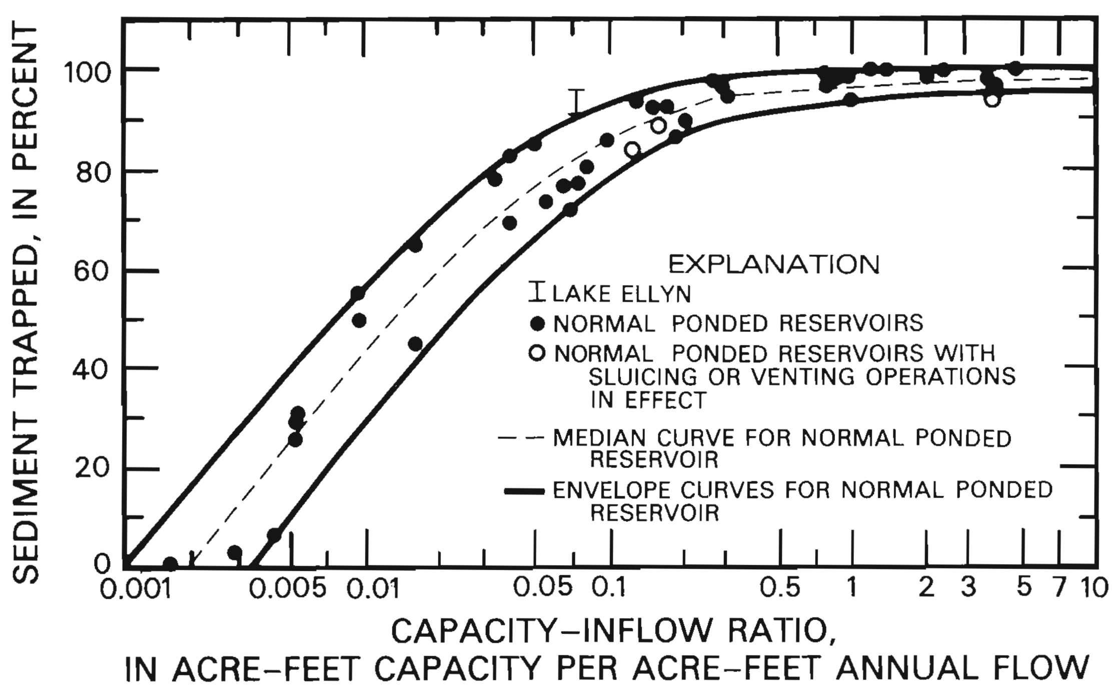

Figure 12. Sediment trap efficiency as related to capacity-inflow ratio for normal-ponded reservoirs and Lake Ellyn (modified from Brune, 1953).

Table 6. Minimum and maximum concentrations of suspended solids and suspended sediments in main inlet, submerged outlet, and surface outlet samples, February 21, 1980, to July 13, 1981, in milligrams per liter

Constituents	Main Inlet			Submerged Outlet			Surface Outlet		
	Minimum concen- tration	Maximum concen- tration	Number of samples	Minimum concen- tration	Maximum concen- tration	Number of samples	Minimum concen- tration	Maximum concen- tration	Number of samples
Suspended solids	0	3,070	108	0	210	64	0	276	66
Suspended sediments	0	1,817	71	6	75	37	1	35	33

Table 7. Minimum and maximum concentrations of total and dissolved metals in main inlet, submerged outlet, and surface outlet samples, February 21, 1980, to July 13, 1981, in micrograms per liter
[<, less than]

Constituents	Main Inlet			Submerged Outlet			Surface Outlet		
	Minimum concen- tration	Maximum concen- tration	Number of samples	Minimum concen- tration	Maximum concen- tration	Number of samples	Minimum concen- tration	Maximum concen- tration	Number of samples
Arsenic, total	1	7	51	0	4	39	1	3	41
Arsenic, dissolved	0	2	51	0	3	40	0	3	41
Cadmium, total	0	4	49	0	1	38	0	6	40
Cadmium, dissolved	0	4	49	0	7	38	0	6	40
Chromium, total	10	80	50	10	30	40	10	50	41
Chromium, dissolved	10	30	50	10	20	40	10	20	41
Copper, total	2	210	103	1	23	62	2	19	64
Copper, dissolved	0	120	103	0	8	62	0	6	64
Iron, total	310	55,000	104	200	2,700	62	160	7,500	64
Iron, dissolved	0	15,000	104	0	190	62	0	120	64
Lead, total	2	1,600	100	0	42	62	0	42	64
Lead, dissolved	0	37	104	0	7	61	0	8	64
Mercury, total	<0.1	0.4	51	<0.1	0.4	39	<0.1	0.5	41
Mercury, dissolved	<0.1	0.4	51	0.1	0.3	40	<0.1	0.4	41
Zinc, total	10	950	106	10	320	61	10	80	64
Zinc, dissolved	4	260	104	0	40	62	0	70	64

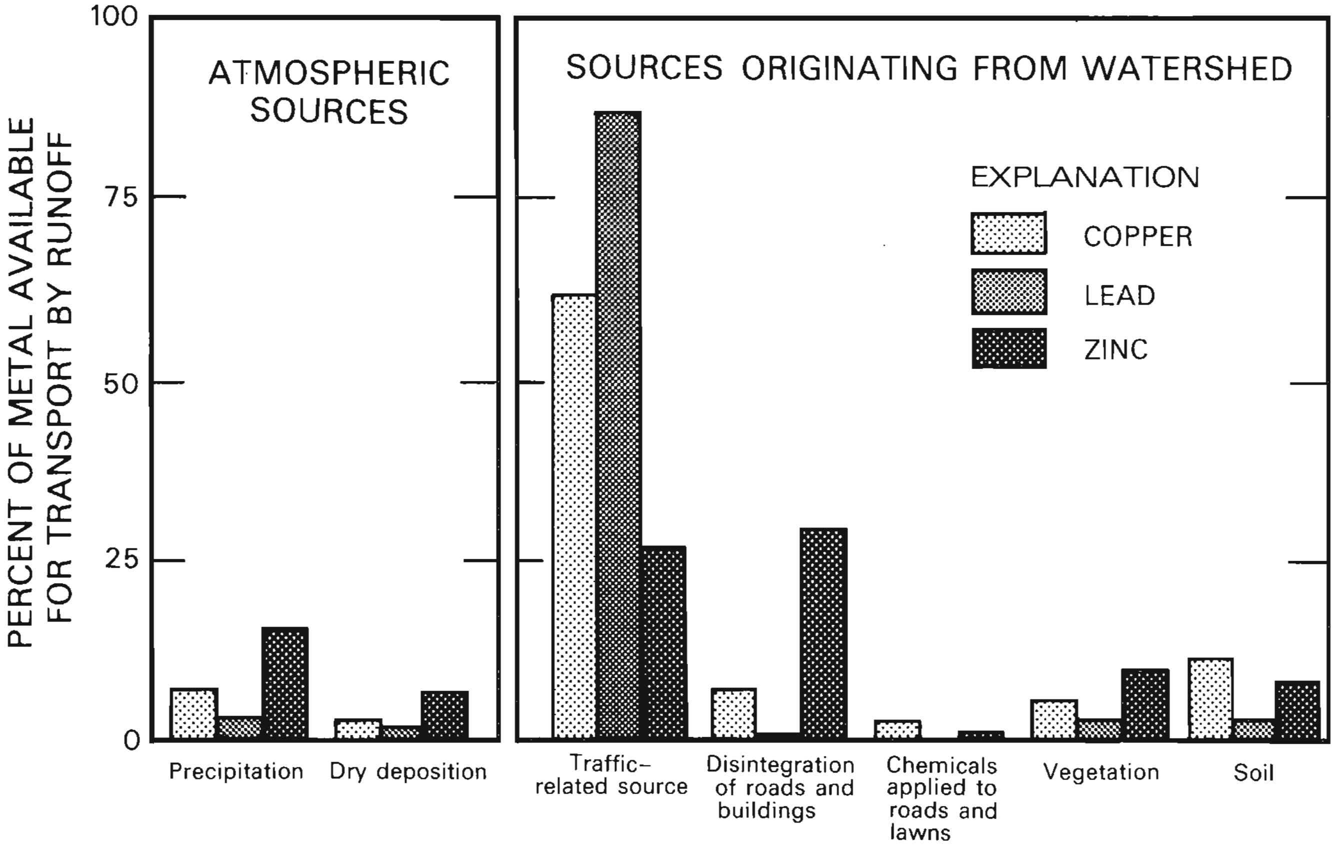

Figure 13. Sources of copper, lead, and zinc available for transport by runoff in the Lake Ellyn watershed (data from Hey and Schaefer, 1983).

variation of dissolved-solids concentrations can be explained by variation of specific conductance (fig. 17). In turn, 94 percent of the variation of chloride concentrations, 76 percent of the variation of sodium concentrations, 86 percent of the variation of calcium concentrations, 83 percent of the variation of magnesium concentrations, and 83 percent of the variations of sulfate concentrations in rainfall-runoff samples collected at main inlet and the outlets can be explained by variation of dissolved-solids concentrations (figs. 18–22). Relations between concentrations of these dissolved ions and dissolved solids in samples of flow less than 0.5 ft^3/s and snowmelt runoff are also shown in figures 18–22, but these were not included in the regression calculations.

Dissolved constituents in runoff to Lake Ellyn have both anthropogenic and geologic sources. Road deicing salt is the primary source of dissolved solids that enter the lake. An estimated 230,000 kg of sodium chloride (rock salt) were applied in the watershed during the winter of 1979–80, and 126,000 kg were applied in 1980–81 (Hey and Schaefer, 1983). Sodium chloride is about 39 percent sodium and 61 percent chloride by weight. Other salts associated with deicing include calcium chloride, which may be added to sodium chloride as a wetting agent to initiate ice melting; and potassium chloride, which is sometimes used in place of sodium chloride. Powdered calcium carbonate and magnesium carbonate are commonly added to deicing salts as anticaking agents.

Geologic sources of dissolved ions include calcium and magnesium contributed by dissolution of local soils, till, and bedrock. Field observations (G.C. Schaefer, Northeastern Illinois Planning Commission, oral commun, 1982) indicate that a major contribution to base flow at main inlet is leakage from water-supply pipes near the village's water tower. The source of water to that tower is a dolomite aquifer that has relatively high calcium, magnesium, and chloride concentrations (Sasman and others, 1981).

Concentrations of dissolved solids and chloride from samples of snow collected in the Lake Ellyn watershed are listed in table 10. Greatest concentrations of these con-

Table 8. Concentrations of copper, lead, and zinc in gasoline and vehicle parts
[From Shaheen, 1975]

Source	Concentration, in milligrams per kilogram		
	Copper	Lead	Zinc
Gasoline	4	660	10
Tires	250	1,100	620
Undercoating	1	120	110
Brake linings	31,000	1	120

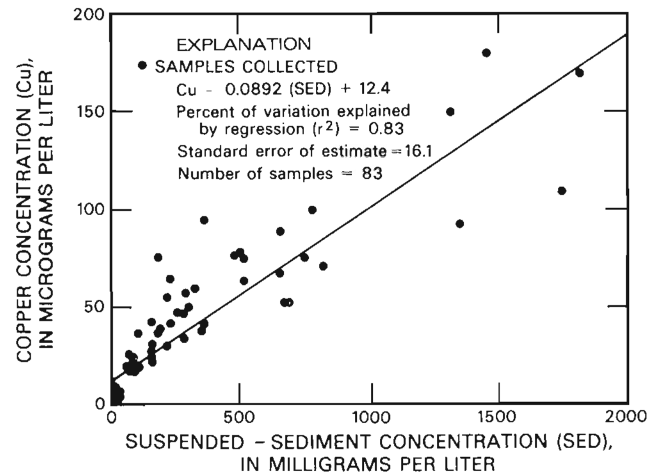

Figure 14. Relation between total-copper concentrations and suspended-sediment concentrations in samples collected at main inlet.

stituents are found along roads with high traffic densities. Most roads in the watershed are connected to the lake by storm drains. Unlike suspended constituents, which require high velocities and turbulence to be transported in high concentrations, dissolved constituents can be concentrated in gradual snowmelt runoff and in low flow. Although snowmelt runoff and low flow were not sampled extensively, it appears that their contributions to Lake Ellyn were much greater than had been anticipated during the design of the sampling program. Because not all dissolved-constituent contributions were measured, calculated trap efficiencies for dissolved constituents were negative (table 20, sections 11–17). This is especially relevant for the winter of 1979–80, when large amounts of road deicing salts were applied to the watershed prior to the period of stream sampling.

The effects of unmeasured inputs were observed throughout 1980. Dilute rainfall runoff during spring and summer mixes with lake water that has been concentrated with dissolved constituents during the previous winter. The resulting outflow has concentrations of dissolved constituents that are greater than those at main inlet, and negative trap efficiencies for individual rainfall-runoff periods. In addition to being input with snowmelt runoff and low flow, calcium and magnesium may also dissolve from lake

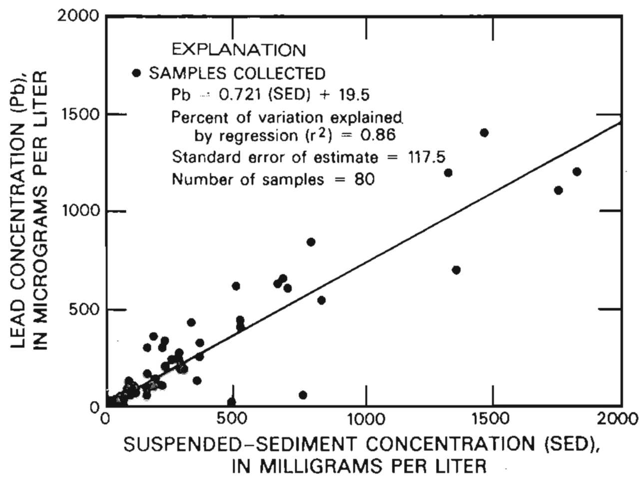

Figure 15. Relation between total-lead concentrations and suspended-sediment concentrations in samples collected at main inlet.

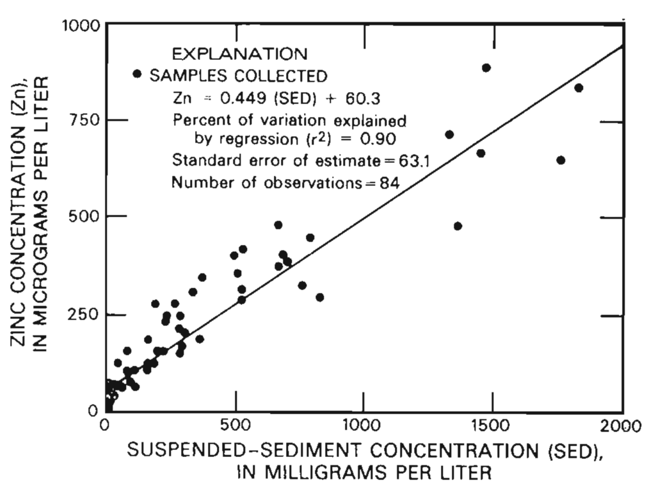

Figure 16. Relation between total-zinc concentrations and suspended-sediment concentrations in samples collected at main inlet.

Table 9. Minimum and maximum concentrations of dissolved solids and major ions in main inlet, submerged outlet, and surface outlet samples, February 21, 1980, to July 13, 1981, in milligrams per liter

Constituents	Main Inlet			Submerged Outlet			Surface Outlet		
	Minimum concen-tration	Maximum concen-tration	Number of samples	Minimum concen-tration	Maximum concen-tration	Number of samples	Minimum concen-tration	Maximum concen-tration	Number of samples
Dissolved solids	17	1,290	122	278	1,480	69	261	1,120	70
Calcium	4.5	130	105	23	90	61	24	90	64
Chloride	3.7	700	104	58	650	62	55	440	64
Magnesium	1.3	59	105	14	39	61	13	37	64
Potassium	0.5	8	94	0.2	5.2	53	2.4	8.5	58
Sodium	2.5	460	105	23	380	62	35	260	64
Sulfate	1.6	200	92	35	130	53	35	120	56

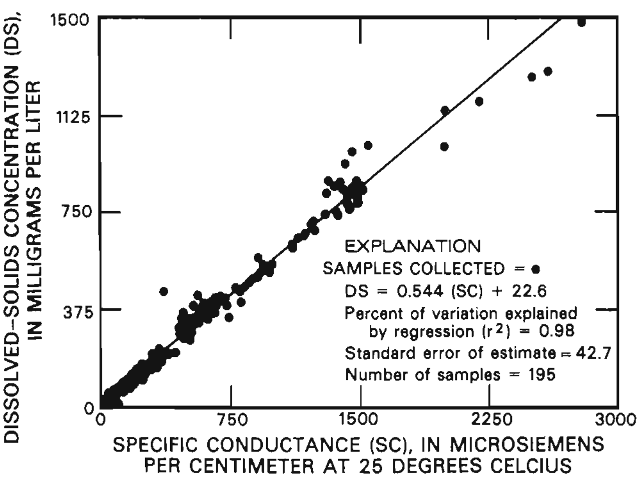

Figure 17. Relation between dissolved-solids concentrations and specific conductance in samples collected at main inlet and lake outlets.

sediments. Conditions for calcium and magnesium dissolution are most favorable in winter when there are potentially high carbon-dioxide partial pressures under the ice cover and long lake-water residence times.

Despite the calculated negative trap efficiencies for chloride and sodium for individual rainfall-runoff periods, annual efficiencies are probably close to zero (input equals output). Annual low concentrations of chloride in lake outflow (fig. 23) are nearly the same in consecutive years. Because the lake volume is essentially constant, and chloride and sodium enter into few chemical reactions that could change their total mass in solution, inputs between the times of low concentrations must be equally balanced with outputs in order to return to the initial concentration. Calcium and magnesium concentrations in lake outflow show annual cycles that are similar but less exaggerated than those for chloride and sodium (fig. 23). Because calcium and magnesium have potential sources from road salt and from the dissolution of sediments, it is not possible to make conclusions about their trap efficiencies that are similar to those made for chloride and sodium.

Nitrogen and Phosphorus

Nitrogen and phosphorus enter Lake Ellyn dissolved in runoff and as suspended organic debris—including leaf litter, grass clippings, and animal feces. Inputs of dissolved nitrogen and phosphorus are greatest in the spring, corresponding to periods of frequent and intense rainfall, and lawn-fertilizer application. Minimum and maximum concentrations of total and dissolved nitrogen, organic nitrogen, and phosphorus, total ammonia, and dissolved nitrate plus nitrite in main inlet, submerged outlet, and surface outlet samples are listed in table 11.

Trap efficiencies for dissolved and total nitrogen and phosphorus are listed in table 20, sections 18–21. The trap efficiencies as listed are conservatively low because they do not account for inputs of leaf litter from the park surrounding Lake Ellyn, or for feces of the many ducks and geese that inhabit the park near the lake. The 30 to 65 percent overall trap efficiency for total phosphorus at Lake Ellyn (table 20, section 20) compares to a 65-percent trap efficiency for total phosphorus measured at Frisco Lake, a

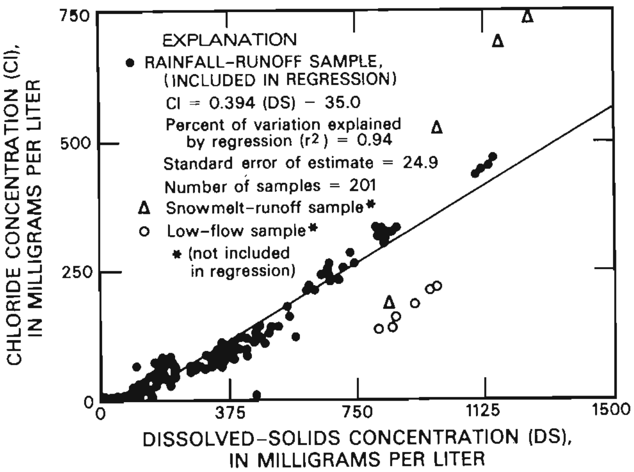

Figure 18. Relation between chloride concentrations and dissolved-solids concentrations in samples collected at main inlet and lake outlets.

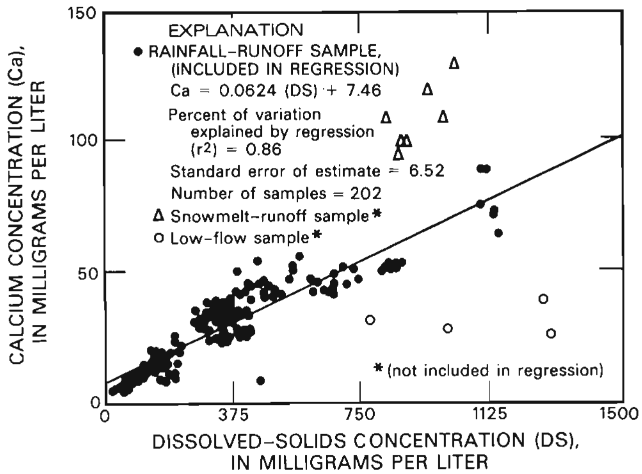

Figure 20. Relation between calcium concentrations and dissolved-solids concentrations in samples collected at main inlet and lake outlets.

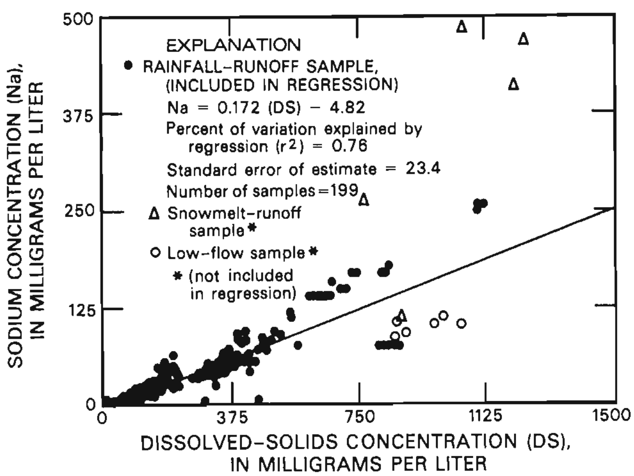

Figure 19. Relation between sodium concentrations and dissolved-solids concentrations in samples collected at main inlet and lake outlets.

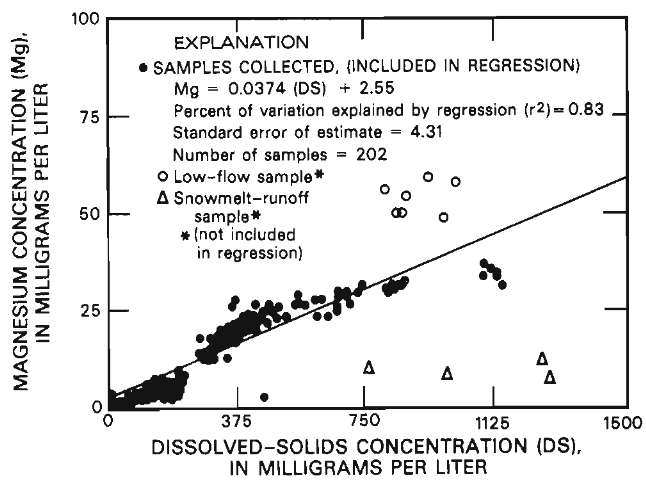

Figure 21. Relation between magnesium concentrations and dissolved-solids concentrations in samples collected at main inlet and lake outlets.

5.7-acre impoundment in a park in Rolla, Mo., for a 6-mo period in 1975 (Oliver and Grigoropoulos, 1981). These authors also reported trap efficiencies of 22 percent for organic nitrogen and −30 percent for nitrogen-ammonia at Frisco Lake (similar calculations were not made for Lake Ellyn).

Organic Compounds

Bottom-sediment samples collected between main inlet and the barrier dam (fig. 1), and storm-runoff samples composited for main inlet and the lake outlets on May 29, 1981, were analyzed by a USEPA contract laboratory for the 129 USEPA priority pollutants. Of the 17 organic com-

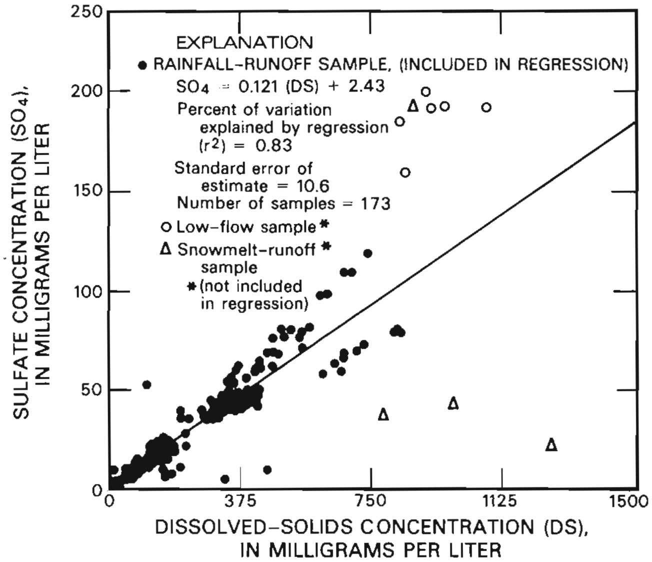

Figure 22. Relation between sulfate concentrations and dissolved-solids concentrations in samples collected at main inlet and lake outlets.

Table 10. Dissolved solids and chloride concentrations in samples of snow collected in the Lake Ellyn watershed (in milligrams per liter of melted sample)
[From Hey and Schaefer, 1983]

	Curbside			
Constituent	High traffic areas	Medium traffic areas	Low traffic areas	Lake Ellyn Park
Dissolved solids	7,560	6,510	5,490	160
Chloride	4,330	3,750	1,420	9

pounds identified (table 12), 9 were found in the main inlet sample, 13 were found in the bottom sediment sample, and 2 were detected in the outlet sample. Composite storm-runoff samples collected on May 17, 1980 (table 13), contained DDD, DDE, DDT, dieldrin, phenols, 2,4,5–TP, and 2–4D in main inlet samples, and phenols, 2,4,5–TP, and 2–4D in outflow. Most organic compounds are probably associated with fine-grained suspended sediments in runoff that are deposited in the lake. Dissolved-organic compounds that are present in the inflow but not in the outflow may be diluted below analytically detectable concentrations, may volatilize, or may enter into chemical reactions while in the lake.

EFFECTS OF RUNOFF ON LAKE ELLYN

Lake Hydrology

Surface runoff from 95 percent of the watershed enters storm drains that empty into the lake. The main inlet storm drain quickly conveys runoff to the lake and has discharge hydrographs that peak sharply and are of short duration (fig. 5). Outlet hydrographs have lower peaks and are of longer duration. Following heavy rains, inflowing water appears to have sufficient energy to mix the lake, preventing prolonged chemical and temperature stratification in summer. The difference between inflow and outflow volumes for a runoff period will temporarily increase lake storage and cause the lake level to rise. Lake-level fluctuations contribute to bank erosion and may disturb littoral communities (Moss, 1980).

Deposition of Bottom Sediments

A commonly noticed effect of routing runoff through detention reservoirs is the deposition of sediments in the reservoirs. Sediments reduce reservoir volumes and tend to fill shallow areas near inlets. Dredging is often necessary to maintain acceptable conditions in detention lakes and ponds. Barrier dams constructed near inlets can be useful in reducing transport to downstream areas of reservoirs and in confining sediment deposition to areas easily accessible for dredging equipment.

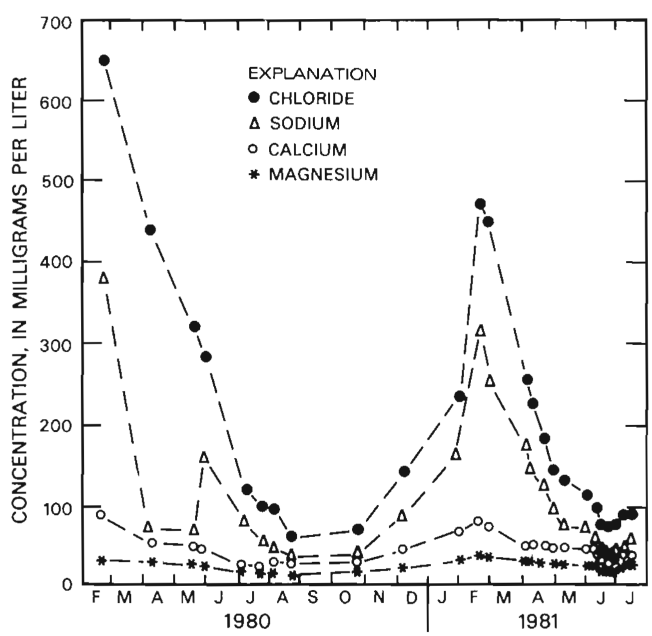

Figure 23. Concentrations of chloride, sodium, calcium, and magnesium in the outflow from Lake Ellyn, 1980–81.

Table 11. Minimum and maximum concentrations of total and dissolved nitrogen and phosphorus in main inlet, submerged outlet, and surface outlet samples, February 21, 1980, to July 13, 1981, in milligrams per liter
[ND, None detected (<0.01 mg/L)]

	Main Inlet			Submerged Outlet			Surface Outlet		
Constituents	Minimum concentration	Maximum concentration	Number of samples	Minimum concentration	Maximum concentration	Number of samples	Minimum concentration	Maximum concentration	Number of samples
Nitrogen, total	0.78	26	104	0.77	4.7	62	0.59	5.8	64
Nitrogen, dissolved	.27	5.7	104	22	3.3	62	.24	2.3	63
Nitrogen, total organic	.27	26	103	.45	3.6	62	.38	5.3	64
Nitrogen, dissolved organic	.02	4.9	104	ND	3.2	62	ND	1.3	64
Nitrogen, total ammonia	ND	1.4	104	.01	2.2	62	ND	1.3	64
Nitrogen, nitrate plus nitrite	.02	3.8	103	ND	0.63	62	.01	2	64
Phosphorus, total	.03	2	103	.08	0.95	62	.02	0.53	64
Phosphorus, dissolved	.01	0.32	104	.01	0.30	62	ND	0.20	64

Lake Ellyn was drained and sediments were removed in 1970. Figure 24 shows the thickness and areal distribution of sediments in Lake Ellyn in 1980 (Cowan, 1982). A maximum sediment thickness of 3.3 ft was measured on the upstream side of the barrier dam near main inlet. A 13-percent loss in lake storage was calculated for the 10-yr period with an area-averaged mean sedimentation rate of 0.8 in/yr.

Lake Ellyn sediments were classified as organic-rich muds (Hill and Hullinger, 1981). Mineral particles in sediments are transported to the lake mainly in runoff. Organic material in sediments settles from runoff and is also produced by biologic activity within the lake. The lake supports populations of fish, aquatic plants, and plankton that settle after dying and accumulate as sediment. Bottom sediment may be resuspended by wind, waves, and high stormwater discharge to the lake. Feeding and spawning fish also cause some resuspension of bottom sediments.

Cores of bottom sediments from Lake Ellyn were collected along transect lines using a BMH-53 sampler (Guy and Norman, 1970). Particle-size distributions of core samples were determined by wet sieving for the fraction greater than 62 μm and by pipet analysis for the fraction less than 62 μm (Guy, 1969). Particle-size distributions of lake sediments near main inlet, in the center of the lake, and near the outlets are listed in table 14. Figure 25 is a map of the areal distribution of mean particle sizes found in Lake Ellyn. The mean size of bottom-sediment particles decreases with distance from main inlet due to the reduction in velocity of inflowing stormwater. The coarsest sediment was deposited near main inlet; it included broken pieces of brick, glass, curb, and storm-drain pipe. Sediment in nearshore areas had a wider mean particle-size range because of erosion of sand and gravel from the bank. The finest mean particle sizes were found in the deepest areas of the lake.

Chemicals Associated with Bottom Sediments

The distribution of constituents in bottom sediments is strongly dependent on particle size (Rickert and others, 1977; Kelly and Hite, 1981). Small particles, such as silt, clay, and organic particulates, have large surface areas per unit volume and have many surface sites for adsorbing chemicals (Feltz, 1980). Mean concentrations of copper, iron, lead, and zinc in Lake Ellyn bottom sediment were inversely proportional to the mean particle size of bottom

Table 12. Concentrations of organic compounds detected in main inlet and combined outlet water samples, and in bottom sediments, May 29, 1981

[Modified from Hey and Schaefer, 1983; D, detected; ND, none detected; µg/L, micrograms per liter; µg/kg, micrograms per kilogram]

Chemical characteristic	Concentration		
	Inflow (µg/L)	Outflow (µg/L)	Bottom sediment (µg/kg, dry weight)
Acenaphthene	ND	ND	540
Anthracene	5	2	1,300
Benzo(a)anthracene	ND	ND	3,800
Dibenzo(a,h)anthracene	ND	ND	4,200
Benzene	D	ND	ND
Chrysene	4.5	ND	3,400
Fluoranthene	11.5	ND	3,700
Benzo(k)fluoranthene	ND	ND	14,000
Fluorene	ND	ND	580
Bis(2-ethylhexyl phthalate)	ND	ND	690
Phenanthrene	5	2	2,800
Pyrene	9.5	ND	3,000
Benzo(a)pyrene	ND	ND	12,000
Ideno(1,2,3-cd) pyrene	ND	ND	15,000
Dichloromethane	D	ND	ND
Tetrachlorethane	D	ND	ND
Toluene	D	ND	ND

Table 13. Concentrations of organic compounds in main inlet, submerged outlet, and surface outlet water samples, May 17, 1980, in micrograms per liter

[ND, none detected]

Organic compound	Main Inlet	Submerged Outlet	Surface Outlet
DDD	0.50	ND	ND
DDE	.06	ND	ND
DDT	3.9	ND	ND
Dieldrin	.31	ND	ND
Phenols	2.0	ND	1.0
2,4,5-TP	.24	0.06	.08
2,4-D	2.2	.57	.74

sediment (fig. 26). This suggests that highest concentrations of heavy metals will be found in the deep areas of lakes where the finest sediments are deposited.

A water sample represents only the conditions that exist during sample collection. If pollutant discharge is intermittent or from nonpoint sources, periodic water samples may have deceptively low concentrations and indicate little or no pollutant discharge. Alternatively, the chemistry of sediment collected from lake bottoms can be used to evaluate the historical levels and distribution of trace-metal contaminants and persistent organic compounds (Rickert and others, 1977; Wahlen and Thompson, 1980; and Feltz, 1980). Bottom sediments are often deposited in discrete layers. Knowledge of the date of deposition and chemistry of these layers is a useful tool for reconstructing past conditions. For Lake Ellyn sediments, it is not possible to identify layers; but it is known that the lake was last dredged in 1970. Deposition of persistent chemicals in the lake since 1970 can

Table 14. Particle-size distributions of Lake Ellyn bottom-sediment samples, in percent by weight

[Modified from Cowan, 1982; >, more than; <, less than; μm, micrometers]

Location	Number of samples	Gravel and sand (>62 μm)	Silt (4-62 μm)	Clay (<4 μm)
Near Main Inlet	6	22.7	43.5	33.8
Center of lake	7	10.8	42.6	46.6
Near outlet	3	6.3	45.3	48.4

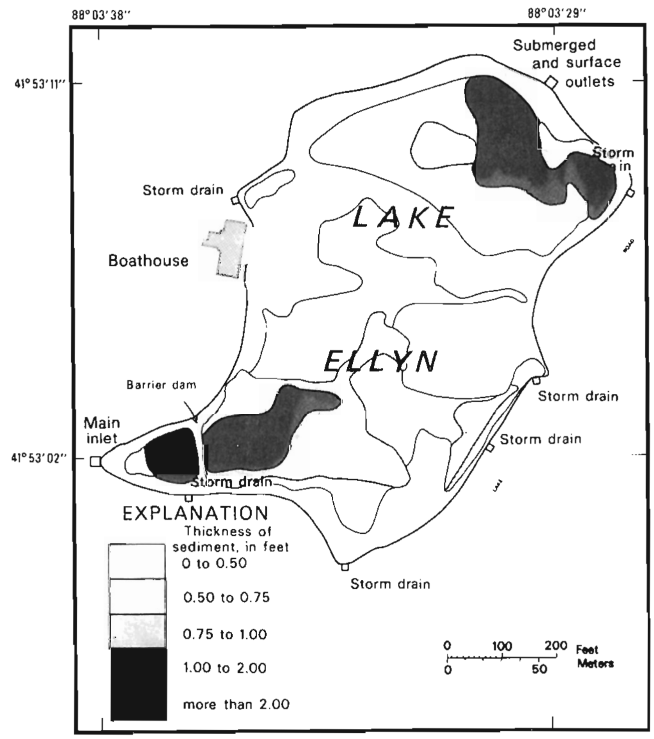

Figure 24. Thickness of bottom sediments accumulated in Lake Ellyn from 1970 to 1980.

therefore be identified by chemical analyses of the sediments. For example, a concentration of 23 μg of mercury per kilogram of dried sediment was measured in the Lake Ellyn sediment sample collected on May 29, 1981, and table 12 lists eight organic compounds detected in that same sample. None of these chemicals were present in detectable quantities in inflow or outflow samples collected that day.

Concentrations of copper, lead, and zinc associated with lake sediments, road dirt, and street sweepings are shown in table 15. Road dirt includes those particles that accumulate on street surfaces and that may be displaced by traffic. Street sweepings include those particles that accumulate on street surfaces and that may be collected with an industrial vacuum cleaner (Hey and Schaefer, 1983). The highest concentrations of lead and zinc were measured along the roadside in high-traffic areas; concentrations were lower in areas with less traffic, and in lake sediment. Copper concentrations were highest in lake sediment, because copper sulfate had been used to control algae in the lake in previous years. Mean concentrations of cadmium, copper, iron, lead, and zinc reported in a 1979 survey of the chemical characteristics of sediments from 63 Illinois lakes (Kelly and Hite, 1981) are lower than concentrations in Lake Ellyn sediments for cadmium, copper, and lead (table 16). Copper and zinc concentrations in Lake Ellyn sediments were within ranges of concentrations reported by the 1979 survey of Illinois lakes, but mean lead concentrations from Lake Ellyn sediments were more than six times greater than the maximum survey concentration for lead.

Sediment samples collected near main inlet had a petroleum-oil coating and odor. Average content of grease and oil in grab samples collected near main inlet was 2.06 percent of the dry weight of the samples (table 17; fig. 27). Average content of grease and oil in other samples decreased with distance from main inlet. The percent dry weight of volatile solids in sediments was 16.5 percent near main inlet and was 13.1 percent in sediment collected in the middle of the lake and near the outlets.

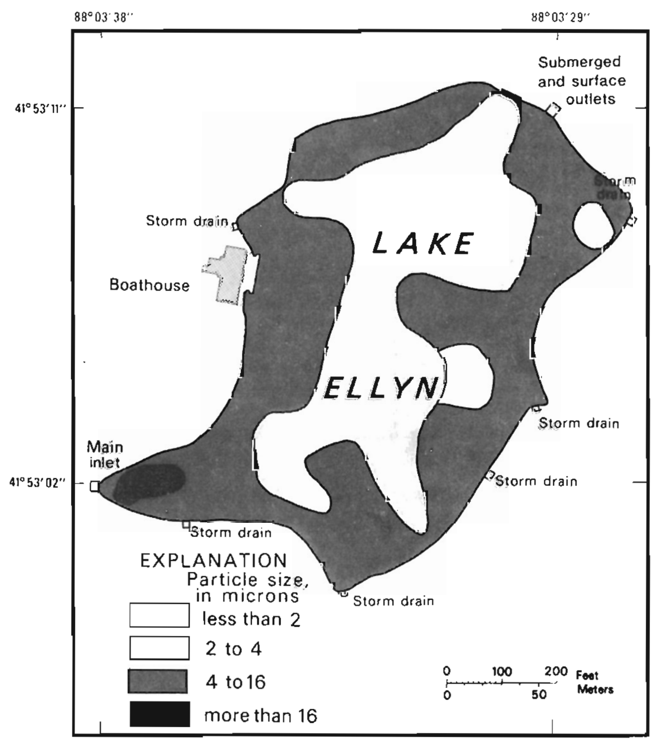

Figure 25. Mean particle size of bottom sediments in Lake Ellyn in 1980.

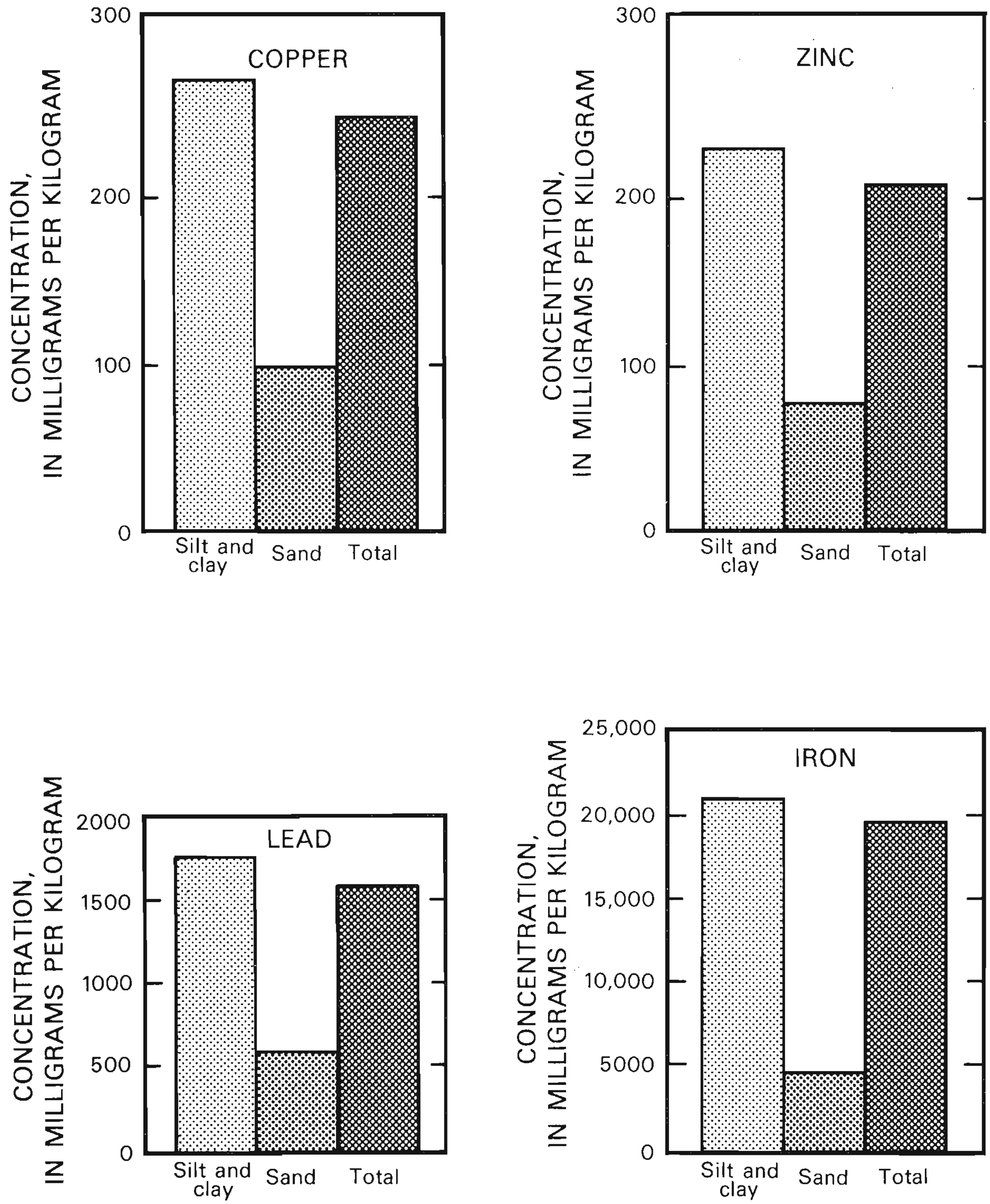

Figure 26. Mean concentrations of metals in Lake Ellyn bottom sediments, by particle size (concentrations in milligrams per kilogram).

Biological Effects of Sediment Deposition

The deposition of solids in Lake Ellyn results in an organic-rich mud bottom that provides an unsuitable substrate for many rooted plants and benthic invertebrates (Fassett, 1940; Pennak, 1953). No rooted submergent plants are present in Lake Ellyn. Three taxa of benthic macroinvertebrates (*Chaoborus*, Chironomidae, and Tubificidae) have been identified in Ekman grab samples collected from three locations in Lake Ellyn (fig. 27). Numbers of organisms per

Table 15. Mean concentrations of copper, lead, and zinc in Lake Ellyn bottom-sediment, road dirt, and street sweepings samples, in milligrams per kilogram dry weight
[Modified from Hey and Schaefer, 1983; <, less than; µm, micrometer]

	Lake Ellyn bottom sediments		Road dirt						Street sweepings	
			High-traffic areas		Medium-traffic areas		Low-traffic areas			
	Size fraction		Size fraction		Size fraction		Size fraction		Size fraction	
Constituent	Silt + clay (<63 µm)	Total	Silt + clay (<63 µm)	Total	Silt + clay (<63 µm)	Total	Silt + clay (<63 µm)	Total	Silt + clay (<63 µm)	Total
Copper	275	250	131	65	83	42	52	25	77	34
Lead	1,750	1,590	2,130	1,550	1,850	1,310	850	645	1,140	543
Zinc	228	210	605	414	442	217	335	148	472	196

Table 16. Concentrations of cadmium, copper, iron, lead, and zinc in bottom sediments from 63 Illinois lakes and Lake Ellyn
[Modified from Kelly and Hite, 1981; Cowan, 1982; <, less than; ≤, less than or equal to; N, number of samples]

		Concentrations, in milligrams per kilogram dry weight						
		63 Illinois lakes			Lake Ellyn			
	N	Mean ± 1 standard deviation	Minimum	Maximum	N	Mean	Minimum	Maximum
Cadmium	272	≤1	<0.5	8	7	4	3	6
Copper	273	42 ± 56	3	560	15	250	73	790
Iron	273	27,080 ± 8,890	4,300	55,000	15	19,420	3,630	28,000
Lead	273	57 ± 43	3	250	15	1,590	410	5,100
Zinc	273	113 ± 66	11	750	15	210	3	500

Table 17. Amounts of grease and oil and of volatile solids in Lake Ellyn bottom sediments
[From Hill and Hullinger, 1981; N, number of samples]

	Amount as a percentage of dry weight			
	Grease and oil	N	Volatile solids	N
Station 1	2.06	6	16.5	9
Station 2	1.43	6	13.1	9
Station 3	1.26	6	13.1	9

square meter of substrate are listed in table 18. All the organisms listed have special adaptations for surviving in soft sediments and are tolerant of anoxic conditions (Hill and Hullinger, 1981). Single-census electroshocking by the Illinois Department of Conservation indicated that six species of fish are present in Lake Ellyn (table 19). Of these, only green sunfish and goldfish reproduce in the lake. Many of the goldfish sampled were observed to have open sores on their fins and bodies. Attempts to stock bluegill and largemouth bass have been unsuccessful. Although stocked fish have survived, they have not reproduced (Hey and Schaefer, 1983). Green sunfish and goldfish spawn in shallows where there has been bank reinforcement and where emergent rooted plants are present. Largemouth bass and bluegills require coarse sediments in deeper waters for nest building and spawning (Pflieger, 1975). No such substrate is present in the limnetic zone of Lake Ellyn (Cowan, 1982).

Effects of Major-Ion Inputs

Runoff during winter results in elevated lake-water concentrations of ions associated with road deicing salts.

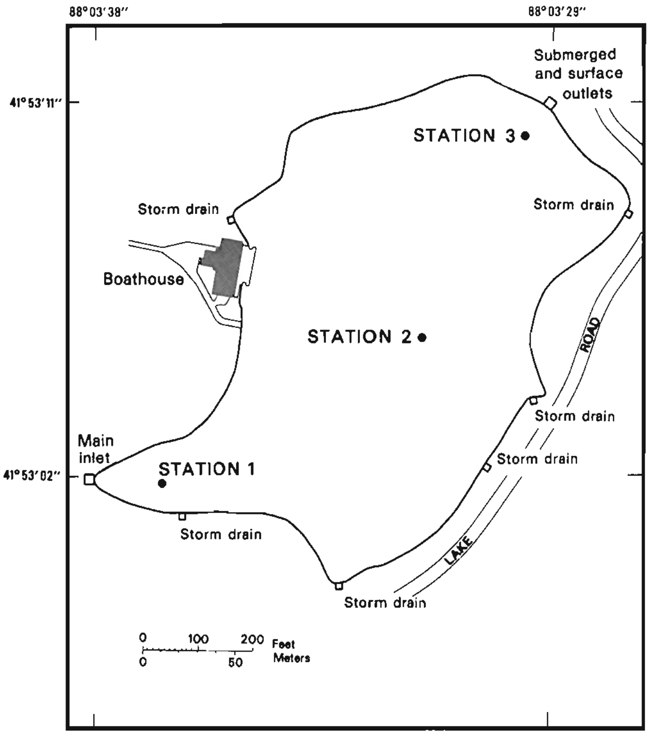

Figure 27. Locations of sampling sites for volatile solids, for grease and oil in sediments, and for benthic macroinvertebrates at Lake Ellyn.

Chloride-, sodium-, calcium-, and magnesium-concentration graphs (fig. 23) for Lake Ellyn show seasonal cycles with peaks in late winter and troughs in September and October. Peaks in chloride and sodium concentrations (fig. 23) can be directly attributed to deicing salt. The use of calcium chloride as a wetting agent, or calcium and magnesium carbonates as anticaking agents mixed with deicing salts may contribute to the calcium and magnesium peaks. Long lake-water residence times during winter and potentially high carbon dioxide partial pressures under ice cover produce favorable conditions for dissolution of calcium and magnesium from deposited sediments (Stumm and Morgan, 1981), which may also contribute to the observed concentration peaks.

Seasonally low, in-lake concentrations of chloride, sodium, calcium, and magnesium are lower than concentrations found in inlet samples at low flow, indicating dilution of lake water by storm runoff. This suggests that winter inputs of these constituents are flushed during spring and summer and are not causing chemical buildup in lake water. Increased buildup of deicing-salt chemicals has caused chemical stratification (meromixis) in other lakes in urban areas (Judd, 1970; Free and Mulamouttil, 1983). Dissolved copper, lead, and zinc do not exhibit seasonal concentration cycles at Lake Ellyn.

Effects of Nitrogen and Phosphorus Inputs

The role of nitrogen and phosphorus in aquatic systems has been extensively documented in the literature (Welch, 1952; Clesceri, 1973; and Cole, 1979), and phosphorus is often considered to be the nutrient that limits algal production and eutrophication in lakes (Hutchinson, 1969; Vallentyne, 1974; Lee and others, 1978; Browman and others, 1979). Lake Ellyn has been described as being eutrophic since the early 1900's (K.M. Hiatt, long-time Glen Ellyn resident, oral commun, 1981).

Large nutrient loads in urban runoff undoubtedly contribute to the eutrophic condition of Lake Ellyn. Algal blooms, although not observed to be frequent, do occur at the lake. Phytoplankton counts of a single lake-water sample collected in July 1980 showed *Anabaena flos-aquae*, a

Table 18. Benthic macroinvertebrates in Lake Ellyn
[Individuals per square meter of substrate; modified from Hill and Hullinger, 1981]

Date of sample	Chaoborus			Chironomidae			Tubificidae		
	Station			Station			Station		
	1	2	3	1	2	3	1	2	3
Oct. 18, 1979	220	2,670	1,938	431	144	0	72	14	0
Dec. 17, 1979	1,033	1,808	603	1,435	1,119	2,196	144	172	14
Mar. 25, 1980	172	1,593	1,507	287	2,024	3,933	115	603	14
May 28, 1980	86	660	703	57	14	43	345	230	43
July 29, 1980	517	3,818	1,751	14	0	0	86	129	14

Table 19. Results of 30-minute electrofishing survey of Lake Ellyn, June 10, 1980
[From Illinois Department of Conservation, written commun, 1980]

Fish species	Number of fish	Length, in millimeters	Comments
Sunfish family (Centrarchidae)			
Largemouth bass (*Micropterus salmoides*)	4	330-368	From previous stocking
Bluegill (*Lepomis macrochirus*)	17	114-165	From previous stocking
Green sunfish (*Lepomis cyanellus*)	32	51-127	Successfully reproducing
Minnow family (Cyprinidae)			
Goldfish (*Carassius auratus*)	32	140-241	Successfully reproducing, open sores commonly observed on fins and body
Carp (*Cyprinus carpio*)	1	584	
Catfish family (Ictaluridae)			
Black bullhead (*Ictalurus melas*)	1	241	

nuisance blue-green alga, densities in excess of 600,000 cells per milliliter.

The infrequency of algal blooms that occur at Lake Ellyn may possibly be attributed to short lake-water residence times during summer high flows that continually wash algae out of the lake, and to high concentrations of suspended sediments in the lake that inhibit light penetration and photosynthesis below the first few inches of the water surface (Wang, 1974). However, such conclusions must be considered to be speculative without supportive data on algal-biomass production. Study of Lake Houston, a water-supply reservoir in Texas, led to conclusions that algal blooms at that reservoir coincide with low-flow periods when light penetration and reservoir-water residence times are greatest (Baca and others, 1982).

SUMMARY AND CONCLUSIONS

Trap-efficiency calculations for 18 runoff periods in 1980–81 indicate that detention storage in Lake Ellyn results in efficient removal of suspended solids, suspended sediments, and sediment-associated metals from runoff. These constituents accumulate as lake sediments at an area-averaged rate of 0.8 in per year and have reduced lake capacity by 13 percent in 10 yr. Concentrations of cadmium, copper, lead, and zinc in lake sediments were high relative to other lakes in Illinois, and were highest in sediments with the smallest particle diameters. A subsurface barrier dam located near the lake inlet is effective in reducing transport of sediments to downstream areas of the lake.

Road deicing salts in snowmelt runoff were the primary source of dissolved-solids and major-ions input to the lake. These inputs resulted in seasonal lake-water concentration hydrographs with peaks in winter and troughs in fall. Calculated trap efficiencies for dissolved solids and major ions were negative, based on load data for rainfall-runoff and high snowmelt-runoff periods. However, steady-state approximations based on concentration hydrographs at the lake outflow indicate that trap efficiencies are actually about 0 percent. Errors in the calculated trap efficiencies for dissolved constituents were probably due to insufficient sampling in winter.

Trap efficiencies for suspended nitrogen and phosphorus were less than those for other suspended constituents, and trap efficiencies for dissolved nitrogen and phosphorus were greater than those for other dissolved constituents. Although nutrient loads to the lake are large, and Lake Ellyn can be considered to be eutrophic, algal blooms are infrequent. This may possibly be attributed to short lake-water residence times during summer that allow algae to be continually washed out of the lake, and to shallow light penetration that results from high suspended-solids concentrations.

Analyses for USEPA priority pollutants detected more organic compounds in lake inlet samples than in outlet samples. Those pollutants detected in outlet samples were lower in concentration than those in inlet samples. Several organic compounds were detected in lake sediments that were not detected in inlet or outlet samples.

Benthic-macroinvertebrate populations are limited to three taxa that tolerate soft sediments and anoxic conditions. No rooted submergent plants grow in Lake Ellyn. Sport fishes that have been stocked in the lake have not reproduced.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois

[ft³/s, cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; kg, kilograms]

(1) Suspended solids

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	590	1,180	52,000	13	19.1	61,300	13	22.6	96.5	97.8
May 17, 1980	.45	67,800	290	557	119,000	16	53.9	132,000	14	52.3	80.9	94.8
May 28, 1980	1.69	269,000	1,300	9,900	394,000	14	156	315,000	39	348	94.9	98.1
July 9, 1980	.42	68,200	44	85.0	107,000	8.8	26.7	112,000	15	47.6	12.6	72.8
July 20, 1980	1.61	429,000	200	2,430	307,000	19	165	256,000	18	131	87.8	90.7
Aug. 4, 1980	.78	153,000	180	780	176,000	11	54.8	162,000	10	45.9	87.1	94.2
Aug. 19, 1980	.46	193,000	150	820	139,000	21	82.7	140,000	15	59.5	82.7	88.0
Sept. 22, 1980	.54	183,000	350	1,810	157,000	9.2	40.9	142,000	16	64.3	94.2	96.5
Oct. 24, 1980	.72	99,500	120	338	72,200	14	28.6	83,000	28	65.8	72.1	82.1
Dec. 7, 1980	1.06	162,000	240	1,100	162,000	12	55.1	198,000	12	67.3	88.9	95.0
Feb. 16, 1981	([1])	154,000	250	1,090	140,000	16	63.4	101,000	8.9	25.5	91.8	94.8
Feb. 22, 1981	.65	260,000	370	2,720	261,000	14	104	214,000	12	72.7	93.5	96.4
Apr. 3, 1981	.41	133,000	500	1,880	69,700	45	88.8	119,000	40	135	88.1	91.6
Apr. 22, 1981	.74	212,000	88	528	171,000	23	111	159,000	19	85.6	62.8	76.1
Apr. 28, 1981	1.46	326,000	490	4,520	500,000	43	609	558,000	45	711	70.8	91.0
May 10, 1981	.62	335,000	83	787	215,000	12	73.1	231,000	12	78.5	80.7	85.5
May 29, 1981	1.09	386,000	280	3,060	253,000	18	129	409,000	16	185	89.7	94.0
June 8, 1981	.28	133,000	260	979	96,900	24	65.9	94,500	24	64.2	86.7	90.8
Total		3,633,900	--	34,564.0	3,391,800	--	1,927.0	3,486,800	--	2,261.8	--	--
Runoff-weighted values		--	340	--	--	20	--	--	23	--	87.9	93.7

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(2) Suspended sediment

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	550	1,200	52,000	5.1	7.51	61,300	3.4	5.90	98.9	99.2
May 17, 1980	.45	67,800	370	710	119,000	22	74.1	132,000	20	74.8	79.0	94.3
May 28, 1980	1.69	269,000	1,700	13,000	394,000	20	223	315,000	52	464	94.7	98.0
July 9, 1980	.42	68,200	58	112	107,000	14	42.4	112,000	21	66.6	2.7	69.7
July 20, 1980	1.61	429,000	260	3,160	307,000	26	226	256,000	25	181	87.1	90.2
Aug. 4, 1980	.78	153,000	240	1,040	176,000	17	84.7	162,000	15	68.8	85.2	93.3
Aug. 19, 1980	.46	193,000	190	1,040	139,000	29	114	140,000	22	87.2	80.7	86.6
Sept. 22, 1980	.54	183,000	450	2,330	157,000	14	62.2	142,000	22	88.5	93.5	96.0
Oct. 24, 1980	.72	99,500	160	451	72,200	20	40.9	83,000	38	89.3	71.1	81.5
Dec. 7, 1980	1.06	162,000	380	1,740	162,000	9.5	43.6	198,000	18	101	91.7	96.3
Feb. 16, 1981	([1])	154,000	250	1,090	140,000	6.8	27.0	101,000	3.3	9.44	96.7	97.9
Feb. 22, 1981	.65	260,000	480	3,530	261,000	9.2	68.0	214,000	8.4	50.9	96.6	98.2
Apr. 3, 1981	.41	133,000	640	2,410	69,700	35	69.1	119,000	24	80.9	93.8	95.6
Apr. 22, 1981	.74	212,000	120	720	171,000	31	150	159,000	3.0	13.5	77.3	85.4
Apr. 28, 1981	1.46	326,000	550	5,080	500,000	57	807	558,000	21	332	77.6	93.1
May 10, 1981	.62	335,000	83	787	215,000	9.6	58.4	231,000	9.7	63.5	84.5	88.4
May 29, 1981	1.09	386,000	260	2,840	253,000	4.4	31.5	409,000	3.0	34.8	97.7	98.6
June 8, 1981	.28	133,000	310	1,170	96,900	8.6	23.6	94,500	4.7	12.6	96.9	97.8
Total		3,633,900	--	42,410	3,391,800	--	2,153.01	3,486,800	--	1,824.74	--	--
Runoff-weighted values		--	410	--	--	22	--	--	18	--	90.6	95.0

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(3) Total copper

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (μg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (μg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (μg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	81	0.161	52,000	5.1	0.008	61,300	7.0	0.012	87.6	92.3
May 17, 1980	.45	67,800	73	.140	119,000	4.9	.017	132,000	5.0	.019	74.3	93.1
May 28, 1980	1.69	269,000	130	.990	394,000	8.1	.090	315,000	5.9	.053	85.6	94.5
July 9, 1980	.42	68,200	78	.151	107,000	7.8	.024	112,000	3.6	.011	76.8	92.8
July 20, 1980	1.61	429,000	42	.510	307,000	5.6	.049	256,000	7.6	.055	79.6	84.5
Aug. 4, 1980	.78	153,000	51	.221	176,000	3.4	.017	162,000	3.7	.017	84.6	93.0
Aug. 19, 1980	.46	193,000	35	.191	139,000	6.3	.025	140,000	6.4	.025	73.8	81.9
Sept. 22, 1980	.54	183,000	54	.280	157,000	5.6	.025	142,000	5.9	.024	82.5	89.3
Oct. 24, 1980	.72	99,500	50	.141	72,200	5.8	.012	83,000	6.5	.015	80.9	87.7
Dec. 7, 1980	1.06	162,000	46	.211	162,000	3.8	.017	198,000	5.1	.029	78.2	90.2
Feb. 16, 1981	([1])	154,000	51	.222	140,000	7.7	.031	101,000	6.5	.019	77.5	85.6
Feb. 22, 1981	.65	260,000	58	.427	261,000	6.4	.047	214,000	5.8	.035	80.8	89.5
Apr. 3, 1981	.41	133,000	11	.041	69,700	6.5	.013	119,000	6.4	.022	14.6	40.5
Apr. 22, 1981	.74	212,000	23	.138	171,000	5.8	.028	159,000	4.8	.022	63.8	76.7
Apr. 28, 198	1.46	326,000	66	.609	500,000	6.1	.086	558,000	7.7	.122	65.8	89.5
May 10, 1981	.62	335,000	24	.228	215,000	5.6	.034	231,000	5.8	.038	68.4	76.2
May 29, 1981	1.09	386,000	46	.503	253,000	6.5	.047	409,000	8.4	.097	71.4	83.3
June 8, 1981	.28	133,000	51	.192	96,900	5.8	.016	94,500	8.9	.024	79.2	85.5
Total		3,633,900	--	5.356	3,391,800	--	0.586	3,486,800	--	0.639	--	--
Runoff-weighted values		--	52	--	--	6.1	--	--	6.5	--	77.1	87.9

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(4) Dissolved copper

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (µg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (µg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (µg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	9.0	0.018	52,000	4.9	0.007	61,300	5.5	0.010	5.6	41.1
May 17, 1980	.45	67,800	14	.027	119,000	4.8	.016	132,000	4.3	.016	-18.5	67.8
May 28, 1980	1.69	269,000	10	.076	394,000	3.4	.038	315,000	3.3	.029	11.8	66.6
July 9, 1980	.42	68,200	14	.027	107,000	4.6	.014	112,000	3.6	.011	7.4	71.2
July 20, 1980	1.61	429,000	9.0	.109	307,000	2.6	.023	256,000	2.1	.015	65.1	73.5
Aug. 4, 1980	.78	153,000	10	.043	176,000	2.7	.013	162,000	3.2	.015	34.9	70.7
Aug. 19, 1980	.46	193,000	7.0	.038	139,000	4.5	.018	140,000	4.6	.018	5.3	34.9
Sept. 22, 1980	.54	183,000	9.4	.049	157,000	3.8	.017	142,000	4.9	.020	24.5	53.5
Oct. 24, 1980	.72	99,500	36	.101	72,200	4.1	.008	83,000	4.8	.011	81.2	88.0
Dec. 7, 1980	1.06	162,000	7.6	.035	162,000	3.8	.017	198,000	5.2	.029	-31.4	40.6
Feb. 16, 1981	([1])	154,000	14	.061	140,000	9.0	.036	101,000	6.5	.019	9.8	42.4
Feb. 22, 1981	.65	260,000	7.0	.052	261,000	5.8	.043	214,000	5.2	.032	-44.2	20.4
Apr. 3, 1981	.41	133,000	4.0	.015	69,700	4.6	.009	119,000	3.6	.012	-40.0	1.8
Apr. 22, 1981	.74	212,000	8.0	.048	171,000	4.6	.022	159,000	4.2	.019	14.6	45.2
Apr. 28, 1981	1.46	326,000	8.3	.077	500,000	2.3	.033	558,000	3.4	.054	-13.0	65.0
May 10, 1981	.62	335,000	7.3	.069	215,000	4.4	.027	231,000	4.6	.030	17.4	38.2
May 29, 1981	1.09	386,000	5.6	.061	253,000	5.9	.042	409,000	6.5	.075	-91.8	-11.4
June 8, 1981	.28	133,000	11	.041	96,900	5.8	.016	94,500	5.4	.014	26.8	49.7
Total		3,633,900	--	0.947	3,391,800	--	0.399	3,486,800	--	0.429	--	--
Runoff-weighted values		--	9.2	--	--	4.2	--	--	4.3	--	12.6	53.8

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(5) Total iron

Date	Rainfall (inches)	Main Inlet			Submerged Outlet			Surface Outlet			Trap efficiency	
		Runoff volume (ft^3/s)	Mean concen-tration (µg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concen-tration (µg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concen-tration (µg/L)	Load (kg)	Mini-mum (per-cent)	Maxi-mum (per-cent)
Apr. 3, 1980	0.38	70,400	15,000	29.9	52,000	270	0.398	61,300	240	0.417	97.3	98.3
May 17, 1980	.45	67,800	7,900	15.2	119,000	270	.910	132,000	260	.972	87.6	96.6
May 28, 1980	1.69	269,000	15,000	114	394,000	490	5.47	315,000	580	5.17	90.7	96.5
July 9, 1980	.42	68,200	36,000	69.5	107,000	500	1.52	112,000	270	.856	96.6	98.9
July 20, 1980	1.61	429,000	6,400	77.8	307,000	420	3.65	256,000	740	5.36	88.4	91.2
Aug. 4, 1980	.78	153,000	6,800	29.5	176,000	260	1.30	162,000	400	1.84	89.4	95.2
Aug. 19, 1980	.46	193,000	4,300	23.5	139,000	410	1.61	140,000	260	1.03	88.8	92.2
Sept. 22, 1980	.54	183,000	7,600	39.4	157,000	350	1.56	142,000	340	1.37	92.6	95.4
Oct. 24, 1980	.72	99,500	3,600	10.1	72,200	520	1.06	83,000	520	1.22	77.4	85.6
Dec. 7, 1980	1.06	162,000	9,200	42.2	162,000	610	2.80	198,000	680	3.81	84.3	93.0
Feb. 16, 1981	([1])	154,000	6,800	29.7	140,000	480	1.90	101,000	240	.686	91.3	94.4
Feb. 22, 1981	.65	260,000	4,900	36.1	261,000	500	3.70	214,000	220	1.33	86.1	92.4
Apr. 3, 1981	.41	133,000	16,000	60.3	69,700	890	1.76	119,000	730	2.46	93.0	95.1
Apr. 22, 1981	.74	212,000	3,100	18.6	171,000	430	2.08	159,000	360	1.62	80.1	87.2
Apr. 28, 1981	1.46	326,000	9,200	84.9	500,000	780	11.0	558,000	880	13.9	70.7	91.0
May 10, 1981	.62	335,000	2,800	26.6	215,000	420	2.56	231,000	470	3.08	78.8	84.1
May 29, 1981	1.09	386,000	5,300	57.9	253,000	500	3.58	409,000	330	3.82	87.2	92.6
June 8, 1981	.28	133,000	4,600	17.3	96,900	420	1.15	94,500	380	1.01	87.5	91.3
Total		3,633,900	--	782.5	3,391,800	--	48.008	3,486,800	--	49.951	--	--
Runoff-weighted values		--	7,600	--	--	500	--	--	510	--	87.5	93.4

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(6) Dissolved iron

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (µg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (µg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (µg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	270	0.538	52,000	64	0.094	61,300	82	0.142	56.1	72.8
May 17, 1980	.45	67,800	100	.192	119,000	65	.219	132,000	70	.262	-151	32.3
May 28, 1980	1.69	269,000	250	1.91	394,000	30	.335	315,000	24	.214	71.3	89.1
July 9, 1980	.42	68,200	160	.309	107,000	51	.155	112,000	40	.127	8.7	71.6
July 20, 1980	1.61	429,000	89	1.08	307,000	23	.200	256,000	31	.225	60.6	70.0
Aug. 4, 1980	.78	153,000	160	.693	176,000	52	.259	162,000	53	.243	27.6	67.2
Aug. 19, 1980	.46	193,000	69	.377	139,000	68	.268	140,000	66	.262	-40.6	2.8
Sept. 22, 1980	.54	183,000	57	.295	157,000	45	.200	142,000	43	.173	-26.4	22.7
Oct. 24, 1980	.72	99,500	180	.507	72,200	68	.139	83,000	84	.197	33.7	57.5
Dec. 7, 1980	1.06	162,000	52	.239	162,000	47	.216	198,000	57	.320	-124	-1.1
Feb. 16, 1981	([1])	154,000	160	.698	140,000	75	.297	101,000	65	.186	30.8	55.8
Feb. 22, 1981	.65	260,000	94	.692	261,000	63	.466	214,000	72	.436	-30.3	28.7
Apr. 3, 1981	.41	133,000	140	.527	69,700	72	.142	119,000	57	.192	36.6	55.4
Apr. 22, 1981	.74	212,000	300	1.80	171,000	76	.368	159,000	81	.365	59.3	73.9
Apr. 28, 1981	1.46	326,000	89	.822	500,000	31	.439	558,000	40	.632	-30.3	59.8
May 10, 1981	.62	335,000	60	.569	215,000	72	.438	231,000	71	.464	-58.5	-19.0
May 29, 1981	1.09	386,000	69	.754	253,000	71	.509	409,000	73	.846	-79.7	-4.7
June 8, 1981	.28	133,000	140	.527	96,900	50	.137	94,500	76	.203	35.5	55.2
Total		3,633,900	--	12.529	3,391,800	--	4.881	3,486,800	--	5.489	--	--
Runoff-weighted values		--	120	--	--	51	--	--	55	--	17.2	55.7

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(7) Total lead

Date	Rainfall (inches)	Main Inlet Runoff volume (ft^3/s)	Main Inlet Mean concentration (µg/L)	Main Inlet Load (kg)	Submerged Outlet Runoff volume (ft^3/s)	Submerged Outlet Mean concentration (µg/L)	Submerged Outlet Load (kg)	Surface Outlet Runoff volume (ft^3/s)	Surface Outlet Mean concentration (µg/L)	Surface Outlet Load (kg)	Trap efficiency Minimum (percent)	Trap efficiency Maximum (percent)
Apr. 3, 1980	0.38	70,400	1,200	2.39	52,000	35	0.052	61,300	41	0.071	94.9	96.8
May 17, 1980	.45	67,800	630	1.21	119,000	33	.111	132,000	34	.127	80.3	94.7
May 28, 1980	1.69	269,000	930	7.08	394,000	14	.156	315,000	11	.098	96.4	98.6
July 9, 1980	.42	68,200	460	0.888	107,000	27	.082	112,000	23	.073	82.5	94.6
July 20, 1980	1.61	429,000	300	3.64	307,000	17	.148	256,000	21	.152	91.8	93.7
Aug. 4, 1980	.78	153,000	370	1.60	176,000	13	.065	162,000	16	.073	91.4	96.1
Aug. 19, 1980	.46	193,000	190	1.04	139,000	30	.118	140,000	31	.123	76.8	83.9
Sept. 22, 1980	.54	183,000	340	1.76	157,000	23	.102	142,000	28	.113	87.8	92.5
Oct. 24, 1980	.72	99,500	200	.564	72,200	32	.065	83,000	37	.087	73.0	82.7
Dec. 7, 1980	1.06	162,000	120	.551	162,000	29	.133	198,000	34	.191	41.2	73.5
Feb. 16, 1981	([1])	154,000	420	1.83	140,000	50	.198	101,000	41	.117	82.8	89.0
Feb. 22, 1981	.65	260,000	460	3.39	261,000	52	.384	214,000	45	.273	80.6	89.4
Apr. 3, 1981	.41	133,000	970	3.65	69,700	46	.091	119,000	46	.155	93.3	95.3
Apr. 22, 1981	.74	--	--	--	--	--	--	--	--	--	--	--
Apr. 28, 1981	1.46	326,000	380	3.51	500,000	35	.496	558,000	43	.680	66.5	89.7
May 10, 1981	.62	335,000	60	.569	215,000	40	.244	231,000	44	.288	6.5	29.8
May 29, 1981	1.09	386,000	220	2.40	253,000	39	.279	409,000	40	.463	69.1	82.0
June 8, 1981	.28	133,000	300	1.13	96,900	29	.080	94,500	41	.110	83.2	88.3
Total		3,421,900	--	37.202	3,220,800	--	2.804	3,327,800	--	3.194	--	--
Runoff-weighted values		--	380	--	--	31	--	--	34	--	83.9	91.5

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(8) Dissolved lead

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (µg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (µg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (µg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	12	0.024	52,000	31	0.046	61,300	36	0.062	-350	-180
May 17, 1980	.45	67,800	9.0	.017	119,000	30	.101	132,000	31	.116	-1,180	-239
May 28, 1980	1.69	269,000	9.0	.069	394,000	2.0	.022	315,000	2.0	.018	42.0	77.9
July 9, 1980	.42	68,200	10	.019	107,000	23	.070	112,000	22	.070	-637	-126
July 20, 1980	1.61	429,000	9.0	.109	307,000	7.0	.061	256,000	11	.080	-29.4	1.7
Aug. 4, 1980	.78	153,000	6.0	.026	176,000	8.0	.040	162,000	14	.064	-300	-81.1
Aug. 19, 1980	.46	193,000	0.25	.001	139,000	20	.079	140,000	25	.099	-17,700	-8,910
Sept. 22, 1980	.54	183,000	4.7	.024	157,000	16	.071	142,000	21	.084	-546	-289
Oct. 24, 1980	.72	99,500	29	.082	72,200	21	.043	83,000	28	.066	-32.9	14.5
Dec. 7, 1980	1.06	162,000	7.0	.032	162,000	24	.110	198,000	31	.174	-788	-298
Feb. 16, 1981	([1])	154,000	16	.070	140,000	96	.381	101,000	95	.272	-833	-498
Feb. 22, 1981	.65	260,000	3.0	.022	261,000	35	.259	214,000	37	.224	-2,100	-1,100
Apr. 3, 1981	.41	133,000	2.0	.008	69,700	32	.063	119,000	29	.098	-1,910	-1,410
Apr. 22, 1981	.74	212,000	5.8	.035	171,000	36	.174	159,000	39	.176	-900	-546
Apr. 28, 1981	1.46	326,000	6.0	.055	500,000	12	.170	558,000	17	.269	-698	-144
May 10, 1981	.62	335,000	3.0	.028	215,000	33	.201	231,000	36	.236	-1,460	-1,050
May 29, 1981	1.09	386,000	.60	.007	253,000	36	.258	409,000	37	.429	-9,710	-6,010
June 8, 1981	.28	133,000	5.0	.019	96,900	24	.066	94,500	39	.104	-795	-527
Total		3,633,900	--	0.647	3,391,800	--	2.215	3,486,800	--	2.641	--	--
Runoff-weighted values		--	6.3	--	--	23	--	--	27	--	-651	-300

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(9) Total zinc

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (µg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (µg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (µg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	690	1.38	52,000	21	0.031	61,300	25	0.043	94.6	96.7
May 17, 1980	.45	67,800	340	0.653	119,000	19	.064	132,000	21	.079	78.1	94.1
May 28, 1980	1.69	269,000	550	4.19	394,000	27	.301	315,000	27	.241	87.1	95.1
July 9, 1980	.42	68,200	320	.618	107,000	32	.097	112,000	20	.063	74.1	91.9
July 20, 1980	1.61	429,000	200	2.43	307,000	24	.209	256,000	36	.261	80.7	85.3
Aug. 4, 1980	.78	153,000	200	.867	176,000	17	.085	162,000	20	.092	79.6	90.8
Aug. 19, 1980	.46	193,000	120	.656	139,000	19	.075	140,000	14	.056	80.0	86.2
Sept. 22, 1980	.54	183,000	250	1.30	157,000	19	.084	142,000	24	.097	86.1	91.4
Oct. 24, 1980	.72	99,500	64	.180	72,200	18	.037	83,000	12	.028	63.9	76.9
Dec. 7, 1980	1.06	162,000	200	.918	162,000	30	.138	198,000	33	.185	64.8	84.2
Feb. 16, 1981	([1])	154,000	240	1.05	140,000	26	.103	101,000	19	.054	85.0	90.4
Feb. 22, 1981	.65	260,000	190	1.40	261,000	25	.185	214,000	31	.188	73.4	85.4
Apr. 3, 1981	.41	133,000	600	2.26	69,700	59	.116	119,000	61	.206	85.8	90.0
Apr. 22, 1981	.74	212,000	120	.720	171,000	38	.184	159,000	25	.113	58.8	73.5
Apr. 28, 1981	1.46	326,000	260	2.40	500,000	35	.496	558,000	42	.664	51.7	85.1
May 10, 1981	.62	335,000	80	.759	215,000	19	.116	231,000	19	.124	68.4	76.2
May 29, 1981	1.09	386,000	250	2.73	253,000	57	.408	409,000	56	.649	61.3	77.4
June 8, 1981	.28	133,000	260	.979	96,900	32	.088	94,500	19	.051	85.8	90.1
Total		3,633,900	--	25.490	3,391,800	--	2.817	3,486,800	--	3.194	--	--
Runoff-weighted values		--	250	--	--	29	--	--	32	--	76.4	87.7

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(10) Dissolved zinc

		Main Inlet			Submerged Outlet			Surface Outlet			Trap efficiency	
Date	Rainfall (inches)	Runoff volume (ft^3/s)	Mean concentration (µg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concentration (µg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concentration (µg/L)	Load (kg)	Minimum (percent)	Maximum (percent)
Apr. 3, 1980	0.38	70,400	150	0.299	52,000	16	0.024	61,300	21	0.036	79.9	87.5
May 17, 1980	.45	67,800	46	.088	119,000	14	.047	132,000	8.9	.033	9.1	75.5
May 28, 1980	1.69	269,000	49	.373	394,000	10	.112	315,000	1.2	.011	67.0	87.5
July 9, 1980	.42	68,200	41	.079	107,000	9.2	.028	112,000	8.3	.026	31.6	78.8
July 20, 1980	1.61	429,000	47	.571	307,000	14	.122	256,000	12	.087	63.4	72.1
Aug. 4, 1980	.78	153,000	44	.191	176,000	14	.070	162,000	12	.055	34.6	70.3
Aug. 19, 1980	.46	193,000	27	.148	139,000	17	.067	140,000	9.0	.036	30.4	51.7
Sept. 22, 1980	.54	183,000	25	.130	157,000	9.5	.042	142,000	1.6	.006	63.1	77.3
Oct. 24, 1980	.72	99,500	61	.172	72,200	7.0	.014	83,000	4.3	.010	86.7	91.0
Dec. 7, 1980	1.06	162,000	21	.096	162,000	6.7	.031	198,000	8.6	.048	17.7	63.1
Feb. 16, 1981	([1])	154,000	81	.353	140,000	15	.059	101,000	5.1	.015	79.0	86.6
Feb. 22, 1981	.65	260,000	31	.228	261,000	15	.111	214,000	5.1	.031	37.7	65.9
Apr. 3, 1981	.41	133,000	6.6	.025	69,700	5.0	.010	119,000	4.7	.016	-4.0	26.3
Apr. 22, 1981	.74	212,000	39	.234	171,000	5.1	.025	159,000	6.9	.031	76.1	84.6
Apr. 28, 1981	1.46	326,000	47	.434	500,000	5.3	.075	558,000	10	.158	46.3	83.5
May 10, 1981	.62	335,000	29	.275	215,000	8.8	.054	231,000	5.1	.033	68.4	76.2
May 29, 1981	1.09	386,000	46	.503	253,000	5.8	.042	409,000	5.2	.060	79.7	88.2
June 8, 1981	.28	133,000	40	.151	96,900	5.3	.015	94,500	5.2	.014	80.8	86.6
Total		3,633,900	--	4.350	3,391,800	--	0.948	3,486,800	--	0.706	--	--
Runoff-weighted values		--	42	--	--	9.9	--	--	7.2	--	62.0	79.8

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(11) Dissolved solids

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	230	459	52,000	930	1,370	61,300	460	799	-373	-194
May 17, 1980	.45	67,800	250	480	119,000	730	2,460	132,000	720	2,690	-973	-190
May 28, 1980	1.69	269,000	190	1,450	394,000	690	7,700	315,000	690	6,160	-856	-263
July 9, 1980	.42	68,200	240	464	107,000	380	1,150	112,000	410	1,300	-428	-64.5
July 20, 1980	1.61	429,000	100	1,220	307,000	350	3,040	256,000	370	2,680	-369	-259
Aug. 4, 1980	.78	153,000	120	520	176,000	380	1,890	162,000	390	1,790	-608	-220
Aug. 19, 1980	.46	193,000	92	503	139,000	320	1,260	140,000	320	1,270	-403	-248
Sept. 22, 1980	.54	183,000	79	409	157,000	340	1,510	142,000	340	1,370	-604	-330
Oct. 24, 1980	.72	99,500	200	564	72,200	360	736	83,000	370	870	-185	-82.7
Dec. 7, 1980	1.06	162,000	310	1,420	162,000	490	2,250	198,000	470	2,640	-244	-54.7
Feb. 16, 1981	([1])	154,000	1,100	4,800	140,000	970	3,850	101,000	670	1,920	-20.2	23.1
Feb. 22, 1981	.65	260,000	52	383	261,000	1,000	7,390	214,000	470	2,850	-2,570	-1,360
Apr. 3, 1981	.41	133,000	220	829	69,700	670	1,320	119,000	590	1,990	-299	-182
Apr. 22, 1981	.74	212,000	450	2,700	171,000	520	2,520	159,000	510	2,300	-78.5	-14.6
Apr. 28, 1981	1.46	326,000	170	1,570	500,000	460	6,510	558,000	420	6,640	-738	-158
May 10, 1981	.62	335,000	470	4,460	215,000	450	2,740	231,000	460	3,010	-28.9	3.1
May 29, 1981	1.09	386,000	69	754	253,000	470	3,370	409,000	470	5,440	-1,070	-581
June 8, 1981	.28	133,000	330	1,240	96,900	430	1,180	94,500	230	616	-44.8	-0.4
Total		3,633,900	--	24,225	3,391,800	--	52,246	3,486,800	--	46,335	--	--
Runoff-weighted values		--	240	--	--	540	--	--	470	--	-307	-111

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(12) Calcium

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	14	27.9	52,000	61	89.8	61,300	69	120	-652	-367
May 17, 1980	.45	67,800	25	48.0	119,000	48	162	132,000	47	176	-604	-90.2
May 28, 1980	1.69	269,000	22	168	394,000	44	491	315,000	46	410	-436	-104
July 9, 1980	.42	68,200	25	48.3	107,000	28	84.8	112,000	28	88.8	-259	-12.0
July 20, 1980	1.61	429,000	12	146	307,000	25	217	256,000	26	188	-177	-112
Aug. 4, 1980	.78	153,000	14	60.7	176,000	33	164	162,000	33	151	-419	-135
Aug. 19, 1980	.46	193,000	9.8	53.6	139,000	33	130	140,000	31	123	-372	-227
Sept. 22, 1980	.54	183,000	9.5	49.2	157,000	36	160	142,000	36	145	-520	-279
Oct. 24, 1980	.72	99,500	20	56.4	72,200	38	77.7	83,000	36	84.6	-188	-84.6
Dec. 7, 1980	1.06	162,000	28	128	162,000	41	188	198,000	40	224	-222	-44.3
Feb. 16, 1981	([1])	154,000	40	174	140,000	64	254	101,000	54	154	-134	-49.4
Feb. 22, 1981	.65	260,000	40	294	261,000	60	444	214,000	34	206	-121	-20.8
Apr. 3, 1981	.41	133,000	22	82.9	69,700	27	53.3	119,000	44	148	-143	-71.2
Apr. 22, 1981	.74	212,000	53	318	171,000	46	223	159,000	43	194	-31.1	15.8
Apr. 28, 1981	1.46	326,000	19	175	500,000	45	637	558,000	39	616	-616	-120
May 10, 1981	.62	335,000	57	541	215,000	42	256	231,000	42	275	1.8	26.2
May 29, 1981	1.09	386,000	8.8	96.2	253,000	43	308	409,000	41	475	-714	-375
June 8, 1981	.28	133,000	13	49.0	96,900	41	112	94,500	41	110	-353	-215
Total		3,633,900	--	2,516.2	3,391,800	--	4,051.6	3,486,800	--	3,888.4	--	--
Runoff-weighted values		--	25	--	--	42	--	--	39	--	-216	-63.0

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(13) Chloride

Date	Rainfall (inches)	Main Inlet Runoff volume (ft^3/s)	Main Inlet Mean concentration (mg/L)	Main Inlet Load (kg)	Submerged Outlet Runoff volume (ft^3/s)	Submerged Outlet Mean concentration (mg/L)	Submerged Outlet Load (kg)	Surface Outlet Runoff volume (ft^3/s)	Surface Outlet Mean concentration (mg/L)	Surface Outlet Load (kg)	Trap efficiency Minimum (percent)	Trap efficiency Maximum (percent)
Apr. 3, 1980	0.38	70,400	80	160	52,000	360	530	61,300	340	590	-600	-336
May 17, 1980	.45	67,800	47	90.2	119,000	280	944	132,000	270	1,010	-2,070	-485
May 28, 1980	1.69	269,000	26	198	394,000	260	2,900	315,000	250	2,230	-2,490	-883
July 9, 1980	.42	68,200	41	79.2	107,000	94	285	112,000	100	317	-660	-137
July 20, 1980	1.61	429,000	13	158	307,000	91	791	256,000	92	667	-823	-603
Aug. 4, 1980	.78	153,000	18	78.0	176,000	87	434	162,000	87	399	-968	-383
Aug. 19, 1980	.46	193,000	11	60.1	139,000	58	228	140,000	57	226	-655	-422
Sept. 22, 1980	.54	183,000	12	62.2	157,000	62	276	142,000	61	245	-738	-413
Oct. 24, 1980	.72	99,500	45	127	72,200	65	133	83,000	65	153	-125	-44.6
Dec. 7, 1980	1.06	162,000	64	294	162,000	120	551	198,000	100	561	-278	-70.4
Feb. 16, 1981	([1])	154,000	540	2,360	140,000	360	1,430	101,000	210	601	13.9	44.9
Feb. 22, 1981	.65	260,000	140	1,030	261,000	350	2,590	214,000	160	970	-246	-89.0
Apr. 3, 1981	.41	133,000	46	173	69,700	230	454	119,000	220	741	-591	-386
Apr. 22, 1981	.74	212,000	44	264	171,000	180	872	159,000	180	811	-538	-309
Apr. 28, 1981	1.46	326,000	36	332	500,000	140	1,980	558,000	120	1,900	-1,070	-260
May 10, 1981	.62	335,000	40	380	215,000	140	852	231,000	150	981	-382	-263
May 29, 1981	1.09	386,000	9.3	102	253,000	140	1,000	409,000	140	1,620	-2,470	-1,400
June 8, 1981	.28	133,000	18	67.9	96,900	110	302	94,500	130	348	-857	-566
Total		3,633,900	--	6,015.6	3,391,800	--	16,552	3,486,800	--	14,370	--	--
Runoff-weighted values		--	58	--	--	170	--	--	150	--	-414	-174

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(14) Magnesium

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	5.3	10.6	52,000	31	45.6	61,300	32	55.6	-855	-495
May 17, 1980	.45	67,800	10	19.2	119,000	30	101	132,000	29	108	-989	-194
May 28, 1980	1.69	269,000	8.5	64.8	394,000	26	290	315,000	26	232	-706	-206
July 9, 1980	.42	68,200	10	19.3	107,000	21	63.6	112,000	23	73.0	-608	-120
July 20, 1980	1.61	429,000	4.8	58.3	307,000	19	165	256,000	19	138	-420	-296
Aug. 4, 1980	.78	153,000	4.6	19.9	176,000	20	99.7	162,000	21	96.3	-885	-345
Aug. 19, 1980	.46	193,000	3.6	19.7	139,000	16	63.0	140,000	16	63.4	-542	-344
Sept. 22, 1980	.54	183,000	3.4	17.6	157,000	19	84.5	142,000	19	76.4	-814	-459
Oct. 24, 1980	.72	99,500	8.6	24.2	72,200	21	42.9	83,000	21	49.4	-281	-144
Dec. 7, 1980	1.06	162,000	13	59.6	162,000	25	115	198,000	24	135	-319	-88.3
Feb. 16, 1981	([1])	154,000	15	65.4	140,000	34	135	101,000	31	88.7	-242	-118
Feb. 22, 1981	.65	260,000	18	132	261,000	31	229	214,000	20	121	-165	-44.4
Apr. 3, 1981	.41	133,000	8.5	32.0	69,700	16	31.6	119,000	29	97.7	-304	-185
Apr. 22, 1981	.74	212,000	25	150	171,000	27	131	159,000	26	117	-65.3	-6.1
Apr. 28, 198	1.46	326,000	7.3	67.4	500,000	24	340	558,000	21	332	-897	-207
May 10, 1981	.62	335,000	27	256	215,000	24	146	231,000	24	157	-18.4	11.2
May 29, 198	1.09	386,000	2.6	28.4	253,000	26	186	409,000	24	278	-1,530	-852
June 8, 1981	.28	133,000	4.4	16.6	96,900	22	60.4	94,500	23	61.6	-635	-411
Total		3,633,900	--	1,061.0	3,391,800	--	2,329.3	3,486,800	--	2,280.1	--	--
Runoff-weighted values		--	10	--	--	24	--	--	23	--	-334	-137

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(15) Potassium

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	--	--	--	--	--	--	--	--	--	--	--
May 17, 1980	.45	--	--	--	--	--	--	--	--	--	--	--
May 28, 1980	1.69	269,000	4.4	33.5	394,000	3.4	37.9	315,000	3.3	29.4	-101	23.8
July 9, 1980	.42	68,200	3.8	7.34	107,000	2.8	8.48	112,000	2.6	8.25	-128	29.0
July 20, 1980	1.61	429,000	1.5	18.2	307,000	3.0	26.1	256,000	2.9	21.0	-159	-96.9
Aug. 4, 1980	.78	153,000	3.2	13.9	176,000	3.0	15.0	162,000	2.7	12.4	-97.1	10.5
Aug. 19, 1980	.46	193,000	1.5	8.20	139,000	1.9	7.48	140,000	1.8	7.14	-78.3	-23.3
Sept. 22, 1980	.54	183,000	2.0	10.4	157,000	2.1	9.34	142,000	1.9	7.64	-63.3	-0.3
Oct. 24, 1980	.72	99,500	3.5	9.86	72,200	2.0	4.09	83,000	1.9	4.47	13.2	44.4
Dec. 7, 1980	1.06	162,000	1.8	8.26	162,000	2.0	9.18	198,000	1.8	10.1	-133	-5.1
Feb. 16, 1981	([1])	154,000	7.2	31.4	140,000	3.3	13.1	101,000	2.5	7.15	35.5	58.8
Feb. 22, 1981	.65	260,000	2.9	21.4	261,000	3.3	24.4	214,000	1.7	10.3	-62.1	11.1
Apr. 3, 1981	.41	133,000	2.2	8.29	69,700	2.2	4.34	119,000	3.8	12.8	-107	-45.7
Apr. 22, 1981	.74	212,000	3.0	18.0	171,000	2.2	10.6	159,000	2.1	9.47	-11.5	28.4
Apr. 28, 1981	1.46	326,000	2.1	19.4	500,000	3.1	43.9	558,000	2.4	37.9	-322	-29.9
May 10, 1981	.62	335,000	3.4	32.3	215,000	2.1	12.8	231,000	1.9	12.4	22.0	41.3
May 29, 1981	1.09	386,000	1.9	20.8	253,000	2.3	16.5	409,000	2.4	27.8	-113	-24.3
June 8, 1981	.28	133,000	2.8	10.6	96,900	1.9	5.21	94,500	1.8	4.82	5.4	33.9
Total		3,495,700	—	271.85	3,220,800	--	248.42	3,293,500	--	223.04	--	--
Runoff-weighted values		—	2.7	—	--	2.7	--	--	2.4	--	-73.4	5.4

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(16) Sodium

Date	Rainfall (inches)	Main Inlet			Submerged Outlet			Surface Outlet			Trap efficiency	
		Runoff volume (ft^3/s)	Mean concentration (mg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concentration (mg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concentration (mg/L)	Load (kg)	Minimum (percent)	Maximum (percent)
Apr. 3, 1980	0.38	70,400	51	102	52,000	51	75.1	61,300	160	278	-246	-116
May 17, 1980	.45	67,800	36	69.1	119,000	53	179	132,000	51	191	-435	-44.5
May 28, 1980	1.69	269,000	25	190	394,000	150	1,670	315,000	150	1,340	-1,480	-500
July 9, 1980	.42	68,200	36	69.5	107,000	58	176	112,000	68	216	-464	-75.5
July 20, 198	1.61	429,000	11	134	307,000	50	435	256,000	49	355	-490	-350
Aug. 4, 1980	.78	153,000	12	52.0	176,000	46	229	162,000	44	202	-729	-275
Aug. 19, 1980	.46	193,000	9.9	54.1	139,000	29	114	140,000	26	103	-301	-177
Sept. 22, 1980	.54	183,000	8.3	43.0	157,000	32	142	142,000	29	117	-502	-268
Oct. 24, 1980	.72	99,500	22	62.0	72,200	33	67.5	83,000	30	70.5	-122	-42.6
Dec. 7, 1980	1.06	162,000	56	257	162,000	73	335	198,000	59	331	-159	-16.6
Feb. 16, 1981	([1])	154,000	370	1,610	140,000	200	793	101,000	98	280	33.4	57.5
Feb. 22, 1981	.65	260,000	120	847	261,000	160	1,180	214,000	66	400	-86.5	2.1
Apr. 3, 1981	.41	133,000	38	143	69,700	63	124	119,000	120	404	-269	-160
Apr. 22, 1981	.74	212,000	52	312	171,000	76	368	159,000	71	320	-120	-41.5
Apr. 28, 1981	1.46	326,000	25	231	500,000	85	1,200	558,000	65	1,030	-865	-198
May 10, 1981	.62	335,000	50	474	215,000	44	268	231,000	45	294	-18.5	11.0
May 29, 1981	1.09	386,000	7	76.5	253,000	46	330	409,000	42	486	-967	-522
June 8, 1981	.28	133,000	12	45.2	96,900	40	110	94,500	33	88.3	-339	-205
Total		3,633,900	--	4,771.4	3,391,800	--	7,795.6	3,486,800	--	6,505.8	--	--
Runoff-weighted values		--	46	--	--	81	--	--	66	--	-200	-59.6

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(17) Sulfate

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	--	--	--	--	--	--	--	--	--	--	--
May 17, 1980	.45	--	--	--	--	--	--	--	--	--	--	--
May 28, 1980	1.69	269,000	32	244	394,000	67	748	315,000	67	598	-452	-109
July 9, 1980	.42	68,200	36	69.5	107,000	35	106	112,000	34	108	-208	4.2
July 20, 1980	1.61	429,000	20	243	307,000	37	322	256,000	37	268	-143	-84.9
Aug. 4, 1980	.78	153,000	17	73.7	176,000	39	194	162,000	37	170	-394	-124
Aug. 19, 1980	.46	193,000	12	65.6	139,000	28	110	140,000	26	103	-225	-125
Sept. 22, 1980	.54	183,000	14	72.6	157,000	33	147	142,000	33	133	-286	-136
Oct. 24, 1980	.72	99,500	40	113	72,200	43	87.9	83,000	39	91.7	-58.9	-2.1
Dec. 7, 1980	1.06	162,000	44	202	162,000	59	271	198,000	53	297	-181	-26.5
Feb. 16, 1981	([1])	154,000	55	240	140,000	77	305	101,000	73	209	-114	-36.8
Feb. 22, 1981	.65	260,000	63	464	261,000	69	510	214,000	37	224	-58.2	13.4
Apr. 3, 1981	.41	133,000	32	121	69,700	96	190	119,000	83	280	-288	-175
Apr. 22, 1981	.74	212,000	88	528	171,000	50	242	159,000	46	207	15.0	45.4
Apr. 28, 1981	1.46	326,000	21	194	500,000	53	751	558,000	45	711	-654	-132
May 10, 1981	.62	335,000	95	901	215,000	44	268	231,000	42	275	39.7	54.7
May 29, 1981	1.09	386,000	9.8	107	253,000	42	301	409,000	41	475	-625	-322
June 8, 1981	.28	133,000	14	52.7	96,900	45	124	94,500	37	99.0	-323	-194
Total		3,495,700	--	3,691.1	3,220,800	--	4,676.9	3,293,500	--	4,248.7	--	--
Runoff-weighted values		--	37	--	--	51	--	--	46	--	-142	-30.8

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(18) Total nitrogen

Date	Rainfall (inches)	Main Inlet: Runoff volume (ft^3/s)	Main Inlet: Mean concentration (mg/L)	Main Inlet: Load (kg)	Submerged Outlet: Runoff volume (ft^3/s)	Submerged Outlet: Mean concentration (mg/L)	Submerged Outlet: Load (kg)	Surface Outlet: Runoff volume (ft^3/s)	Surface Outlet: Mean concentration (mg/L)	Surface Outlet: Load (kg)	Trap efficiency: Minimum (percent)	Trap efficiency: Maximum (percent)
Apr. 3, 1980	0.38	70,400	4.3	8.57	52,000	2.0	2.94	51,300	2.1	3.65	23.1	52.2
May 17, 1980	.45	67,800	6.2	11.9	119,000	1.3	4.38	132,000	1.5	5.61	16.1	77.3
May 28, 1980	1.69	269,000	8.1	61.7	394,000	1.8	20.1	315,000	1.8	16.1	41.3	77.7
July 9, 1980	.42	68,200	5.7	11.0	107,000	3.0	9.09	112,000	3.0	9.52	-69.2	47.4
July 20, 1980	1.61	429,000	2.6	31.6	307,000	2.7	23.5	256,000	3.2	23.2	-47.8	-12.6
Aug. 4, 1980	.78	153,000	2.5	10.8	176,000	2.5	12.5	162,000	2.1	9.63	-105	7.5
Aug. 19, 1980	.46	193,000	2.2	12.0	139,000	1.9	7.48	140,000	1.8	7.14	-21.8	15.9
Sept. 22, 1980	.54	183,000	3.1	16.1	157,000	1.2	5.34	142,000	1.2	4.83	36.8	61.3
Oct. 24, 1980	.72	99,500	2.8	7.89	72,200	1.6	3.27	83,000	1.6	3.76	10.9	42.9
Dec. 7, 1980	1.06	162,000	1.8	8.26	162,000	1.4	6.42	198,000	1.2	6.73	-59.2	28.3
Feb. 16, 1981	([1])	154,000	6.9	30.1	140,000	1.4	5.55	101,000	1.2	3.43	70.2	80.9
Feb. 22, 1981	.65	260,000	3.1	22.8	261,000	1.4	10.4	214,000	1.2	7.27	22.5	57.6
Apr. 3, 1981	.41	133,000	5.6	21.1	69,700	1.1	2.17	119,000	1.2	4.04	70.6	79.2
Apr. 22, 1981	.74	212,000	2.0	12.0	171,000	1.2	5.81	159,000	1.2	5.40	6.6	40.0
Apr. 28, 1981	1.46	326,000	4.1	37.8	500,000	1.5	21.2	558,000	1.6	25.3	-23.0	62.1
May 10, 1981	.62	335,000	2.4	22.8	215,000	1.5	9.13	231,000	1.6	10.5	13.9	35.2
May 29, 1981	1.09	386,000	3.5	38.3	253,000	1.6	11.5	409,000	1.8	20.8	15.7	50.8
June 8, 1981	.28	133,000	15	56.5	96,900	1.8	4.94	94,500	1.7	4.55	83.2	88.3
Total		3,633,900	--	421.22	3,391,800	--	165.72	3,486,800	--	171.46	--	--
Runoff-weighted values		--	4.1	--	--	1.7	--	--	1.7	--	20.0	57.8

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(19) Dissolved nitrogen

Date	Rainfall (inches)	Main Inlet Runoff volume (ft^3/s)	Main Inlet Mean concentration (mg/L)	Main Inlet Load (kg)	Submerged Outlet Runoff volume (ft^3/s)	Submerged Outlet Mean concentration (mg/L)	Submerged Outlet Load (kg)	Surface Outlet Runoff volume (ft^3/s)	Surface Outlet Mean concentration (mg/L)	Surface Outlet Load (kg)	Trap efficiency Minimum (percent)	Trap efficiency Maximum (percent)
Apr. 3, 1980	0.38	70,400	2.4	4.78	52,000	1.1	1.62	61,300	1.2	2.08	22.6	52.0
May 17, 1980	.45	67,800	2.2	4.22	119,000	0.63	2.12	132,000	0.76	2.84	-17.5	68.3
May 28, 1980	1.69	269,000	1.4	10.7	394,000	.68	7.59	315,000	.70	6.24	-29.3	50.8
July 9, 1980	.42	68,200	3.1	5.99	107,000	.86	2.61	112,000	.61	1.94	24.0	76.3
July 20, 1980	1.61	429,000	1.1	13.4	307,000	.54	4.70	256,000	.46	3.34	40.0	54.2
Aug. 4, 1980	.78	153,000	0.7	3.03	176,000	1.6	7.98	162,000	1.2	5.51	-345	-101
Aug. 19, 1980	.46	193,000	1.6	8.74	139,000	1.4	5.51	140,000	1.1	4.36	-12.9	21.9
Sept. 22, 1980	.54	183,000	1.3	6.74	157,000	.49	2.18	142,000	.35	1.41	46.7	67.4
Oct. 24, 198	.72	99,500	2.0	5.64	72,200	.57	1.16	83,000	.42	0.987	61.9	75.6
Dec. 7, 1980	1.06	162,000	.74	3.40	162,000	.55	2.52	198,000	.44	2.47	-46.8	33.9
Feb. 16, 1981	([1])	154,000	2.0	8.72	140,000	.73	2.89	101,000	.54	1.54	49.2	67.5
Feb. 22, 1981	.65	260,000	1.3	9.57	261,000	.75	5.54	214,000	.55	3.33	7.3	49.3
Apr. 3, 1981	.41	133,000	1.2	4.52	69,700	.65	1.28	119,000	.34	1.15	46.2	62.1
Apr. 22, 1981	.74	212,000	1.3	7.81	171,000	.54	2.62	159,000	.63	2.84	30.1	55.1
Apr. 28, 1981	1.46	326,000	1.8	16.6	500,000	.71	10.1	558,000	.88	13.9	-44.6	55.5
May 10, 1981	.62	335,000	1.7	16.1	215,000	.55	3.35	231,000	.54	3.53	57.3	68.0
May 29, 1981	1.09	386,000	1.4	15.3	253,000	.71	5.09	409,000	.56	6.49	24.3	55.9
June 8, 1981	.28	133,000	1.2	4.52	96,900	.56	1.54	94,500	.46	1.23	38.7	57.4
Total		3,633,900	--	149.78	3,391,800	--	70.40	3,486,800	--	65.187	--	--
Runoff-weighted values		--	1.5	--	--	0.73	--	--	0.66	--	9.6	53.6

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(20) Total phosphorus

Date	Rainfall (inches)	Main Inlet			Submerged Outlet			Surface Outlet			Trap efficiency	
		Runoff volume (ft^3/s)	Mean concen-tration (mg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concen-tration (mg/L)	Load (kg)	Runoff volume (ft^3/s)	Mean concen-tration (mg/L)	Load (kg)	Mini-mum (per-cent)	Maxi-mum (per-cent)
Apr. 3, 1980	0.38	70,400	0.58	1.16	52,000	0.12	0.177	61,300	0.13	0.226	65.3	78.3
May 17, 1980	.45	67,800	.61	1.17	119,000	.18	.607	132,000	.16	.598	-3.0	72.2
May 28, 1980	1.69	269,000	.84	6.40	394,000	.28	3.12	315,000	.27	2.41	13.6	67.2
July 9, 1980	.42	68,200	.53	1.02	107,000	.25	.758	112,000	.22	.698	-42.7	55.7
July 20, 1980	1.61	429,000	.30	3.64	307,000	.26	2.26	256,000	.27	1.96	-15.9	11.8
Aug. 4, 1980	.78	153,000	.48	2.08	176,000	.20	.997	162,000	.17	.780	14.6	61.3
Aug. 19, 1980	.46	193,000	.10	0.547	139,000	.12	.472	140,000	.10	.396	-58.7	-9.9
Sept. 22, 1980	.54	183,000	.48	2.49	157,000	.23	1.02	142,000	.21	.845	25.1	54.1
Oct. 24, 1980	.72	99,500	.55	1.55	72,200	.18	.368	83,000	.17	.400	50.5	68.2
Dec. 7, 1980	1.06	162,000	.66	3.03	162,000	.16	.734	198,000	.17	.953	44.3	74.9
Feb. 16, 1981	([1])	154,000	.41	1.79	140,000	.16	.634	101,000	.10	.286	48.6	67.1
Feb. 22, 1981	.65	260,000	.31	2.28	261,000	.11	.813	214,000	.13	.788	29.8	61.6
Apr. 3, 1981	.41	133,000	1.0	3.77	69,700	.19	.375	119,000	.19	.640	73.1	81.0
Apr. 22, 1981	.74	212,000	.53	3.18	171,000	.14	.678	159,000	.14	.630	58.9	73.6
Apr. 28, 1981	1.46	326,000	.74	6.83	500,000	.18	2.55	558,000	.19	3.00	18.7	75.0
May 10, 1981	.62	335,000	.68	6.45	215,000	.18	1.20	231,000	.17	1.11	64.2	73.1
May 29, 1981	1.09	386,000	.43	4.70	253,000	.24	1.72	409,000	.14	1.62	28.9	58.6
June 8, 1981	.28	133,000	.53	2.00	96,900	.22	.604	94,500	.21	.562	41.7	59.4
Total		3,633,900	—	54.087	3,391,800	--	19.087	3,486,800	--	17.902	--	--
Runoff-weighted values		—	0.53	—	--	0.20	--	--	0.18	--	31.6	64.2

[1] Runoff measured on this date resulted from snowmelt.

Table 20. Loads and trap efficiencies for 21 constituents for 18 runoff periods from April 3, 1980, to June 8, 1981, Lake Ellyn at Glen Ellyn, Illinois—Continued

(21) Dissolved phosphorus

Date	Rainfall (inches)	Main Inlet Runoff volume (ft^3/s)	Main Inlet Mean concentration (mg/L)	Main Inlet Load (kg)	Submerged Outlet Runoff volume (ft^3/s)	Submerged Outlet Mean concentration (mg/L)	Submerged Outlet Load (kg)	Surface Outlet Runoff volume (ft^3/s)	Surface Outlet Mean concentration (mg/L)	Surface Outlet Load (kg)	Trap efficiency Minimum (percent)	Trap efficiency Maximum (percent)
Apr. 3, 1980	0.38	70,400	0.06	0.120	52,000	0.02	0.029	61,300	0.02	0.035	46.7	66.8
May 17, 1980	.45	67,800	.05	.096	119,000	.04	.135	132,000	.04	.150	-197	19.8
May 28, 1980	1.69	269,000	.07	.533	394,000	.09	1.00	315,000	.08	.714	-222	-21.9
July 9, 1980	.42	68,200	.13	.251	107,000	.01	.030	112,000	.01	.032	75.3	92.3
July 20, 1980	1.61	429,000	.03	.364	307,000	.02	.174	256,000	.02	.145	12.4	33.3
Aug. 4, 1980	.78	153,000	.03	.130	176,000	.04	.199	162,000	.04	.184	-195	-33.4
Aug. 19, 1980	.46	193,000	.07	.383	139,000	.06	.236	140,000	.04	.159	-3.1	28.6
Sept. 22, 1980	.54	183,000	.11	.570	157,000	.10	.445	142,000	.08	.322	-34.6	17.7
Oct. 24, 1980	.72	99,500	.14	.394	72,200	.03	.061	83,000	.02	.047	72.6	82.4
Dec. 7, 1980	1.06	162,000	.08	.367	162,000	.02	.092	198,000	.02	.112	44.4	75.0
Feb. 16, 1981	([1])	154,000	.18	.785	140,000	.03	.119	101,000	.02	.057	77.6	85.7
Feb. 22, 1981	.65	260,000	.09	.663	261,000	.04	.296	214,000	.09	.545	-26.8	30.5
Apr. 3, 1981	.41	133,000	.11	.414	69,700	.05	.099	119,000	.04	.135	43.5	60.2
Apr. 22, 1981	.74	212,000	.14	.841	171,000	.04	.194	159,000	.04	.180	55.5	71.4
Apr. 28, 1981	1.46	326,000	.11	1.02	500,000	.03	.425	558,000	.02	.316	27.4	77.5
May 10, 1981	.62	335,000	.18	1.71	215,000	.03	.183	231,000	.02	.131	81.6	86.2
May 29, 1981	1.09	386,000	.03	.328	253,000	.06	.430	409,000	.03	.347	-137	-38.0
June 8, 1981	.28	133,000	.04	.151	96,900	.04	.110	94,500	.04	.107	-43.7	-0.1
Total		3,633,900	--	9.120	3,391,800	--	4.257	3,486,800	--	3.718	--	--
Runoff-weighted values		--	0.09	--	--	0.04	--	--	0.04	--	12.6	54.5

[1] Runoff measured on this date resulted from snowmelt.

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GLOSSARY

Adsorption (n).—To take up and hold a substance to a surface of a solid.

Algal bloom (n).—A high concentration of a particular algal species, generally amounting to one half to one million cells or more per milliliter of water.

Aliquot (n).—An exact part of a larger sample.

Anoxic (adj).—Devoid of oxygen.

Anthropogenic (adj).—Originating from, or caused by, human activity.

Aquifer (n).—A saturated geologic unit that yields significant quantities of water to wells and springs.

Base flow (n).—The portion of streamflow that originates from ground-water discharge.

Bathymetry (n).—The measurement of depth in a surface-water body.

Bedload (n).—Coarse sediment particles with a relatively fast settling rate that move by rolling and bouncing along the streambed.

Benthos (n); benthic (adj).—Organisms living in or on the bottom of an aquatic environment.

Clay (n).—Sediment particles with diameters less than 2 micrometers.

Concentration (n).—Amount of a constituent per unit volume or mass of sample.

Conservative (adj).—Refers to a chemical constituent that remains dissolved in water and whose net mass in solution is generally unaffected by physical and chemical processes. Chloride (Cl^-) is a common conservative constituent found in natural waters.

Constituent (n).—A dissolved or suspended component of a sample.

Density (n).—The mass of a substance per unit volume. Pure water has a density of 1.00000 g/mL at 3.98 degrees Celsius.

Detention storage (n).—The temporary storage of runoff in a lake, pond, or reservoir.

Discharge (n).—The volume of water that flows past a channel cross-section per unit time.

Dissolved (adj).—Refers to those constituents that can pass through a 0.45-micrometer filter.

Dolomite (n).—A magnesium-rich carbonate sedimentary rock, $CaMg(CO_3)_2$.

Dry deposition (n).—Fallout of particulate matter from the atmosphere without the aid of precipitation.

Environment (n).—The sum of all the external physical, chemical, and biological conditions and influences that affect the life and development of an organism.

Erosion (n).—The general process or group of processes whereby the materials of the Earth's crust are loosened, dissolved, or worn away, and moved from one place to another by some force, such as water movement.

Eutrophication (n).—The complex sequence of changes initiated by the enrichment of lakes and ponds with plant nutrients. Increased production of photosynthetic plants is followed by other changes that increase biological production at all levels of the food chain.

Flocculation (n).—The formation of small, loosely held masses or aggregates of fine particles suspended in or precipitated from a solution.

Geologic (n).—Of or pertaining to the Earth.

Ground water (n).—Water in the saturated zone that is under a pressure equal to or greater than atmospheric pressure.

Habitat (n).—The environment in which an organism or a biological population normally lives or occurs.

Hydrograph (n).—A graph showing the stage, flow, velocity, or other property of water with respect to time.

Inflow (n).—Water discharge into a system, such as a lake.

Invertebrate (n).—An animal without a backbone. Common aquatic examples include worms, insects, snails, and crayfish.

Ion (n).—An electrically charged particle of matter. For example, in water, salt dissolves to form sodium ions (Na^+) with positive charges, and chloride ions (Cl^-) with negative charges.

Least squares linear regression (n).—A statistical procedure for quantifying the mathematical relation between two or more variables.

Limnetic zone (n).—The open water zone of a body of water that receives relatively little influence from the shore or bottom.

Littoral zone (n).—The shallow zone of a body of water where light penetrates to the bottom.

Load (n).—The amount of mass of a given constituent that is transported to or from a system during a specific period of time.

Mass balance (n).—A comparison of the load of a constituent into a system to the load of that same constituent out of the system for specific period of time.

Mean concentration (n).—The arithmetic average of observed concentrations in a group of samples. In this report, mean concentrations are mathematically adjusted to represent the total discharge during a runoff period.

Meromictic (adj).—Referring to a lake in which some water remains partly or wholly unmixed due to chemical-density gradients.

National Geodetic Vertical Datum of 1929 (NGVD of 1929) (n).—A geodetic datum derived from a general adjustment of the first-order levels of both the United States and Canada; referred to in text as "sea level."

Nonpoint (adj).—Originating from more than one site or process, or from a diffuse undefinable source.

Nutrient (n).—Any chemical element, ion, or compound that is required by an organism for the continuation of growth, reproduction, and other life processes.

Organic compounds (n).—Complex molecules whose chemical structures are based on carbon.

Outflow (n).—Water discharge out of a system, such as a lake.

Overland flow (n).—Precipitation that remains on the surface of the ground, fills small depressions, and eventually spills over and flows downslope into lakes and streams.

Partial pressure (n).—The pressure that is exerted by a gas in a mixture of gases. The total pressure of a mixture of gases, such as air, is equal to the sum of the partial pressures of each gas in the mixure.

Particle size (n).—The diameter, in millimeters, of suspended sediment or bed material determined by either sieve or sedimentation methods. Sedimentation methods determine the effective fall diameters of particles with respect to spheres of a standard density (2.65 g/cm^3).

Particle-size distribution (n).—The listing of the relative mass (usually percentages) of sediments of different diameters in a sample.

pH (n).—The negative logarithm of the hydrogen-ion activity, measured on a scale of 1 to 14, with 1 being most acid, 14 being most basic, and 7 being neutral.

Photosynthesis (n).—The process whereby green plants utilize light as an energy source and convert chemical compounds to carbohydrates. In the process, carbon dioxide is consumed and oxygen is released.

Plankton (n).—The community of suspended, floating, or weakly swimming organisms that live in open water.

Pollution (n).—Impairment of the natural quality of a resource by man-caused changes.

Precipitation (n).—The discharge of water, in liquid or solid state, out of the atmosphere, generally upon land or water surface.

Runoff (n).—Surface-water discharge as a result of drainage off a land surface.

Sediment (n).—Solid material that originates mostly from disintegrated rock and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material, such as humus.

Specific conductance (n).—A measure of the ability of water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25 degrees Celsius.

Specific gravity (n).—The ratio of the mass of solid or liquid to the mass of an equal volume of pure water at 3.98 degrees Celsius.

Stage (n).—Water level referred to an arbitrary datum.

Standard error of estimate (n).—A statistic that refers to the interval delineated by a pair of lines that are parallel to, and an equal distance on each side of, a linear regression line, and within which 67 percent of the data can be plotted.

Stokes' Law (n).—A hydrodynamic law relating the settling of particles in suspension through time.

Stratification (n).—The layering of water in a lake caused by thermal or chemical gradients.

Substrate (n).—The physical surface upon which an organism lives.

Surface water (n).—Water on the land surface; oceans, lakes, ponds, rivers, etc.

Suspended sediment (n).—Sediment that at any given time is maintained in suspension by the upward components of turbulent currents or exists in suspension as a colloid.

Suspended solids (n).—Particles that at any time are maintained in suspension by the upward components of turbulent currents or exist in suspension as a colloid, and that may be retained on a glass-fiber filter.

Till (n).—Sediment deposited directly by glacial ice.

Total (adj).—Referring to the total amount of a given constituent in a water-suspended sediment sample, regardless of the constituent's physical or chemical form.

Trap efficiency (n).—The efficiency of detention storage for retaining constituents transported by runoff, in percent.

Water quality (n).—That phase of hydrology that deals with the kinds and amounts of matter dissolved and suspended in natural water, the physical characteristics of water, and ecological relationships between aquatic organisms and their environment.

Watershed (n).—The area drained by, or contributing water to, a stream, lake, or other body of water.

Water table (n).—The level in the saturated zone at which the pressure is equal to the atmospheric pressure.

Weathering (n).—The chemical and physical processes by which rocks are broken down into sediments.

Wisconsinan (n).—The most recent period of significant glacial activity in the United States, beginning approximately 35,000 years ago and ending 10,000 years ago; sometimes referred to as the Wisconsin Stage.

CONVERSION FACTORS

Readers who prefer metric (International System) units of measurement rather than the inch-pound units used in this report may use the following conversion factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	0.09294	square meter (m^2)
acre	0.4047	square hectometer (hm^2) or hectare (ha)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
ounce, avoirdupois (oz)	28.35	gram (g)

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