WATER QUALITY OF ALIMAGNET, FARQUAR, AND LONG LAKES IN APPLE VALLEY, MINNESOTA

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By M. R. Have, G. A. Payne, and M. A. Ayers

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CONVERSION FACTORS

Multiply inch-pound unit	By	To obtain SI unit
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	4047	square meter (m^2)

WATER QUALITY OF ALIMAGNET, FARQUAR, AND LONG LAKES IN APPLE VALLEY, MINNESOTA

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ABSTRACT

Alimagnet, Farquar, and Long Lakes, in Apple Valley, Minnesota, were sampled from 1973-79 to determine their physical and chemical characteristics. A storm-sewer inlet to Alimagnet Lake was also sampled during two storms in 1978. All the lakes have at least one storm-sewer inlet draining residential areas. Alimagnet and Farquar Lakes have lift-station outlets and Long Lake is connected by a culvert to Farquar Lake.

The 1976-77 drought caused a more noticeable effect on the quality of the lakes than any other factor. Chloride concentrations were 10 to 15 milligrams per liter before the drought, but increased 2 to 4 times during the drought. Dissolved solids reacted similarly. Dissolved oxygen and pH were governed mainly by biological activity. During the summer, dissolved oxygen was often above 100-percent saturation and pH was as high as 9.0. In February 1977, dissolved-oxygen concentration was less than 0.5 milligrams per liter in the three lakes. Ratios between mean total nitrogen and mean total phosphorus ranged from 22:1 to 26:1, indicating that nitrogen most likely was not limiting algal productivity in any of the lakes.

Trophic-state indices indicate that the lakes are eutrophic. There was no evidence of long-term trends; however, increased trophic-state indices during the drought occurred in Alimagnet Lake. Blue-green algae dominated the phytoplankton populations. *Aphanizomenon*, *Anacystis*, and *Oscillatoria* were the most common genera in the samples.

Storms sampled at a storm-sewer inlet to Alimagnet Lake showed higher concentrations of chromium, copper, nickel, and zinc than of lead, arsenic, cadmium, and mercury. Total phosphorus for the September 1978 storm had a concentration of 1.7 milligrams per liter, which means that approximately 29 pounds entered the lake during the 5.5-hour sampling period.

INTRODUCTION

The community of Apple Valley is in northern Dakota County, south of Minneapolis and St. Paul. The northern part of Apple Valley is characterized by steep slopes with many hills and depressions. These depressions are suitable for long-term storage of storm runoff. The southern part of Apple Valley is characterized by more gently sloping land that drains into shallow draws.

Apple Valley is a rapidly growing and changing community. Since the 1950's, the community has changed from a rural to a suburban environment. Much of the land that was formerly fields and woodlands now is used for homes, shopping centers, businesses, and industries. Because such land uses commonly degrade the quality of water in lakes, in 1973 the U.S. Geological Survey was asked by the city of Apple Valley to determine the water quality of Alimagnet, Farquar (Farquhar), and Long Lakes (fig. 1). The purpose of the study was to establish a water-quality baseline and to monitor changes in water quality over time. An approximation of land use in 1975 is presented. Except for the watershed of Alimagnet Lake, there was not much additional development between September 1973 and August 1979, the period of this study.

HISTORY OF THE MONITORING PROGRAM

Water-quality monitoring of Alimagnet, Farquar, and Long Lakes began in September 1973. A second site near the south end of Alimagnet was added in November 1976. The last samples from Alimagnet site 2, Farquar, and Long were collected in August 1978. Because of greater development in its watershed, Alimagnet site 1 was maintained until August 1979.

Each year the monitoring program was reassessed in order to stay within a reasonable budget, to delete constituents that were not considered key diagnostic constituents, and to add constituents that could improve the program. Dates that samples were collected, sites that were sampled, and constituents that were analyzed are shown in table 1. Have (1975) described the results of the first 2 years of this study.

In addition to the sampling shown in table 1, a channel entering Alimagnet Lake was sampled during two rainstorms. The purpose of this sampling was to determine the amount and type of load discharging into the lake from a residential area that was under construction. The constituents and properties determined in the two samples of storm runoff included flow, specific conductance, water temperature, pH, dissolved chloride, biochemical oxygen demand (BOD), nutrients, and heavy metals.

METHODS OF SAMPLING AND ANALYSIS

Water samples were collected 2 to 3 feet below the surface near the middle or deepest part of each lake and analyzed by the methods of Brown and others (1970), Goerlitz and Brown (1972), and Skougstad and others (1978). Total coliform, fecal coliform, and fecal *Streptococci* bacteria were determined by the membrane-filter method described by Slack and others (1973). Phytoplankton and chlorophyll concentrations were determined by the methods described by Slack and others (1973) and Greeson and others (1977).

Drainage-basin and lake areas were determined from topographic and Apple Valley storm-sewer maps (Bonestroo and others, 1978). Lake area was included in the total drainage area. Land use expressed as undeveloped, developed, and lake area was calculated as a percentage of the respective drainage-basin area. The shoreline configuration is a dimensionless ratio of the length of shoreline to the circumference of a circle having an area equal to that of the lake. Shoreline-configuration values indicate relative amounts of contact

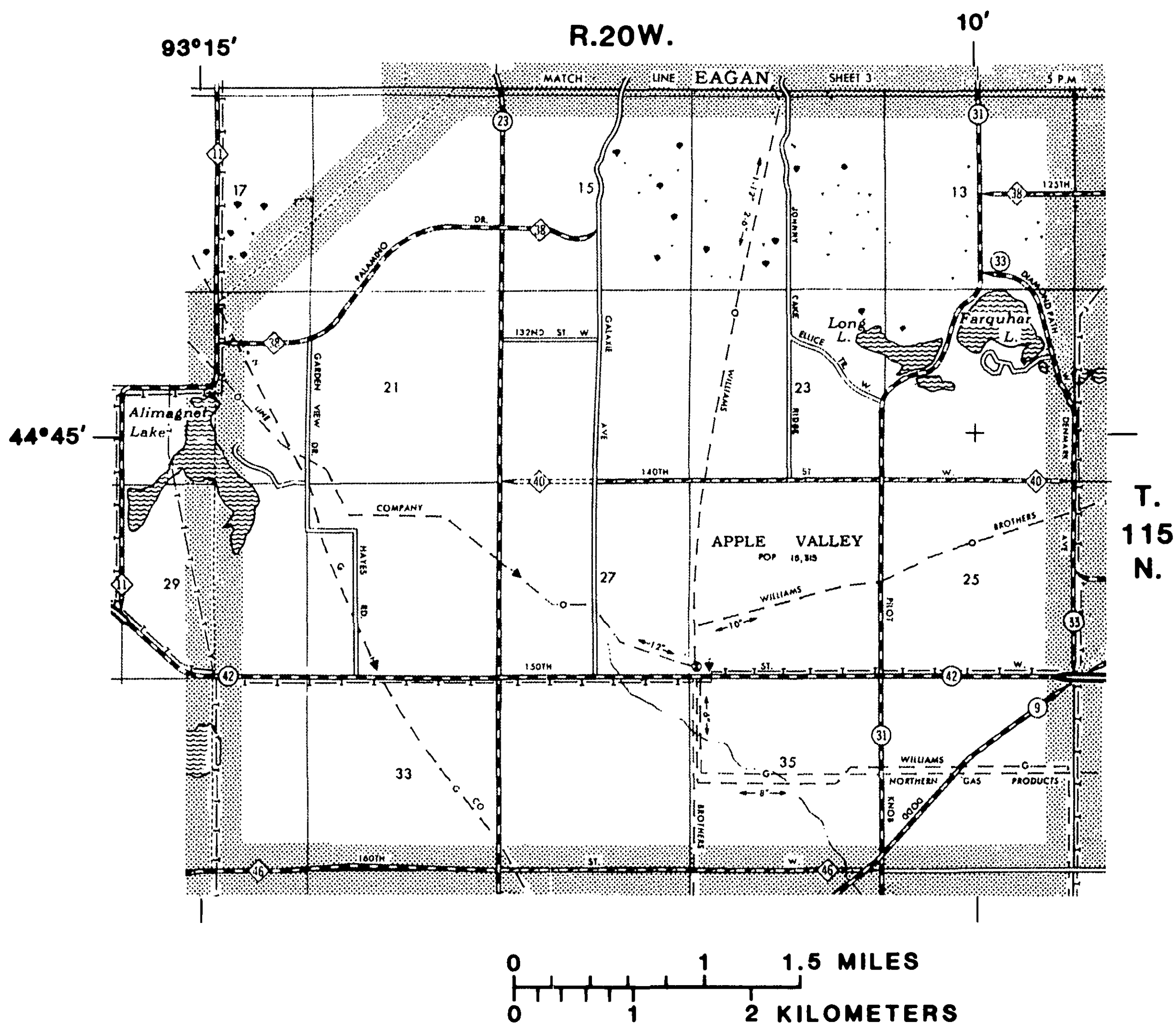

Figure 1.--Location of lakes sampled in Apple Valley, Minnesota

Table 1.--Summary of lake-monitoring

[A-1, Alimagnet Lake, site 1; A-2, Alimagnet

Dates sampled	Sites sampled A-1	A-2	F	L	Temperature	Specific conductance	Solids, dissolved	Solids, suspended	Turbidity	Transparency	pH	Oxygen, dissolved	Alkalinity, total	Silica, dissolved	Ammonia as nitrogen, total	Organic nitrogen, total	Ammonia plus organic nitrogen, total	Nitrite plus nitrate as nitrogen, total
1973																		
Sept. 25,26	X	-	X	X	X	X	X	X	X	-	X	X	X	X	X	X	-	X
1974																		
May 15,20	X	-	X	X	X	X	X	X	X	-	X	X	X	X	X	X	-	X
Oct.31, Nov.4	X	-	X	X	X	X	X	X	X	-	X	X	-	-	-	-	X	X
1975																		
June 23,24	X	-	X	X	X	X	X	X	X	-	X	X	-	-	-	-	X	X
1976																		
Feb. 26	X	-	X	X	X	X	X	X	X	-	X	X	X	-	-	-	X	X
Apr. 8	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X
July 26,27	X	-	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
Aug. 23	X	-	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
Sept. 29,30	X	-	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
Nov. 3,4	X	X	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
1977																		
Feb. 9,10	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-	-	-	-
Apr. 3,6	X	X	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
Aug. 11	X	X	X	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-
1978																		
May 9,11	X	X	X	X	X	X	-	-	-	X	X	X	-	-	-	-	-	-
Aug. 22	X	X	X	X	X	X	-	-	-	X	X	X	-	-	-	-	-	-
1979																		
Apr. 26	X	-	-	-	X	X	X	-	-	X	X	X	-	-	-	-	X	-
Aug. 28	X	-	-	-	X	X	X	-	-	X	X	X	-	-	-	-	X	-

program in Apple Valley, Minnesota

Lake, site 2; F, Farquar Lake; L, Long Lake]

Nitrite plus nitrate as nitrogen, dissolved	Nitrogen in bottom sediment	Orthophosphate as phosphorus, dissolved	Phosphorus, dissolved	Phosphorus, total	Phosphorus in bottom sediment	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Chloride, dissolved	Organic carbon, total	Organic carbon in bottom sediment	Inorganic carbon in bottom sediment	Biochemical oxygen demand	Total coliform bacteria	Fecal coliform bacteria	Fecal <u>Streptococci</u> bacteria	Phytoplankton identification
X	-	X	X	X	-	X	X	X	X	X	-	-	-	X	X	X	X	X
X	-	X	X	X	-	X	X	X	X	X	-	-	-	X	X	X	X	X
X	X	X	-	X	X	-	-	-	-	X	X	-	X	-	-	X	X	X
X	X	X	-	X	X	-	-	-	-	X	X	X	-	-	-	-	-	X
X	X	X	-	X	X	-	-	-	-	X	-	X	-	-	-	-	-	X
X	X	X	-	X	X	-	-	-	-	X	-	X	-	-	-	-	-	X
-	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	X
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-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
-	-	-	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	X
-	-	-	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	X

between land and water, and hence, the potential for growth of rooted aquatic plants and nutrient enrichment from near-shore development and runoff; the higher the shoreline configuration the higher the potential.

LAKE DESCRIPTIONS

Alimagnet Lake, Sites 1 and 2

USGS Station Identification Numbers. 444500093150000 for site 1 and 444440093144102 for site 2.

City of Apple Valley Lake Idenification Number. HP-1

Location. Lake is on corporate boundary between Apple Valley and Burnsville, 2.5 miles south of intersection of Minnesota Highway 13 and Dakota County Road 11 (fig. 2); sampling site 1 is near center of north arm of lake; site 2 is in southeast arm.

Physical Characteristics of Lake.

Surface area - 112 acres

Depth at sampling site 1 - about 10 feet

Depth at sampling site 2 - about 9 feet

Length of shoreline - 3.4 miles

Shoreline configuration - 2.3

Drainage Basin.

Size - About 640 acres of natural drainage area. Storm sewers may contribute up to 270 acres of additional drainage area.

Geology - Drift, about 200 feet thick, consisting of undifferentiated reddish-brown to brown sandy till. Contains some sand and gravel over sandstone bedrock (Norvitch and others, 1973).

Soils - Mostly loamy over sandy, well-drained, light-colored soils; some poorly drained soils in level areas (University of Minnesota, 1975).

Land use -	Percent
Undeveloped, wooded parks and grassy fields	65
Developed, mainly residential	17
Lake surface	18

Hydrology. Receives direct precipitation and storm water from developed and sewered areas along its shoreline. Developed areas, and consequently the amount of storm-water input, have increased substantially during the past 2 years of sampling. There are presently (1981) four storm-sewer inlets. High lake stages are controlled by a lift-station outlet near the southeast corner of the lake.

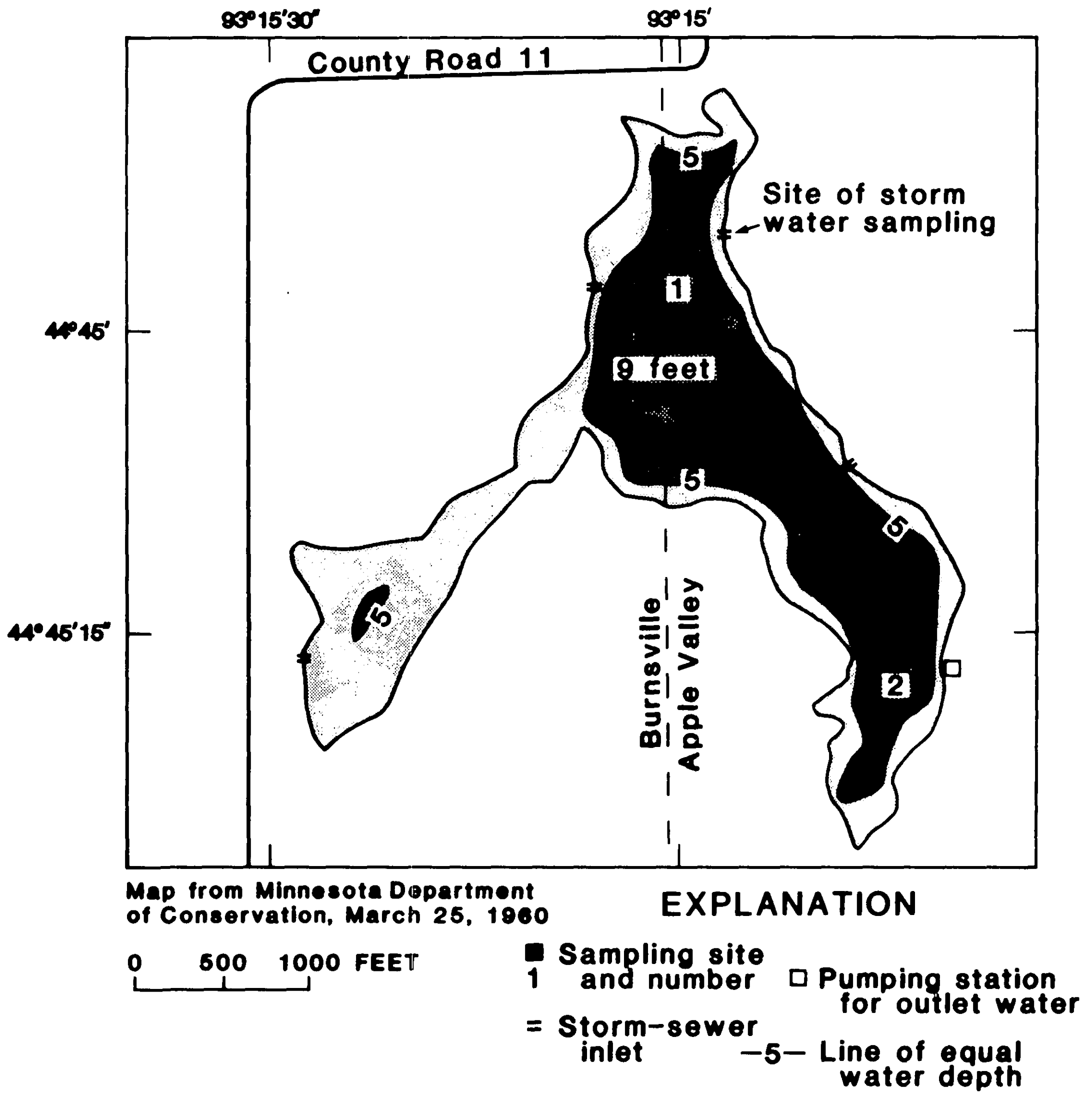

Figure 2.--Alimagnet Lake, Apple Valley, Minnesota

Farquar Lake

USGS Station Identification Number. 444500093095200.

City of Apple Valley Lake Identification Number. BP-11.

Location. On east side of Pilot Knob Road, 2.5 miles south of intersection of Cliff Road and Pilot Knob Road (fig. 3); sampling point near center of lake.

Physical Characteristics of Lake.

Surface area - 64 acres

Depth at sampling site - about 8 feet

Length of shoreline - 1.5 miles

Shoreline configuration - 1.3

Drainage Basin.

Size - 272 acres plus 717 acres from tributary Long Lake drainage basin.

Geology - Drift, about 75 feet thick, consisting of undifferentiated reddish-brown to brown sandy till. Contains some sand and gravel over sandstone bedrock (Norvitch and others, 1973).

Soils - Mostly loamy over sandy, well-drained, light-colored soils. Some poorly drained soils in level areas (University of Minnesota, 1975).

Land use - Excluding Long Lake drainage basin.	Percent
Undeveloped, mostly cropland and grassland	55
Developed, mostly single-family residential on large wooded lots	21
Lake surface	24

Hydrology. Receives water from direct precipitation, overland flow, one storm-sewer inlet, and overflow from Long Lake. The lake has no natural outlet, but a lift-station outlet was constructed in 1976.

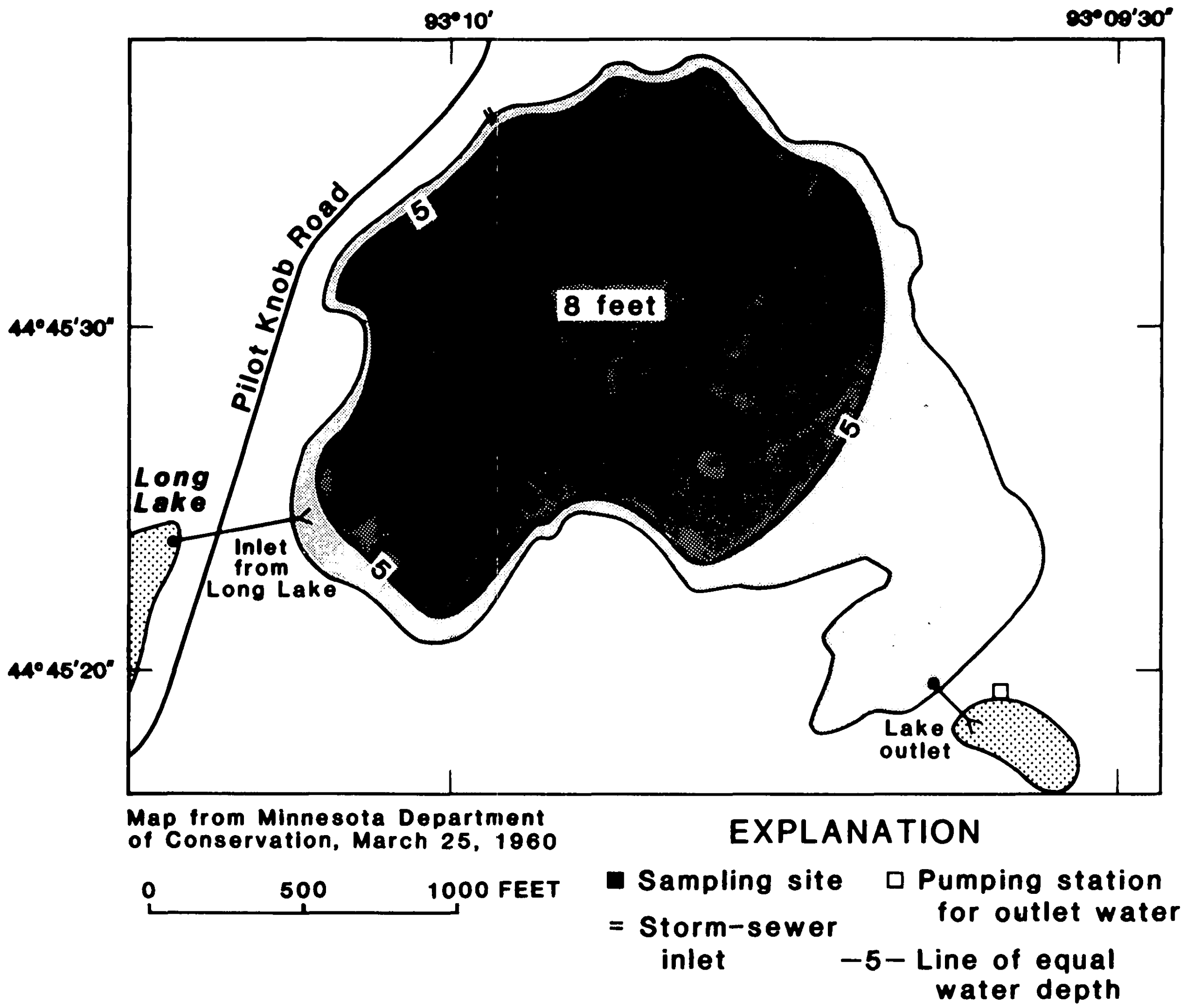

Figure 3.--Farquar Lake, Apple Valley, Minnesota

Long Lake

USGS Station Identification Number. 444522093102600.

City of Apple Valley Lake Identification Number. BP-10.

Location. On west side of Pilot Knob Road, 2.5 miles south of intersection of Cliff Road and Pilot Knob Road (fig. 4); sampling point near center of eastern end of lake.

Physical Characteristics of Lake.

Surface area - 32 acres

Depth at sampling site - about 5 feet

Length of shoreline - 1.2 miles

Shoreline configuration - 1.5

Drainage Basin.

Size - About 717 acres including drainage from storm-sewered areas.

Geology - Drift, about 75 feet thick, consisting of undifferentiated reddish-brown to brown sandy till. Contains some sand and gravel over sandstone bedrock (Norvitch and others, 1973).

Soils - Loamy over sandy, well-drained, light-colored soils. Some poorly drained soils in level areas (University of Minnesota, 1975).

Land use -	Percent
Undeveloped, includes parks	8
Developed, mostly single-family residential	88
Lake surface	4

Hydrology. Receives water from direct precipitation, overland flow, and five storm-sewer inlets. There is a culvert outlet to Farquar Lake.

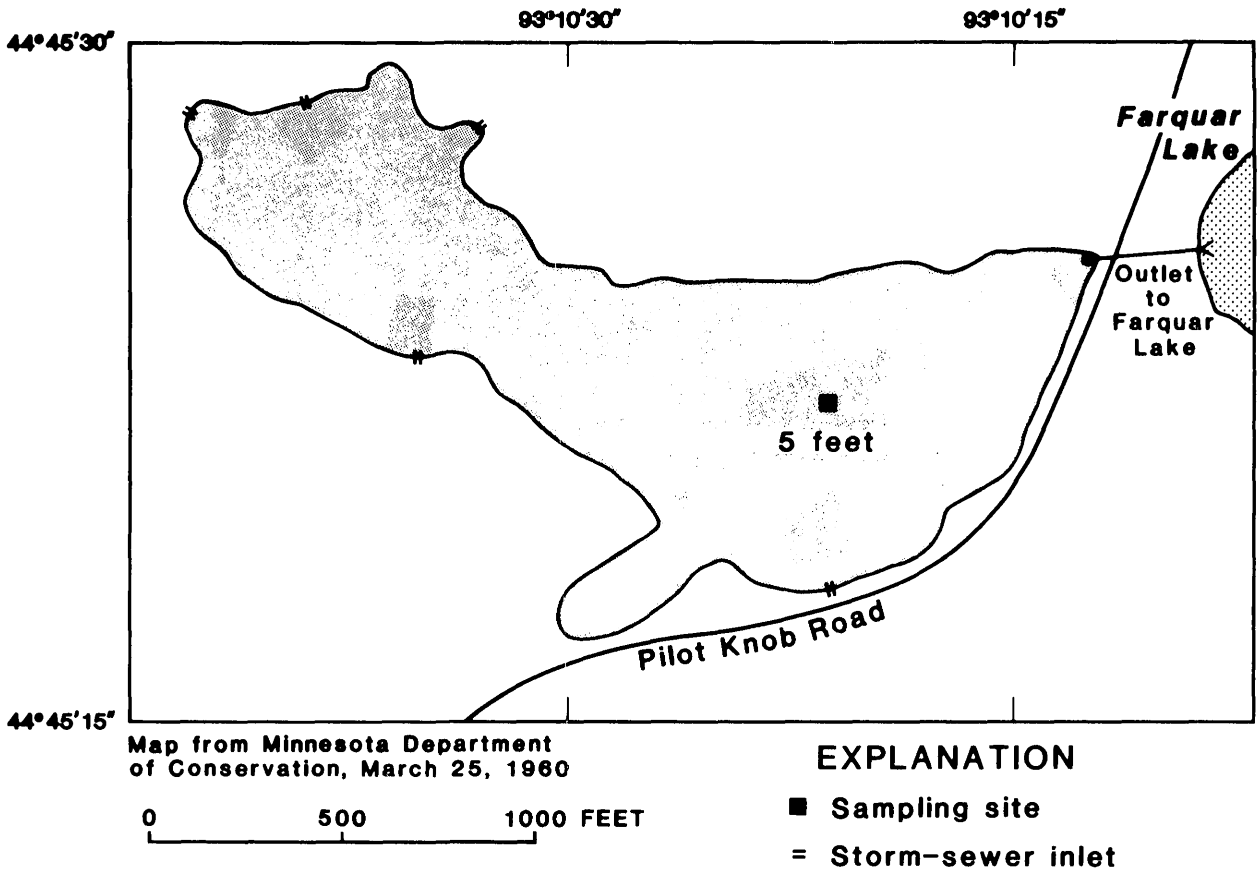

Figure 4.--Long Lake, Apple Valley, Minnesota

RESULTS AND DISCUSSION

Lake Stage

Lake-stage data for Alimagnet Lake were collected during open-water months from 1974-78 by the Minnesota Department of Natural Resources. Figure 5 shows the lake-stage hydrograph and its relation to precipitation. It is assumed that water levels in Farquar and Long Lakes responded in similar fashion.

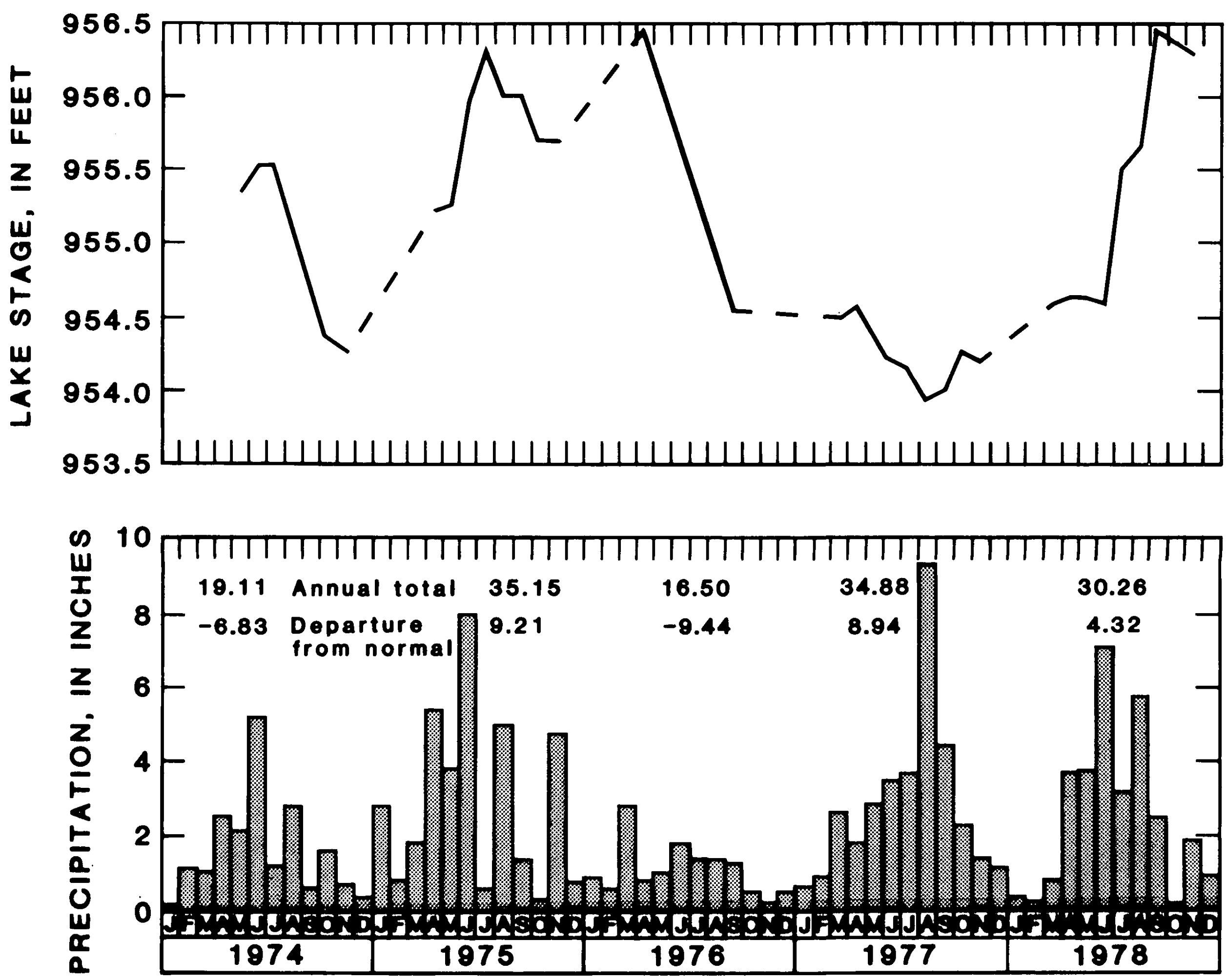

Figure 5.--Lake stage and its relation to precipitation for Alimagnet Lake.

Water levels in spring were probably dependent on both the amount of precipitation during the preceding year and on spring runoff (fig. 5). The effect of precipitation on the lake stage at the start of the open-water season depends on the ground-water inflow during the winter. Figure 5 also shows that lake levels generally respond to rainfall provided the rainfall is great enough. For example, in 1975 the water level rose from April to July because the rainfall was above normal during that period. On the other hand, the water level declined throughout 1976 because of insufficient rainfall.

As will be shown in this report, the drought of 1976 through early 1977 also had a significant effect on certain chemical constituents in the lake water.

Major Chemical Constituents

The first two samples collected at each lake were analyzed for selected major chemical constituents in order to determine the overall water quality at the beginning of the study. These data indicate that all three lakes contained a mixed calcium magnesium bicarbonate type water.

Of the major constituents, attention was focused primarily on chloride, because it is often highly concentrated in runoff from urban areas. Sodium chloride is used as a deicing agent on roads and is a major source of chloride in both ground and surface waters. Chloride concentrations in lake water, therefore, can indicate effects of urbanization on water quality. In the nearby community of Eagan, Ayers and others (1980) found that chloride concentrations greater than 6.0 milligrams per liter occur only in lakes receiving urban runoff.

Chloride concentrations were greater than 6.0 milligrams per liter in the Apple Valley lakes, which have man-made inlets and outlets. The concentrations would be expected to fluctuate in response to varying inputs of chloride and moderating effects of flushing. Chloride concentrations in Alimagnet and Farquar Lakes, however, remained relatively stable except during the 1976-77 drought (fig. 6). Long Lake, on the other hand, showed the expected fluctuations in chloride concentrations.

Each lake showed a steady increase in chloride concentration in 1976 and, except for Farquar Lake, the highest concentration occurred in February 1977 when the concentrating effects of the drought and of the freezing of lake water into ice was at a maximum. The high chloride concentration in Farquar Lake in April 1977 may have resulted from sample contamination, although it may also have been caused by high-chloride water being flushed from tributary Long Lake.

The large increase in chloride concentration in Long Lake in February 1977 apparently resulted from the higher ice-to-water ratio compared to the ratios for the other two lakes; this higher ratio in Long Lake was due to its shallower depth. Ice formation excludes ions, which then become more concentrated in the remaining water.

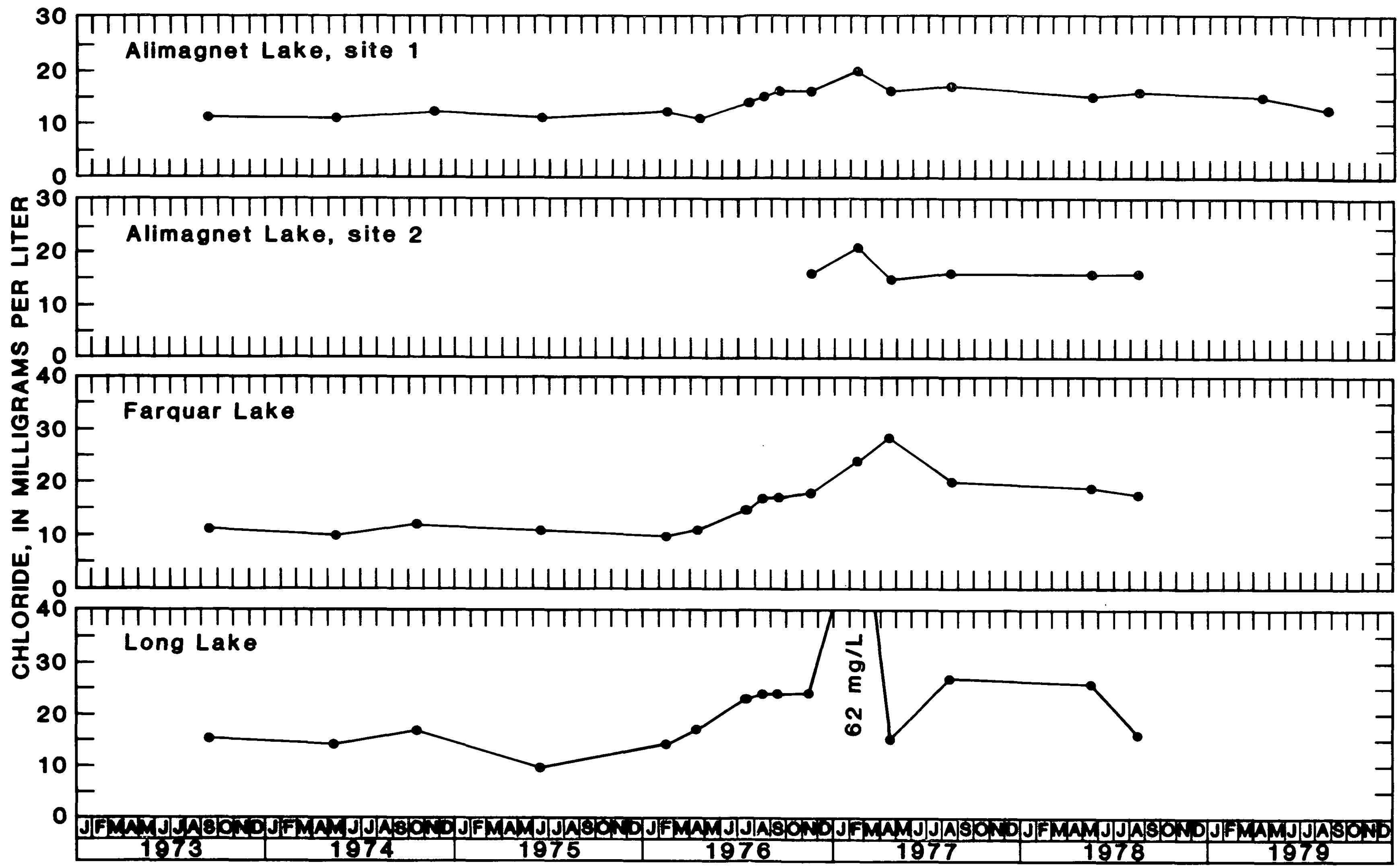

Figure 6.--Chloride concentrations in the Apple Valley lakes

After the drought ended in early 1977, chloride concentrations declined in each lake but remained higher than before the drought. Concentrations were still decreasing, however, when monitoring was terminated.

As with chloride, dissolved-solids concentrations significantly increased during the drought from September 1976 to February 1977 (fig. 7). The highest concentrations were observed in February 1977 when ice caused a further increase in the concentration of dissolved salts in the water. Long Lake, again because of its shallower depth, showed the greatest increase. Concentrations declined by April 1977, and by August 1977 were within the range of values observed before September 1976.

Concentrations of dissolved solids showed more fluctuation than chloride. The reason for this greater fluctuation is that dissolved solids are composed of many different dissolved substances, of which chloride is only one. Concentrations of most dissolved substances vary with environmental stresses such as temperature, pH, and biological activity. Chloride, on the other hand, is much less affected by these stresses.

Specific conductance is a function of dissolved solids, hence, they correlate well with each other. Correlation coefficients ranged from 0.86 for Alimagnet Lake to 0.99 for Long Lake. Dissolved-solids concentrations were about 65 percent of the specific conductance. Therefore, dissolved-solids concentrations could be estimated in the future by measuring specific conductance.

Dissolved Oxygen and pH

Epilimnion dissolved-oxygen concentrations were greater than 5.0 milligrams per liter in all three lakes during open-water conditions, and the saturation of dissolved oxygen ranged from 63 to 137 percent (fig. 8). Concentrations under ice cover, however, dropped below 5.0 milligrams per liter in each lake. In February 1976, the lowest dissolved-oxygen concentration was observed in Alimagnet Lake, site 1, where it was 1.2 milligrams per liter; concurrent dissolved-oxygen concentrations at Farquar and Long Lakes were 4.3 and 4.6 milligrams per liter, respectively. Samples taken under ice cover in February 1977 had the lowest dissolved-oxygen concentrations of all other samples. Concentrations at all four sites were less than 0.5 milligrams per liter; less water volume because ice and drought conditions may have magnified the effects of the decomposition processes.

Although fish vary in their oxygen requirements according to species, age, activity, temperature, and nutritional state, the extremely low dissolved-oxygen concentrations found in Alimagnet Lake in 1976 and in all the lakes in 1977 would probably result in winter fish kills of most species of game fish. Other field studies indicate that a dissolved-oxygen concentration of 3.0 milligrams per liter is too low to maintain a good fish population (Thompson, 1925; Ellis, 1937; Brinley, 1944), and this finding is supported by laboratory observations (Lindroth, 1949; Mount, 1960; Hermann and others, 1962).

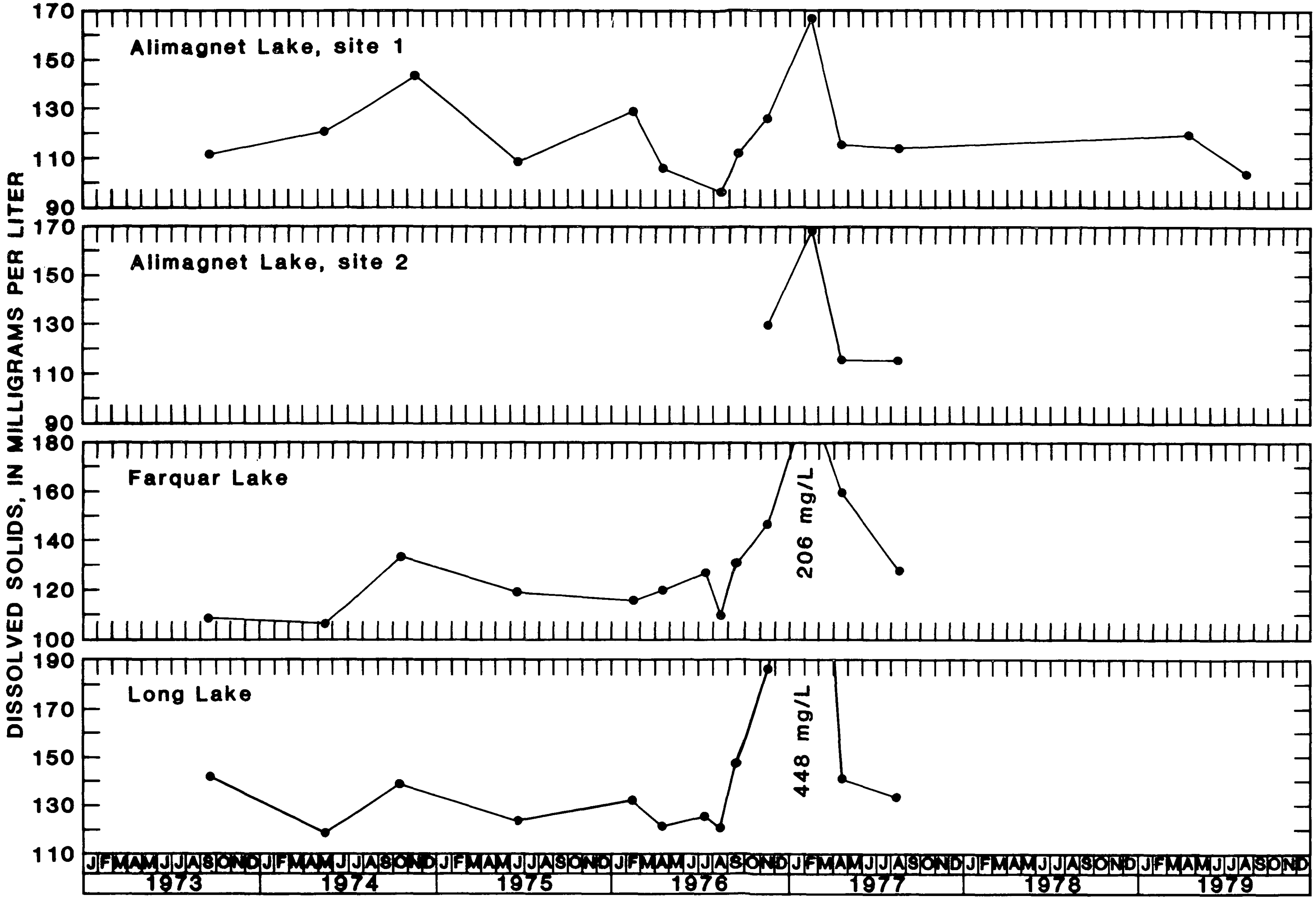

Figure 7.--Dissolved-solids concentrations in the Apple Valley lakes

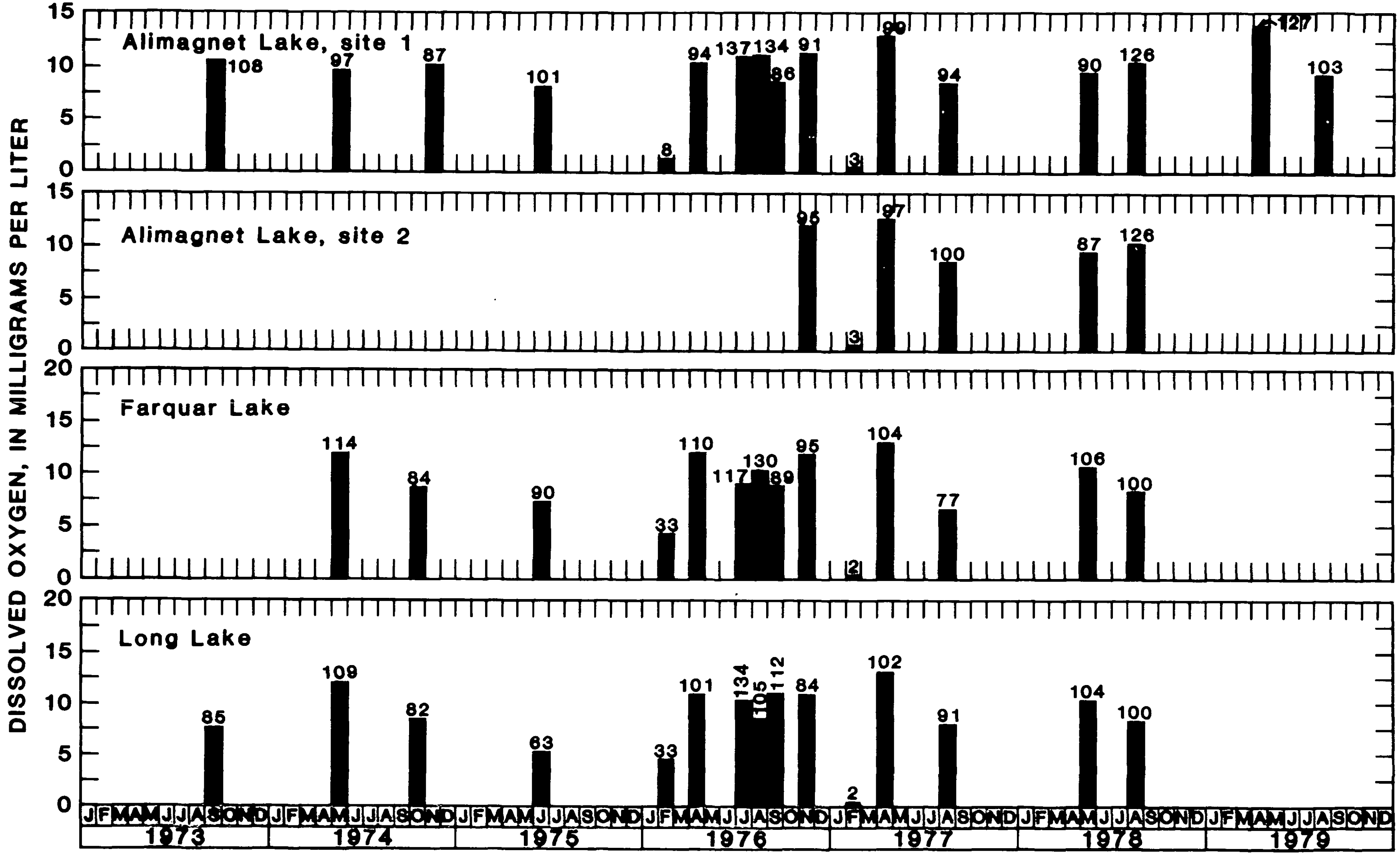

Figure 8.--Epilimnion dissolved-oxygen concentrations in the Apple Valley lakes. The number above the bar is the percent saturation of dissolved oxygen

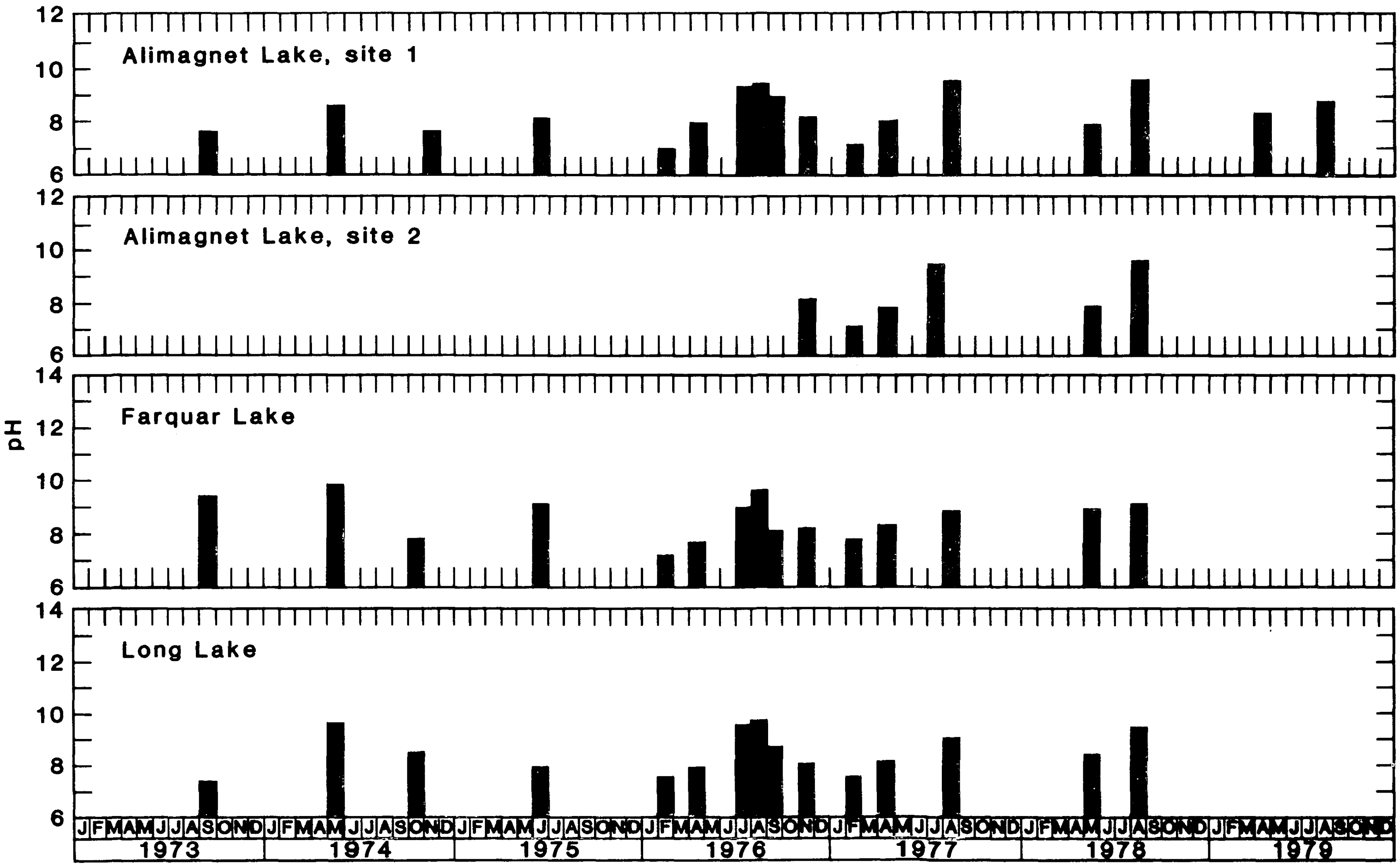

Figure 9.--pH of the Apple Valley lakes

Generally, pH is affected by photosynthesis, respiration, and other biologically-related processes in a manner similar to dissolved oxygen. The lowest pH values occurred in winter and the highest in summer (fig. 9). The low pH in winter resulted from decomposition of organic matter, and the higher values (over 8.3) occurred during the algal growing season as a result of photosynthesis. The drought and ice effect in February 1977 did not lower the pH below what it was in February 1976 as occurred with dissolved oxygen.

Nutrients

Although many nutrients are essential for algal growth, attention is generally focused on nitrogen and phosphorus, since they are often present in limiting quantities. Vollenwieder (1976) as well as other researchers have shown good correlations between algal productivity and phosphorus concentration.

Urbanization can increase nutrient loading to lakes, which may enrich the lakes sufficiently to cause algal blooms. Severe algal blooms can result in a loss of light transparency, bad odors, reduced oxygen concentrations, algal mats, and other undesireable effects.

There are many different ways of measuring productivity, and they all have their advantages and disadvantages. The determination of chlorophyll a was used as a measure in this study; however, it did not correlate well with total phosphorus. Insufficient data and the rapid decomposition of chlorophyll between collection and analysis probably affected the correlation.

Table 2.--Statistical summary of total-phosphorus concentration and pH data, and their correlation with light transparency

[Total phosphorus concentrations are in milligrams per liter; pH values are in pH units; N is the number of samples; r is the correlation coefficient]

	Total phosphorus concentration					pH				
Lake	N	r	Maximum	Minimum	Mean	N	r	Maximum	Minimum	Mean
Alimagnet, site 1	10	-0.50	0.31	0.02	0.10	12	-0.79	9.6	7.0	7.8
Alimagnet, site 2	4	-.75	.31	.09	.14	6	-.92	9.6	7.1	7.7
Farquar	7	-.12	.33	.02	.13	9	-.85	9.9	7.1	8.0
Long	7	-.90	.25	.03	.14	9	-.85	9.7	7.4	8.1

The best correlation related to productivity was between light transparency, determined using a Secchi disc, and pH. Good correlation was also found between transparency and total phosphorus in all lakes except Farquar. The statistical summary of pH and total phosphorus concentrations is shown in table 2. The negative correlation coefficients show that as pH and total phosphorus increase transparency decreases. These relationships are largely controlled by biological activity.

The study lakes showed little stability with respect to their nutrient concentrations. Total-phosphorus concentrations, for example, ranged from 0.02 to 0.31 milligrams per liter in Alimagnet Lake, 0.02 to 0.33 in Farquar Lake, and 0.03 to 0.25 in Long Lake (table 2). The fluctuations, furthermore, did not follow expected seasonal trends.

Nitrogen was primarily in the organic form, with total ammonia plus organic nitrogen ranging from 1.1 to 3.0 milligrams per liter in Alimagnet Lake, 1.7 to 4.0 milligrams per liter in Farquar Lake, and 1.5 to 5.0 milligrams per liter in Long Lake (table 3).

Table 3.--Statistical summary of nitrogen concentrations and ratios of total nitrogen to total phosphorus

[N is the number of samples; concentrations are in milligrams per liter]

	Total ammonia plus organic nitrogen				Total nitrite plus nitrate as nitrogen				Ratio of total nitrogen to total phosphorus
Lake	N	Maximum	Minimum	Mean	N	Maximum	Minimum	Mean	
Alimagnet site 1	8	3.0	1.1	1.6	6	0.31	0.00	0.08	23:1
Farquar	6	4.0	1.7	3.0	6	.29	.01	.12	26:1
Long	6	5.0	1.5	3.0	6	.26	.01	.09	22:1

Nitrite plus nitrate concentrations were usually less than 0.10 milligrams per liter for each of the lakes. It was highest in the February 1976 samples for all sites when phytoplankton growth was at a minimum.

Some investigators have looked at ratios of total nitrogen to total phosphorus in order to determine whether or not a lake is nitrogen limited. Sakamoto (1966) reported that lakes having nitrogen to phosphorus ratios greater than 15:1 to 17:1 were not nitrogen limited. Similarly, Smith (1979) reported that lakes with ratios greater than 20:1 were not likely to be nitrogen limited.

Nitrogen to phosphorus ratios (table 3), determined from mean concentrations of nitrogen and phosphorus, indicate that phosphorus, not nitrogen, is more likely to be limiting the growth of phytoplankton in the lakes.

Nutrients probably cycle between bottom sediments and the lake water. Mechanical mixing of the bottom sediments by wave action, diving birds, and aquatic rodents recycle nutrients to the water and make them available for algal growth. Nutrients are returned to the sediments as algae die and settle to the lake bottom. Accordingly, nitrogen, phosphorus, and organic carbon concentrations were determined for the bottom sediments. Four samples of nitrogen and phosphorus were collected from each lake; three samples of organic carbon were collected from Alimagnet Lake site 1 and Farquar Lake, and two samples were collected from Long Lake. A summary of the results are shown in table 4. The resulting nutrient concentrations are comparable to those found in other shallow eutrophic lakes sampled in Dakota County (Have, 1975, 1980; Payne, 1980; Tornes and Have, 1980).

Table 4.--Nutrient concentrations in bottom-sediment samples

[Concentrations are in milligrams per liter]

	Nitrogen			Phosphorus			Organic carbon		
Lake	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Alimagnet, site 1...	19,600	700	7,500	280	69	195	154,000	52,000	95,000
Farquar....	9,500	1,600	5,500	413	77	220	66,000	43,000	58,000
Long.......	9,600	70	5,140	200	50	130	64,000	38,000	51,000

Trophic States

Lakes go through a natural aging process called eutrophication. Eutrophication of a lake consists of the progression from one life stage to another based upon changes in the degree of nutrient enrichment and productivity. These stages, beginning with low nutrient concentrations and low productivity, progress to high nutrient concentrations and high productivity, and are termed oligotrophic, mesotrophic, and eutrophic.

There are many ways of characterizing lakes in order to classify them. Carlson (1977) devised a method called the trophic state index (TSI) that uses summer chlorophyll a concentrations, summer total-phosphorus concentrations, or summer Secchi-disk transparencies for assigning a TSI to a particular lake. Reckhow (1979) divided Carlson's TSI scale into three general trophic states as shown in figure 10.

The Apple Valley lakes were classified according to Carlson's method using total-phosphorus concentrations and Secchi-disk transparency values for June through September for each year of the study. Chlorophyll was not used because of its questionable concentrations as pointed out earlier. As shown in figure 10, all three lakes could be considered eutrophic according to Reckhow's guidelines. The TSI values obtained show good agreement between the two trophic variables selected. Neither the total phosphorus nor the Secchi-disk TSI's indicate long-term trends of improvement or worsening of trophic conditions over the period of study. However, increased eutrophic conditions during the drought are indicated in Alimagnet Lake.

Phytoplankton

Phytoplankton are essential for aquatic animal life to exist; however, when they become too numerous some water uses can be adversely affected. The Apple Valley lakes had high phytoplankton concentrations, typical of eutrophic lakes. Mean concentrations ranged from 310,000 cells per milliliter at Alimagnet Lake site 1 to 1,250,000 cells per milliliter at Long Lake (fig. 11). In contrast, the medians ranged from 23,000 cells per milliliter at Alimagnet site 2 to 280,000 cells per milliliter at Farquar; this difference from the mean indicates how variable the phytoplankton counts were.

Blue-green algae were dominant in 88 percent of the samples; the three most frequently occurring genera were Aphanizomenon, Anacystis, and Oscillatoria (table 5). These types of populations were also found in other Dakota County Lakes (Ayers and others, 1980; Tornes and Have, 1980). Anacystis is infamous because of the many records of acute and often fatal poisoning of livestock that drank water containing it (Palmer, 1962, p. 53).

Storm-Runoff Sampling

Runoff from two storms was sampled at a storm-sewer inlet to Alimagnet Lake (fig. 2). The 78-acre drainage area of this subwatershed is largely residential and, at the time of sampling, residential construction was in progress less than 1,000 feet above the mouth of the inlet. During rainfall, exposed red clay from the construction was carried by overland runoff to a natural open channel, through a swamp, and then to the lake.

Sampling of the first storm on August 28, 1978, was not considered to be representative because the major part of the storm was missed; the water discharge was only 0.32 cubic foot per second at the time the sample was collected. A more representative sample was obtained during the second storm on September 12, 1978, when 2.70 inches of rain fell at the sampling site.

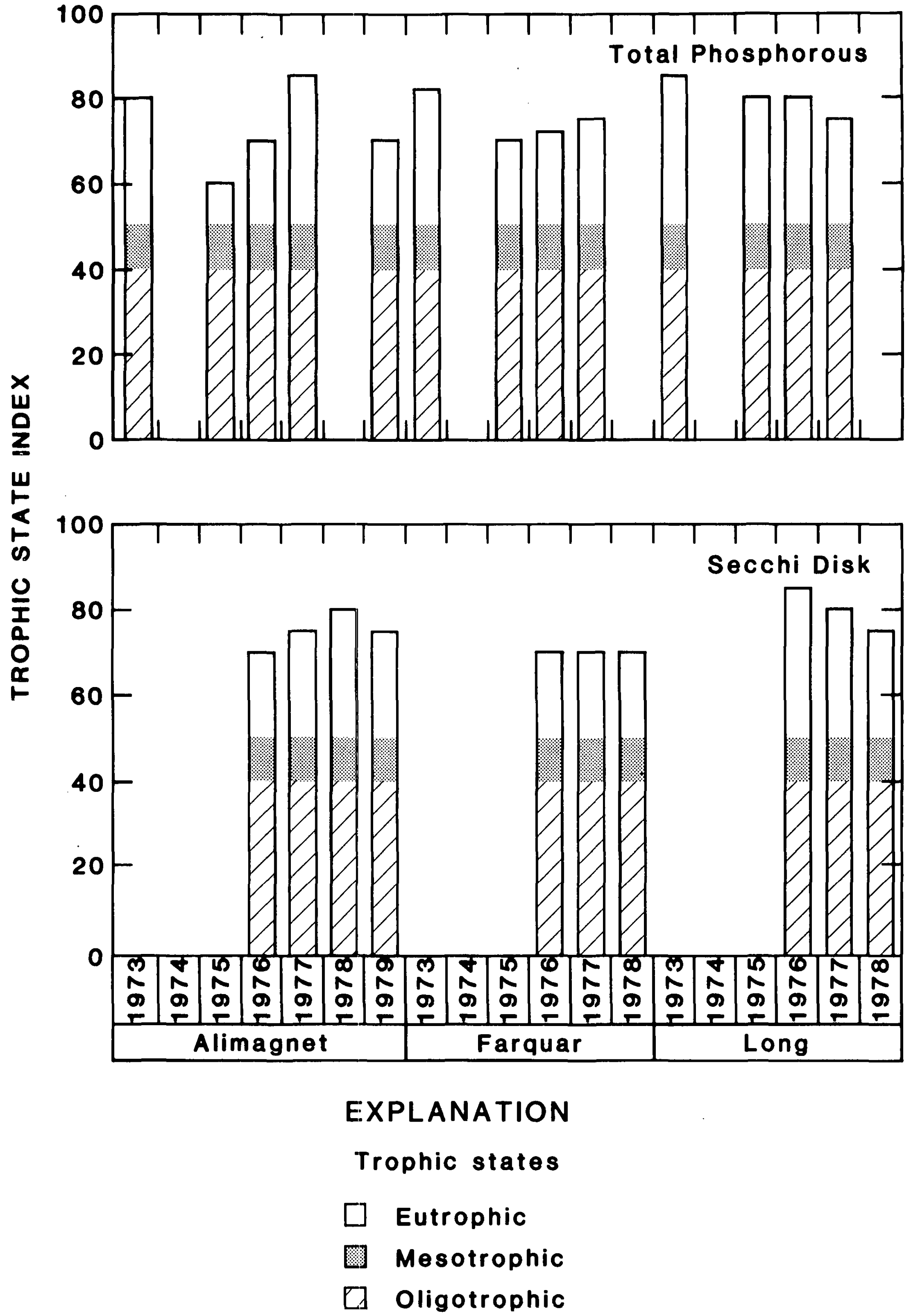

Figure 10.--Trophic state indices for Apple Valley lakes based on Carlson (1977) and Reckhow (1979)

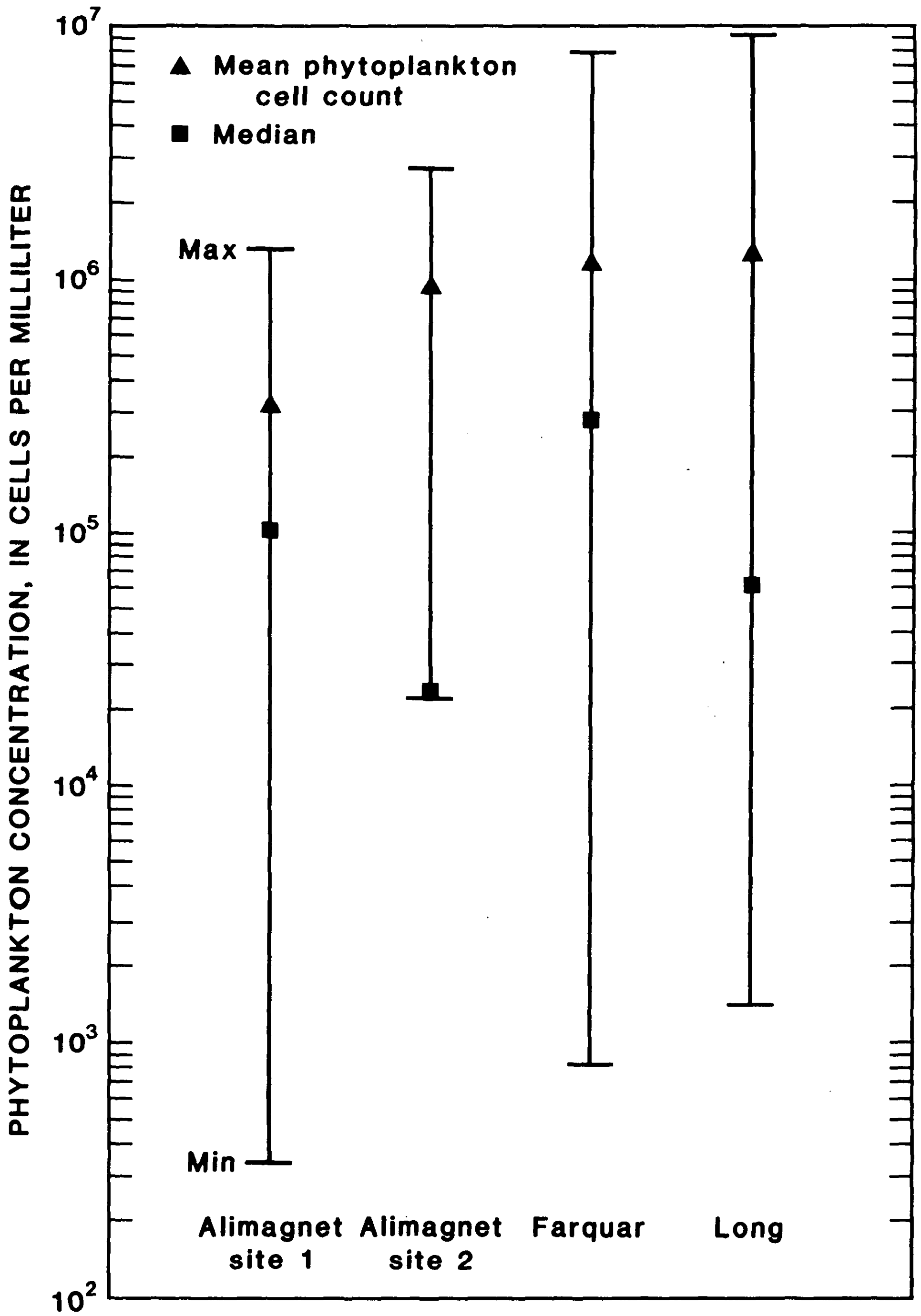

Figure 11.--Phytoplankton concentrations in Apple Valley lakes (length of bar indicates range)

Table 5.--Dominant and codominant algal genera in phytoplankton samples for Apple Valley study lakes

[N, number of samples analyzed]

Genera	Number of occurrences in which each genus comprised at least 15 percent of the phytoplankton population				
	Alimagnet Lake, site 1 (N=14)	Alimagnet Lake, site 2 (N=3)	Farquar Lake (N=12)	Long Lake (N=11)	Total occurrences of each genera in all lakes
Blue-green algae					
Agmenellum	---	1	---	---	1
Aphanizomenon	3	1	4	2	10
Anabaena	1	---	1	2	4
Anacystis	10	1	6	3	20
Cylindrospermum	---	---	---	2	2
Gomphosphaeria	---	---	1	1	2
Lyngbya	---	---	2	4	6
Oocystis	1	---	---	---	1
Oscillatoria	2	1	5	5	13
Green algae					
Ankistrodesmus	---	---	1	---	1
Botryococcus	1	---	---	---	1
Dictosphaerium	1	1	---	1	3
Gleoactinum	1	---	---	---	1
Kirchneriella	1	---	1	---	2
Pediastrium	2	---	---	---	2
Scenedesmus	---	---	1	---	1
Schroederia	1	---	---	1	2
Euglenoids					
Trachelomonas	---	---	1	---	1
Number of genera found in each lake	24	5	23	21	

The hydrograph in figure 12 shows that flow in the inlet channel began around 1:00 p.m. on September 12, 1978, and continued until about 9:00 a.m. on September 14, 1978. Stage was measured until 9:30 a.m. on September 13. After that time, it was assumed that flow continued for about another 24 hours as indicated by the dashed line on the hydrograph. The mean flow from the time runoff started to the estimated time it ended was 4.4 cubic feet per second.

Fourteen water-quality samples were collected between 1:19 and 6:30 p.m. on September 12. When the last sample was collected, rainfall was light and flow was decreasing rapidly. The 14 individual samples were flow-composited into a single sample for chemical analysis. During the sample-collection period of 5.2 hours, the mean flow was 13.7 cubic feet per second. A peak flow of 23.2 cubic feet per second occurred at 4:15 p.m. (fig. 12).

The results of the sample analyses for both storms are shown in table 6. Total loads of the September storm were computed for both the 5.2-hour sampling period on September 12 and the estimated 44-hour runoff period.

The metals chromium, copper, nickel, and zinc had noticeably higher concentrations than the other metals. Lead is sometimes the most concentrated metal in urban runoff because of automobile emissions, but in this case it was the lowest of the four major metals.

As expected, heavy metals were carried mostly on the sediment particles as indicated by the high suspended concentrations relative to the dissolved concentrations. An exception was arsenic; its concentration was low but it was entirely in the dissolved state. The arsenic in this area may occur as calcium or magnesium arsenate, which are very soluble forms (Hem, 1970).

Most of the nitrogen and phosphorus were also carried on the sediment. The nitrogen was 98 percent ammonia plus organic nitrogen and 2 percent nitrite plus nitrate. The concentration of total phosphorus was 1.7 milligrams per liter during the September 12 storm, which meant that 29 pounds during the 5.2-hour sampling period and over 73 pounds during the 44-hour runoff period were discharged to Alimagnet Lake. If one assumes that similar loads are contributed to the lake from the other three storm sewers, over 100 pounds of phosphorus would have been discharged to the lake just during this 5.5-hour sampling period. This is important because phosphorus is most likely limiting phytoplankton growth, as discussed earlier.

There are no effluent standards for storm runoff as there are for various other point sources. For example, the phosphorus standard for effluent from municipal treatment plants is 1 milligram per liter; however, when discharged to lakes, the removal of phosphorus is to be to the fullest practicable extent wherever sources of it are considered to be actually or potentially detrimental to designated water uses. (Minnesota Pollution Control Agency, 1978). In comparison, therefore, the phosphorus concentration in storm runoff to Alimagnet Lake can be higher than what would be allowed for a municipal treatment plant.

Table 6.--Chemical data for storm runoff to Alimagnet Lake

Date	Concentrations in microgram per liter unless otherwise indicated		Total load in pounds per 5.2 hours at 13.7 ft^3/s	Total load in pounds per 44 hours at 4.4 ft^3/s
	8-28-78	9-12-78	9-12-78	9-12-78 to 9-14-78
Arsenic, dissolved.......	2	2	0.03	0.09
Arsenic, suspended.......	0	0	.00	.00
Cadmium, dissolved.......	2	0	.00	.00
Cadmium suspended........	0	1	.02	.04
Chloride, dissolved (milligrams per liter)..	1.8	2.5	42	110
Chromium, dissolved......	2	0	.00	.00
Chromium, suspended......	8	120	2.0	5.2
Copper, dissolved........	1	4	.07	.17
Copper, suspended........	7	170	2.9	7.4
Lead, dissolved..........	3	2	.03	.09
Lead, suspended..........	10	14	.24	.61
Mercury, dissolved.......	0.5	0.5	.01	.02
Mercury, suspended.......	.5	.5	.01	.02
Nickel, dissolved........	1	2	.03	.09
Nickel, suspended........	24	49	.83	2.1
Ammonia plus organic nitrogen, dissolved (milligrams per liter)..	1.3	.49	8.3	21
Ammonia plus organic nitrogen, suspended (milligrams per liter)..	.90	25	420	1100
Nitrite plus nitrate nitrogen, total (milligrams per liter)..	.26	.49	8.3	21
Phosphorus, dissolved (milligrams per liter)..	.25	.19	3.2	8.3
Phosphorus, suspended (milligrams per liter)..	.51	1.5	25	65
Zinc, dissolved..........	0	10	.17	.44
Zinc, suspended..........	30	290	4.9	13
BOD, (milligrams per liter).................	---	14.0	240	610
pH......................	---	8.2	---	---
Specific conductance (micromhos per meter at at 25 degrees Celsius)..	---	120	---	---
Mean temperature (degrees Celsius).......	---	18.0	---	---

Table 7.--Analyses of water

[NTU, nephelometric turbidity units; $CaCO_3$,
Values are in milligrams per

Site	Sept 26, 1973	May 20, 1974	Nov. 4, 1974	June 24, 1975	Feb. 26, 1976	Apr. 8, 1976	July 27, 1976
Depth at sampling site, in feet..	9.4	8.0	10.0	--	--	10.0	10.0
Temperature, in degrees Celsius..	17.5	15.0	8.5	26.0	1.5	11.0	26.5
Specific conductance, in micromhos per centimeter at 25 degrees Celsius..........	185	189	215	180	184	150	187
Solids, dissolved...............	111	120	143	109	129	104	106
Solids, suspended...............	13	7	5	12	1	3	--
Turbidity, NTU..................	9	4	4	2	2	3	--
Transparency, in feet...........	--	--	--	--	--	3.8	1.8
pH, units.......................	7.6	8.5	7.6	8.1	7.0	7.9	9.3
Oxygen, dissolved...............	10.2	9.6	10.0	8.1	1.2	10.1	10.8
Percent saturation of oxygen, dissolved,....................	108	97	87	101	8	94	137
Alkalinity as $CaCO_3$, total.......	74	65	--	--	65	65	--
Silica, dissolved...............	0.2	0.1	--	--	--	--	--
Ammonia as N, total.............	.51	.09	--	--	--	--	--
Organic N as N, total...........	2.5	1.3	--	--	--	--	--
Ammonia plus organic N as N, total........................	--	--	1.2	1.1	1.3	1.3	--
Nitrite plus nitrate as N, total.	.04	.05	0.01	0.06	0.31	0.00	--
Nitrite plus nitrate as N, dissolved.....................	.03	.06	.01	.06	.27	.00	--
N in bottom sediment, milligrams per kilogram..................	--	--	700	19600	1500	8200	--
Orthophosphate as P, dissolved...	.00	.00	.01	.00	.00	.00	--
Phosphorus, dissolved...........	.02	.06	--	--	--	--	--
Phosphorus, total...............	.18	.08	.06	.04	.04	.04	0.07
Phosphorus in bottom material, milligrams per kilogram.........	--	--	69	280	190	240	--
Calcium, dissolved..............	19	19	--	--	--	--	--
Magnesium, dissolved............	6.1	5.4	--	--	--	--	--
Sodium, dissolved...............	6.5	6.2	--	--	--	--	--
Potassium, dissolved............	5.8	4.1	--	--	--	--	--
Chloride, dissolved.............	11	11	12	11	12	11	14
Organic carbon, total...........	--	--	11	5.7	20	7.6	--
Organic carbon in bottom sediment, grams per kilogram........	--	--	--	154	52	80	--
Inorganic carbon in bottom sediment, grams per kilogram........	--	--	.1	--	--	--	--
Biochemical oxygen demand........	8.3	4.2	--	--	--	--	--
Total coliform, colonies per 100 milliliter.................	180	1	--	--	--	--	--
Fecal coliform, colonies per 100 milliliter.................	25	1	4	--	--	--	--
Fecal _Streptococci_, colonies per 100 milliliter.............	--	--	31	--	--	--	--
Chlorophyll _a_, micrograms per liter........................	--	--	--	--	--	--	12
Chlorophyll _b_, micrograms per liter........................	--	--	--	--	--	--	5.2

samples from Alimagnet Lake, site 1

calcium carbonate; N, nitrogen; P, phosphorus.
liter unless otherwise indicated]

Aug. 23, 1976	Sep. 30, 1976	Nov. 3, 1976	Feb. 10, 1977	Apr. 6, 1977	Aug. 11, 1977	May 9, 1978	Aug. 22, 1978	Apr. 26, 1979	Aug. 28 1979	Mean
10.0	10.0	9.6	9.0	10.0	9.5	11.0	11.0	11.0	12.0	9.9
24.5	14.5	5.0	3.0	3.5	22.0	12.0	24.5	10.0	20.0	--
190	177	185	273	182	175	187	177	193	177	159
97	112	125	167	115	114	--	--	120	104	119
--	--	--	--	--	--	--	--	--	--	6.8
--	--	--	--	--	--	--	--	--	--	6
1.8	1.8	2.3	--	4.6	1.3	2.3	1.0	3.3	1.3	2.5
9.4	8.5	8.1	7.1	8.0	9.5	7.9	9.6	8.3	8.8	7.8
11.0	8.6	11.3	0.4	12.8	8.4	9.5	10.3	14.0	9.2	9.1
134	86	91	3	99	94	90	126	127	105	95
--	--	--	--	--	--	--	--	--	--	67
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	1.4	2.1	1.4
--	--	--	--	--	--	--	--	--	--	0.08
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	7500
--	--	--	--	--	--	--	--	0.00	0.01	.00
--	--	--	--	--	--	--	--	--	--	--
0.13	0.10	0.10	.14	0.08	0.31	--	--	.02	.11	.10
--	--	--	--	--	--	--	--	--	--	195
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
15	16	16	20	16	17	15	16	15	13	14
--	--	--	--	--	--	--	--	--	--	12
--	--	--	--	--	--	--	--	--	--	12
--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--
26	55	6.7	--	.66	.19	--	--	--	101	29
1.4	27	.87	--	.12	.00	--	--	--	.00	4.9

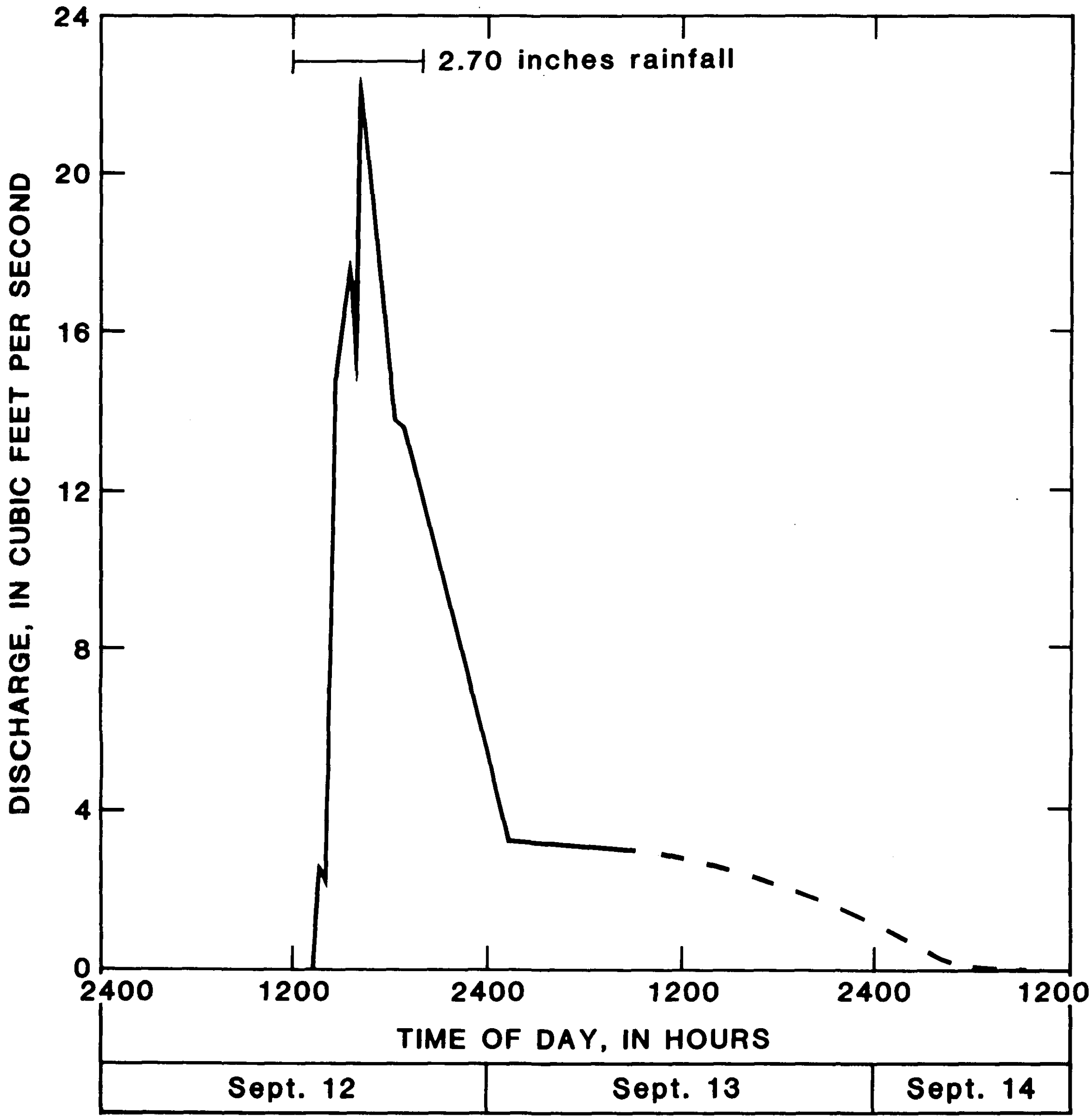

Figure 12.--Rainfall runoff on September 12, 1978, at an Alimagnet Lake storm-sewer inlet

Table 8.--Analyses of water samples from Alimagnet Lake, site 2

[Values are in milligrams per liter unless otherwise indicated]

Date	Nov. 3, 1976	Feb. 10, 1977	Apr. 6, 1977	Aug. 11 1977	May 9, 1978	Aug. 22, 1978	Mean
Depth at sampling site, in feet	8.9	8.0	9.2	9.0	10.0	10.0	9.2
Temperature, in degrees Celsius	5.0	2.0	3.5	22.0	12.0	24.5	11.5
Specific conductance, in micromhos per centimeter at 25 degrees Celsius	187	268	177	170	187	178	194
Solids, dissolved	130	169	116	113	--	--	132
Transparency, in feet	2.3	--	3.9	1.3	2.6	1.1	2.5
pH, units	8.1	7.1	7.9	9.5	7.9	9.6	8.4
Oxygen, dissolved	11.8	0.4	12.5	8.6	9.4	10.3	8.8
Percent saturation of oxygen, dissolved	95	3	97	100	87	126	85
Phosphorus, total	0.09	.10	0.31	--	--	--	0.14
Chloride, dissolved	16	21	15	16	16	16	16.7
Chlorophyll a, micrograms per liter	.00	--	1.32	1.40	--	--	.91
Chlorophyll b, micrograms per liter	.00	--	.46	0.48	--	--	.31

Table 9.--Analyses of water

[NTU, nephelometric turbidity units; $CaCO_3$,
Values are in milligrams per liter

Site	Sept 25, 1973	May 15, 1974	Oct. 31, 1974	June 23, 1975	Feb. 26, 1976	Apr. 8, 1976
Depth at sampling site, in feet..	6.3	8.0	7.5	--	--	12.0
Temperature, in degrees Celsius..	16.0	12.0	12.5	25.0	3.5	10.0
Specific conductance, in micromhos per centimeter at 25 degrees Celsius..........	165	165	195	155	189	180
Solids, dissolved...............	108	106	134	119	116	120
Solids, suspended...............	16	16	28	48	1	5
Turbidity, NTU..................	20	8	20	11	4	5
Transparency, in feet...........	--	--	--	--	--	3.2
pH, units.......................	9.4	9.9	7.8	9.1	7.1	7.7
Oxygen, dissolved...............	--	12.0	8.7	7.4	4.3	12.1
Percent saturation of oxygen, dissolved......................	--	114	84	90	33	110
Alkalinity as $CaCO_3$, total.......	71	62	--	--	69	77
Silica, dissolved...............	--	--	--	--	--	--
Ammonia as N, total.............	0.09	0.06	--	--	--	--
Organic N as N, total...........	3.9	2.9	--	--	--	--
Ammonia plus organic N as N, total..........................	4.0	3.0	4.0	2.6	1.7	2.5
Nitrite plus nitrate as N, total.	.08	.21	0.04	0.11	0.29	0.01
Nitrite plus nitrate as N, dissolved......................	.02	.20	.00	.11	.24	.01
N in bottom sediment, milligrams per kilogram...................	--	--	1600	9500	2400	8500
Orthophosphate as P, dissolved...	.01	.01	.00	.31	.00	.00
Phosphorus, dissolved...........	.02	.01	--	--	--	--
Phosphorus, total...............	.24	.10	.13	.10	.02	.10
Phosphorus in bottom material, milligrams per kilogram.........	--	--	413	77	150	240
Calcium, dissolved..............	15	16	--	--	--	--
Magnesium, dissolved............	6.7	6.3	--	--	--	--
Sodium, dissolved...............	5.7	5.1	--	--	--	--
Potassium, dissolved............	7.0	5.8	--	--	--	--
Chloride, dissolved.............	11	10	12	11	10	11
Organic carbon, total...........	--	--	22	18	10	14
Organic carbon in bottom sediment, grams per kilogram........	--	--	--	43	66	67
Inorganic carbon in bottom sediment, grams per kilogram........	--	--	<.1	--	--	--
Biochemical oyxgen demand........	20	13	--	--	--	--
Total coliform, colonies per 100 milliliter.................	35	2	--	--	--	--
Fecal coliform, colonies per 100 milliliter.................	--	<1	--	--	--	--
Fecal _Streptococci_, colonies per 100 milliliter.............	--	--	--	--	--	--
Chlorophyll _a_, micrograms per liter.........................	--	--	--	--	--	--
Chlorophyll _b_, micrograms per liter.........................	--	--	--	--	--	--

samples from Farquar Lake

calcium carbonate; N, nitrogen; P, phosphorus.
unless otherwise indicated; <, less than]

July 26, 1976	Aug. 23, 1976	Sep. 29, 1976	Nov. 4, 1976	Feb. 10, 1977	Apr. 3, 1977	Aug. 11, 1977	May 11, 1978	Aug. 22, 1978	Mean
8.0	8.0	7.2	7.1	7.0	6.0	7.6	9.0	9.0	7.9
28.0	26.0	15.0	5.0	1.0	5.0	22.0	14.0	23.0	14.5
218	210	207	215	336	225	195	193	213	204
127	109	131	147	206	160	127	--	--	132
--	--	--	--	--	--	--	--	--	19
--	--	--	--	--	--	--	--	--	11
1.2	1.2	2.0	3.0	2.3	--	1.3	1.8	1.3	0.39
9.0	9.6	8.1	8.3	7.8	8.3	8.8	8.9	9.1	--
9.0	10.4	8.8	11.8	0.3	12.9	6.6	10.7	8.4	8.9
117	130	89	95	2	104	77	106	106	90
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--	--	--	--	--	--	--	--	--	5500
--	--	--	--	--	--	--	--	--	.02
--	--	--	--	--	--	--	--	--	--
0.17	0.13	0.07	0.09	.33	0.17	0.13	--	--	.13
--	--	--	--	--	--	--	--	--	220
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15	17	17	18	24	29	20	19	18	16
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10	4.9	7.5	5.8	--	.90	--	--	--	5.8
5.8	.20	2.6	.00	--	.60	--	--	--	1.7

Table 10.--Analyses of water

[NTU, nephelometric turbidity units; $CaCO_3$,
Values are in milligrams per liter

Site	Sept 26, 1973	May 15, 1974	Oct. 31, 1974	June 23, 1975	Feb. 26, 1976	Apr. 8, 1976
Depth at sampling site, in feet..	4.7	5.0	4.0	--	--	5.5
Temperature, in degrees Celsius..	20.0	10.0	12.5	24.5	0.0	11.0
Specific conductance, in micromhos per centimeter at 25 degrees Celsius..........	189	190	210	206	231	212
Solids, dissolved...............	142	118	139	123	132	121
Solids, suspended...............	32	11	13	44	9	9
Turbidity, NTU..................	20	8	9	22	5	6
Transparency, in feet...........	--	--	--	--	--	2.9
pH, units.......................	7.4	9.6	8.5	7.9	7.5	7.9
Oxygen, dissolved...............	7.6	12.0	8.5	5.2	4.6	10.9
Percent saturation of oxygen, dissolved......................	--	109	82	63	33	101
Alkalinity as $CaCO_3$, total.......	73	70	--	--	87	81
Silica, dissolved...............	--	--	--	--	--	--
Ammonia as N, total.............	0.45	0.07	--	--	--	--
Organic N as N, total...........	4.6	2.5	--	--	--	--
Ammonia plus organic N as N, total..........................	5.0	2.6	4.0	2.9	1.7	1.5
Nitrite plus nitrate as N, total.	.03	.02	0.01	0.16	.26	0.10
Nitrite plus nitrate as N, dissolved.....................	.03	.03	.00	.16	.26	.10
N in bottom sediment, milligrams per kilogram..................	--	--	70	9600	2200	8700
Orthophosphate as P, dissolved...	--	.01	--	.21	.01	--
Phosphorus, dissolved...........	.03	.03	--	--	--	--
Phosphorus, total...............	.25	.11	.19	.21	.03	.05
Phosphorus in bottom material, milligrams per kilogram.........	--	--	143	50	130	200
Calcium, dissolved..............	19	19	--	--	--	--
Magnesium, dissolved............	6.9	7.0	--	--	--	--
Sodium, dissolved...............	6.3	5.9	--	--	--	--
Potassium, dissolved............	4.3	3.1	--	--	--	--
Chloride, dissolved.............	15	14	17	9.7	14	17
Organic carbon, total............	--	--	29	7.7	8.3	7.8
Organic carbon in bottom sediment, grams per kilogram........	--	--	--	38	--	64
Inorganic carbon in bottom sediment, grams per kilogram........	--	--	<.1	--	--	--
Biochemical oyxgen demand........	20	13	--	--	--	--
Total coliform, colonies per 100 milliliter..................	520	2	--	--	--	--
Fecal coliform, colonies per 100 milliliter..................	--	2	--	--	--	--
Fecal *Streptococci*, colonies per 100 milliliter............	--	--	--	--	--	--
Chlorophyll *a*, micrograms per liter..........................	--	--	--	--	--	--
Chlorophyll *b*, micrograms per liter..........................	--	--	--	--	--	--

samples from Long Lake

calcium carbonate; N, nitrogen; P, phosphorus.
unless otherwise indicated; <, less than]

July 26, 1976	Aug. 23, 1976	Sep. 29, 1976	Nov. 4, 1976	Feb. 9, 1977	Apr. 3, 1977	Aug. 11, 1977	May 11, 1978	Aug. 22, 1978	Mean
5.0	5.0	4.3	4.0	3.6	7.8	5.4	6.0	5.5	5.1
28.0	24.5	14.5	3.5	2.0	4.0	20.5	15.0	23.0	--
235	210	226	290	745	185	226	250	190	253
125	120	147	186	448	141	134	--	--	160
--	--	--	--	--	--	--	--	--	19
--	--	--	--	--	--	--	--	--	12
0.7	0.5	0.5	3.6	--	2.1	1.0	2.5	1.3	1.6
9.5	9.7	8.7	8.0	7.5	8.2	9.0	8.4	9.4	--
10.3	8.6	11.2	10.9	0.2	13.1	8.0	10.3	8.4	8.6
134	105	112	84	2	102	51	104	100	87
--	--	--	--	--	--	--	--	--	77
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	---	--
--	--	--	--	--	--	--	--	--	3.0
--	--	--	--	--	--	--	--	--	0.09
--	--	--	--	--	--	--	--	--	.09
--	--	--	--	--	--	--	--	--	5100
--	--	--	--	--	--	--	--	--	.03
--	--	--	--	--	--	--	--	--	--
.18	.18	.23	0.06	.11	0.16	0.15	--	--	.14
--	--	--	--	--	--	--	--	--	131
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--	--	--	--	--	--	--	--	--	--
23	24	24	24	62	15	27	26	16	21
--	--	--	--	--	--	--	--	--	13
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42	8.4	69	2.6	--	3.5	--	--	--	21
24	2.5	18	.9	--	2.5	--	--	--	8.0

SUMMARY AND CONCLUSIONS

Alimagnet, Farquar, and Long Lakes in Apple Valley, Minn., were sampled for various water-quality constituents in order to establish baseline water quality and to detect long-term trends. The monitoring was done from 1973 to 1979. It is suggested that lakes be resampled every 3 to 5 years for further assessment of long-term trends.

None of the lakes has a natural surface-water inlet or outlet, but all have one or more storm-sewer inlets and artificial outlets. Alimagnet and Farquar Lakes have lift-station outlets and Long Lake discharges by culvert to Farquar Lake.

Development within the watershed is virtually all residential. The Long Lake watershed is the most developed. The Alimagnet Lake watershed was sampled longer because it has recently been developing at a faster rate.

Chloride concentrations were usually higher than 10 milligrams per liter with the highest concentrations occurring during the drought of 1976-77. After that period, chloride concentrations receded to near predrought levels. Dissolved solids reacted similarly to chloride, but with greater fluctuations.

Dissolved oxygen and pH were governed mainly by biological activity. In the summer months, saturation of dissolved oxygen was commonly above 100 percent and pH values were equal to or higher than 9.0. In the winter dissolved-oxygen concentrations and pH dropped because of decomposition processes occurring under the ice. In February 1977, dissolved-oxygen concentrations were less than 0.5 milligram per liter in all three lakes, and probably caused fish to die.

Nutrient concentrations were determined, and correlations observed between transparency versus pH and total phosphorus. Nutrient fluctuations did not indicate any seasonal or long-term trends. The ratios between mean total nitrogen and mean total phosphorus ranged from 22:1 to 26:1 indicating that nitrogen was probably not limiting in any of the lakes.

Trophic state indices determined from total-phosphorus concentrations and Secchi-disk transparency data show that each lake was eutrophic. There was no evidence of long-term trends; however, increased TSI's during the drought of 1976-77 occurred in Alimagnet Lake.

Blue-green algae were dominant in 88 percent of the samples. The three most frequently occurring genera were Aphanizomenon, Anacystis, and Oscillatoria.

Runoff from two storms in 1978 was sampled at a storm-sewer inlet to Alimagnet Lake. Total loads were determined for various heavy metals and nutrients. Most of the metals were carried on the sediment. Chromium, copper, nickel, and zinc had the highest concentrations with lead being moderately high compared to other metals. Arsenic and cadmium were relatively low.

Total-phosphorus concentration for the September 12, 1978, storm was 1.7 milligrams per liter. Based on this concentration, 29 pounds during the 5.2-hour sampling period and over 73 pounds of phosphorus during the estimated 44-hour runoff period were discharged to Alimagnet Lake.

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