HYDROLOGY OF THE GOAT LAKE WATERSHED,

SNOHOMISH COUNTY, WASHINGTON, 1982-87

By N.P. Dion, J.C. Ebbert, J.E. Poole, and B.S. Peck

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 88-4235

Tacoma, Washington
1989

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233.6	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
tons (short)	0.8929	tons (long)

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

degree Fahrenheit (°F) °C = 5/9 (°F-32) degree Celsius (°C)

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ABSTRACT

The Goat Lake watershed in Snohomish County, Washington, functions as an "experimental watershed" for long-term studies to determine the effects of acidic precipitation on water resources. The watershed is located in a wilderness area of the Cascade Range and is downwind of an industrial and urban area that produces chemical compounds found in acidic precipitation. The lake is considered sensitive to acidic inputs from atmospheric deposition and streamflow.

A long-term program of data collection that included continuous monitoring of the discharge of the outlet stream and sampling the outflow water for chemical analysis 10-12 times per year began at Goat Lake in October 1982. The discharge of the principal lake inlet also is measured and sampled, when conditions permit.

The mean annual discharge of the Goat Lake outflow is 35 cubic feet per second; precipitation on the watershed is calculated to be about 170 inches per year. The inflow to Goat Lake is sufficient to replace the entire contents of the lake basin on an average every 21.5 days, or 17 times per year.

Water in Goat Lake and in the inlet and outlet is of low ionic strength and of calcium-bicarbonate type. The lake, although considered oligotrophic, is sufficiently deep to stratify thermally, and summer dissolved-oxygen concentrations in the hypolimnion are depressed.

Limited sampling of the lake biota indicated that the phytoplankton and zooplankton populations were dominated by diatoms and rotifers, respectively. The lake presently (1989) has resident populations of rainbow and eastern brook trout.

Even though alkalinity and specific conductance at Goat Lake are in the range considered sensitive to acidic inputs, the pH of water in the lake has consistently ranged from 6.1 to 7.2, indicating that the lake is not acidified at this time.

INTRODUCTION

Scientists in Scandinavia, eastern Europe, and the northeastern United States have shown that highly acidic precipitation can have several deleterious effects on the quality of water and biota in rivers and lakes (Evans and others, 1981; Haines, 1981; Tollan, 1980). In particular, acidic precipitation is thought to be responsible for: (1) a reduction in the diversity of aquatic organisms, especially those with calcareous shells; (2) a decrease in primary productivity and oxygen production; (3) an increase in the abundance of sphagnum moss and bottom-dwelling filamentous algae; (4) a reduction in the abundance of decomposing bacteria; (5) impairment of fish growth and reproduction; and (6) mortality of fish, primarily by gill damage. Acidic precipitation probably is also responsible for the impairment of the growth of selected sensitive plants, leaching of toxic heavy metals (such as copper, lead, and aluminum) from soils to surface waters, and damage to buildings and statuary made of limestone or marble.

Acidic precipitation is caused by the combining of moisture in the atmosphere with sulfur dioxide and nitrogen oxides to form mild solutions of sulfuric acid and nitric acid, respectively. Sulfur dioxide and the nitrogen oxides are emitted primarily from industrial and electric-utility smokestacks, automobiles, and natural sources such as volcanoes (Electric Power Research Institute, 1983; U.S. Environmental Protection Agency, 1980).

Some lakes and streams are affected more than others, either because they receive more acidic precipitation or because their waters and (or) watersheds lack the buffering capacity needed to counteract acidity. Reduced buffering capacity is typical of lakes (1) at high altitude and in headwater areas; (2) located in regions of relatively insoluble rock, such as granite; (3) having small drainage basins relative to lake size; (4) surrounded by terrain having thin soils, which is typical of glaciated environments; and (5) having relatively clear, dilute waters.

In 1982, the Goat Lake watershed in Snohomish County, Wash., (see fig. 1) was selected by the U.S. Geological Survey as an "experimental watershed" to function as the focus for long-term studies on the effects of acidic precipitation on water resources. The reasons for selecting Goat Lake for long-term monitoring and research were as follows: (1) the lake contains dilute water and is highly sensitive to acidic inputs from atmospheric deposition and streamflow (Omernik and Griffith, 1986); (2) during the rainy (winter) season, the lake is downwind of the Tacoma-Seattle-Everett industrial and urban area that emits sulfurous and nitrous oxides that combine with atmospheric moisture to produce acidic precipitation; (3) the lake is situated at high altitude and receives more than 150 inches of precipitation per year, much of it as snow; (4) the lake is in a wilderness area, where land-use changes are unlikely; (5) the lake is relatively inaccessible and is unlikely to be substantially affected by man; and (6) the lake is typical of numerous lakes in the Cascade Range.

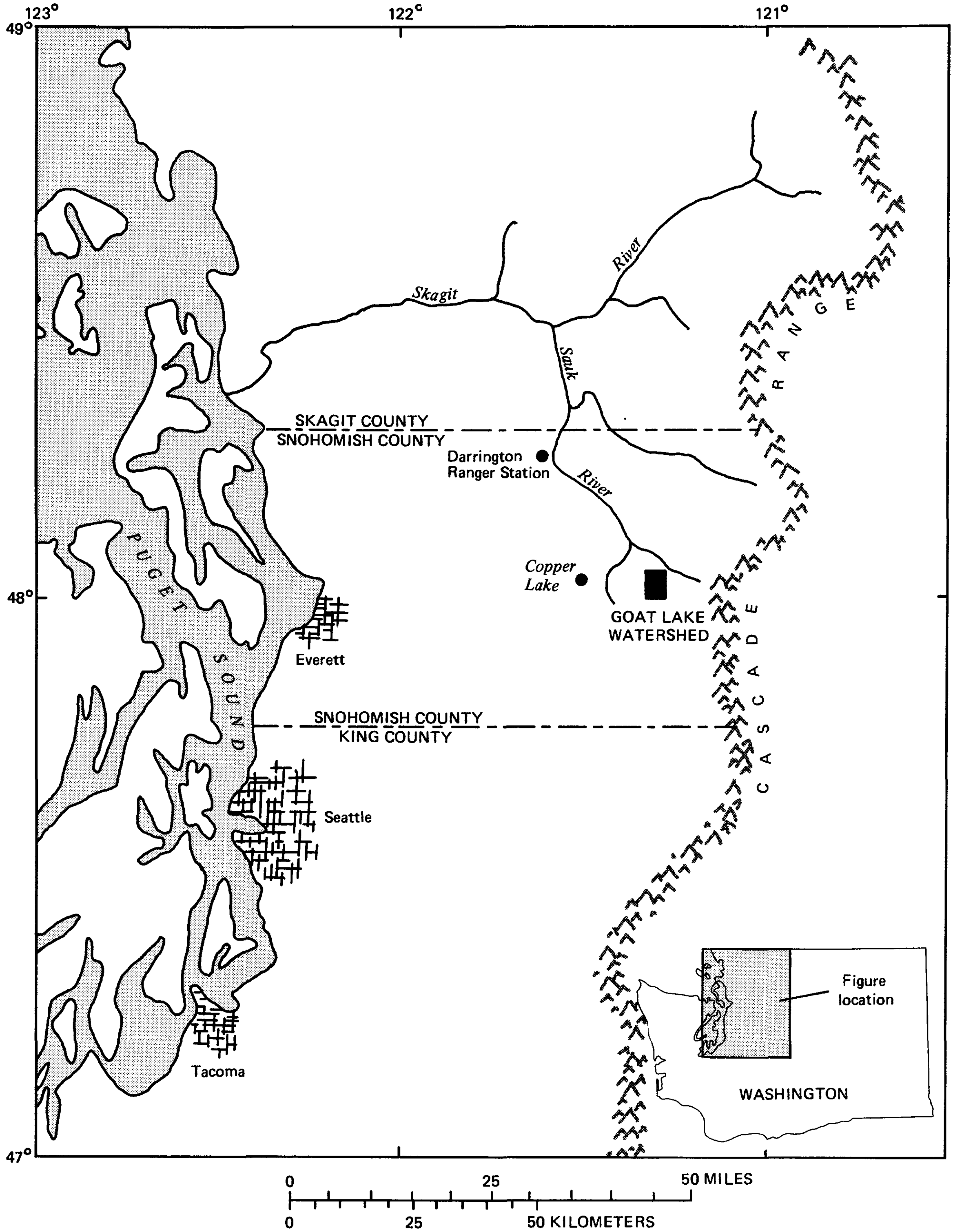

Figure 1.--Location of the Goat Lake watershed.

The objective of the ongoing data-collection project at Goat Lake is to collect sufficient discharge and water-quality data for the inflow and outflow to enable a general assessment of the water-quality characteristics of the streams, especially with respect to those constituents that are sensitive to, or indicative of, acidic precipitation. The purposes of this report are to (1) describe the lake and its watershed, (2) present the discharge, chemical, and biological data collected from 1982 to 1987 in the Goat Lake watershed, (3) present an analysis of the data, and (4) identify data needs and additional studies in the watershed.

DESCRIPTION OF THE STUDY AREA

The Watershed

The Goat Lake watershed comprises 3.0 square miles (1,940 acres) in southeastern Snohomish County, Wash., about 45 miles east of Everett, Wash. (see fig. 1). Being in the North Cascades Range, the watershed is characterized by steep slopes, sharp ridges, and high peaks (fig. 2). Although the lake altitude is only about 3,160 feet above sea level, the drainage divide of the watershed is locally above 7,000 feet (fig. 3). The watershed is in the headwaters of the Sauk River, which is tributary to the Skagit River (see fig. 1). The lake and its watershed are depicted on the Sloan Peak and Blanca Lake topographic quadrangles of the U.S. Geological Survey (scale 1:24,000).

The climate of the Goat Lake watershed is typical of the North Cascades as described by Rasmussen and Tangborn (1976). Moist Pacific marine air sweeps generally eastward over the coastal and urban Puget Sound area. Most of the precipitation falls during the winter period when winds are from the southwest.

According to the rainfall map of Washington (U.S. Weather Bureau, 1965), the watershed is likely to receive about 150 inches of precipitation per year. Annual precipitation during the period 1909-18 at a station just outside the watershed and at an altitude of 2,900 feet (exact location unknown) ranged from 84 to 108 inches and averaged about 95 inches (Phillips, 1966). The largest average monthly precipitation (12.64 inches) occurred in January and the smallest (2.21 inches) in August. Rasmussen and Tangborn (1976) reported that the variability of precipitation for North Cascades catchments during the summer period is nearly twice that of the winter period. Snowfall during the 1909-18 period generally occurred from October through May and totaled about 261 inches per season. In December 1985, a precipitation sampler was installed about three-quarters of a mile northwest of the lake outlet at an altitude of about 2,800 feet (see fig. 2) as part of a precipitation-sampling program in cooperation with the State of Washington Department of Ecology (WDOE). During the first full year of operation, the instrument collected about 90 inches of precipitation. The instrument has proven adequate for measuring quantity of precipitation, but inadequate for measuring quality.

In a typical year, the surface of Goat Lake freezes completely. Small glaciers or perennial snow occur on the south slope of the watershed near the drainage divide (see fig. 2).

The bedrock geology of the watershed (fig. 4) was described by Heath (1971). He indicated that most of the Goat Lake watershed is underlain by quartz diorite, an intrusive igneous rock that mineralogically resembles granite, and by pelitic schist, a medium-grade metamorphic rock that somewhat resembles slate. The basin also contains smaller amounts of volcanic breccia, black phyllite, and biotite schist. A large fan of coarse colluvium occurs at the southern (inlet) end of the lake; smaller amounts occur near the lake outlet. The soils in the watershed are characteristically thin, and in the steeper parts of the basin there is no soil at all.

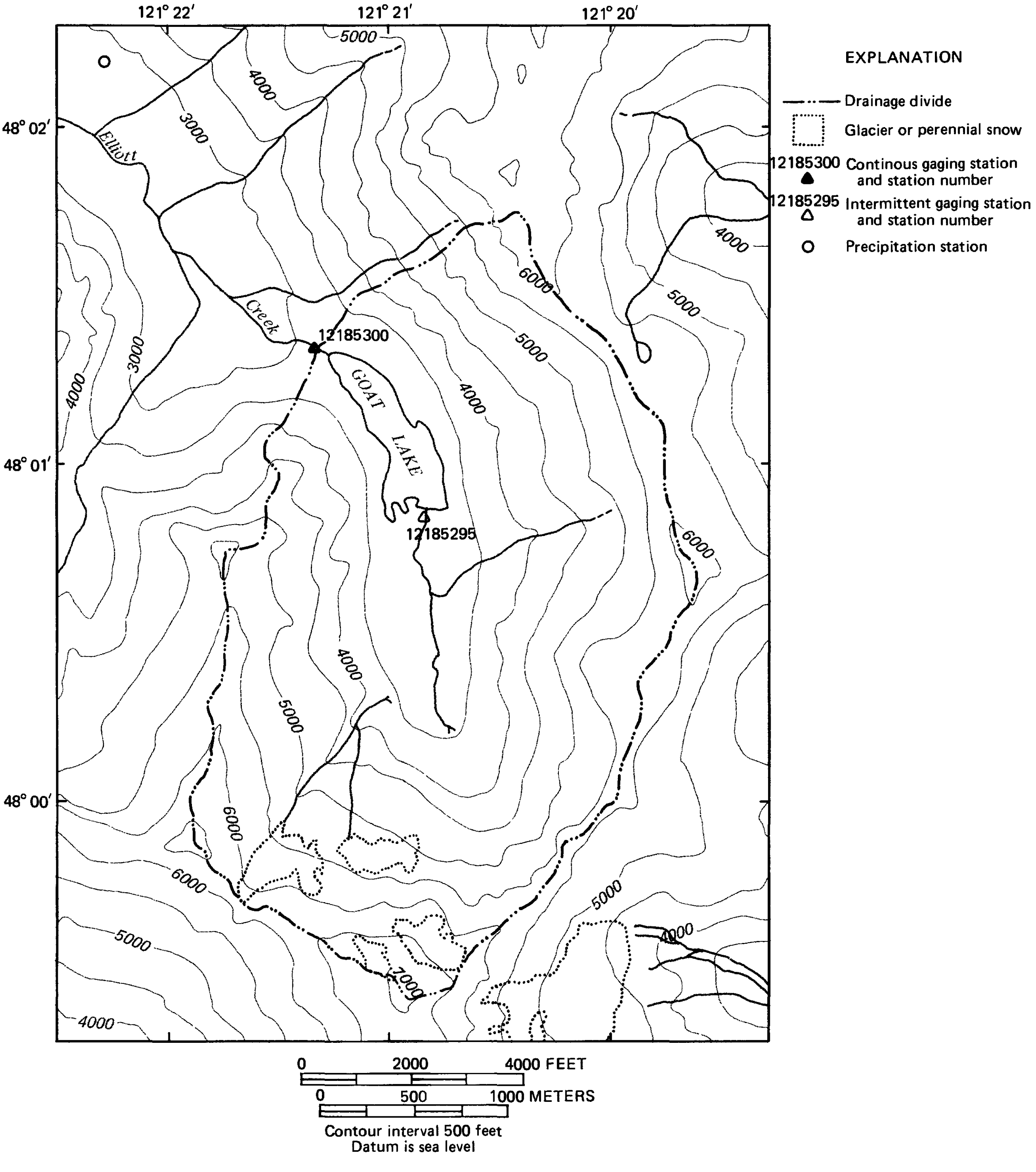

Figure 2.--Extent and drainage of Goat Lake watershed, and location of data-collection sites. See figure 1 for location of watershed.

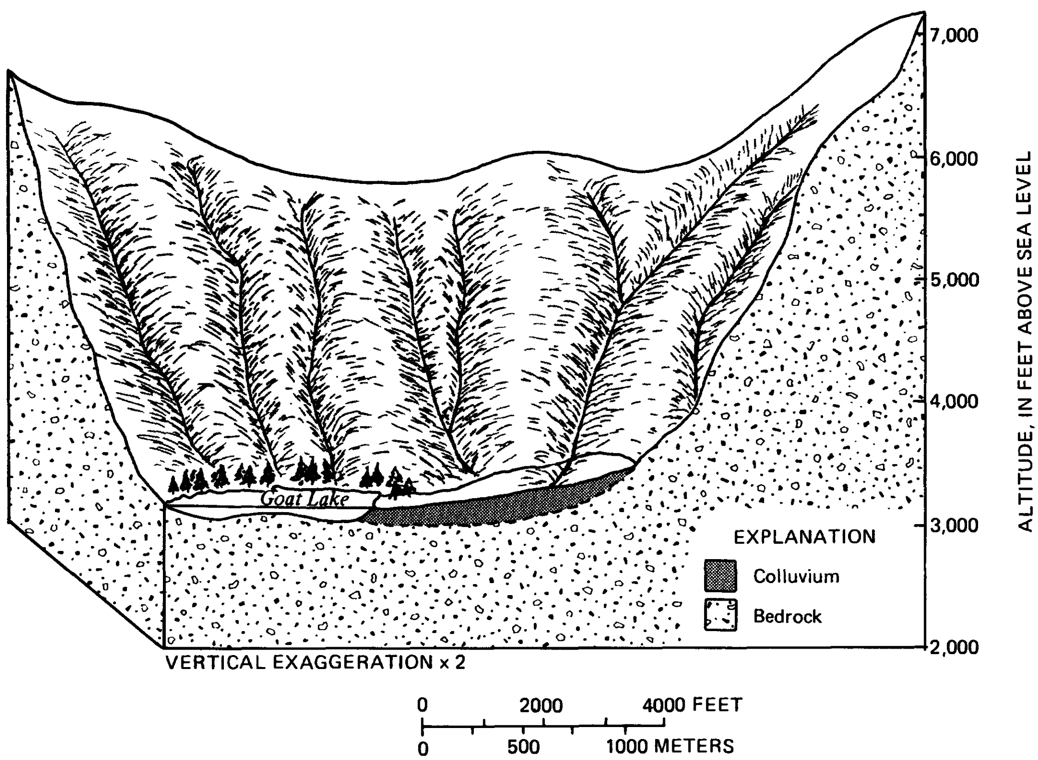

Figure 3.--Schematic diagram of topography of the Goat Lake watershed.

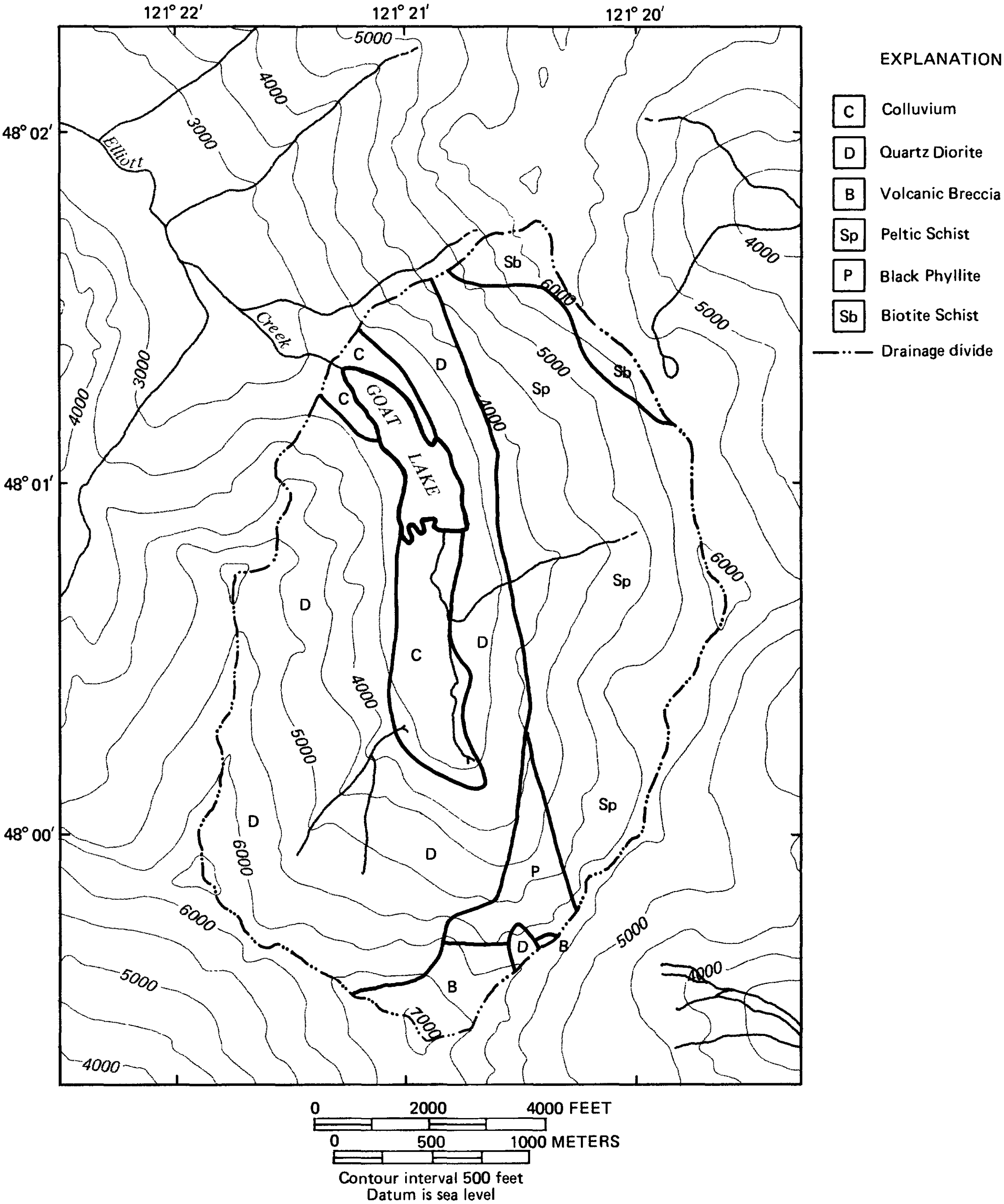

Figure 4.--Geology of the Goat Lake watershed (modified from Heath, 1971).

The Goat Lake watershed was the focus of intensive mining activity from the turn of the century until the 1930's. According to Broughton (1942) and Huntting (1956), at least nine mines were operated in the basin for the recovery of silver and gold and, to a lesser extent, copper and lead. The only current use of the watershed is recreational; a small, unimproved campground is located near the lake outlet. The campground and lake are accessible by trail, which connects with a road about 5 miles away.

The vegetation within the Goat Lake watershed is limited by the lake's position near tree line and by the distribution of soil. The part of the watershed at lower altitude is covered by coniferous forest, and the part at high altitude has little or no vegetation (fig. 5). The remainder of the watershed is covered by shrubs. The vegetation pattern depicted in figure 5 is based on a visual examination of topographic quadrangles and aerial photographs.

Goat Lake

The basin of Goat Lake is most likely a cirque of glacial origin. As shown in the bathymetric map (fig. 6), the basin appears to have been divided almost in half by a rock slide originating to the northeast. Goat Lake has an area of 56 acres and a volume of approximately 1,500 acre-feet (Bortleson and others, 1976). It has a maximum depth of 82 feet and a mean depth of 27 feet.

The principal inlet to the lake is a well-defined, perennial stream that flows from the colluvium at the south end of the lake (see fig. 2). The lake also receives inflow from smaller intermittent streams, ground water, and precipitation on the lake. Outflow from the lake is by a perennial stream that flows over a bedrock lip and then falls precipitously to form the headwaters of Elliott Creek. The outflow gaging station is located on the bedrock lip between the lake and the falls. The stage of Goat Lake is controlled partly by manmade wooden flashboards that probably date back to the days of mining activity. Numerous large floating logs have accumulated on the lake surface directly behind the flashboards, but the logs do not appear to restrict drainage from the lake.

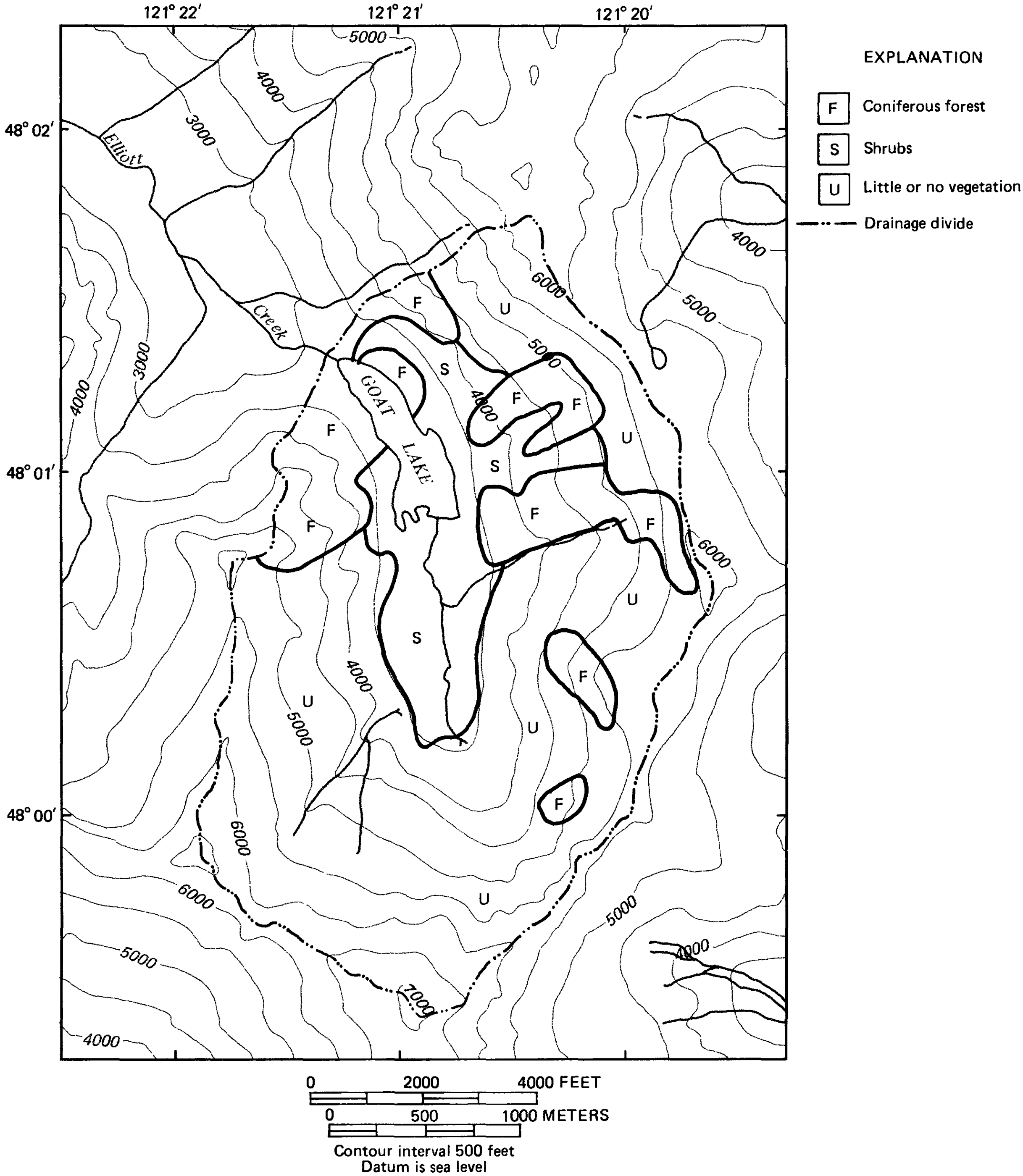

Figure 5.--Generalized vegetation cover of the Goat Lake watershed.

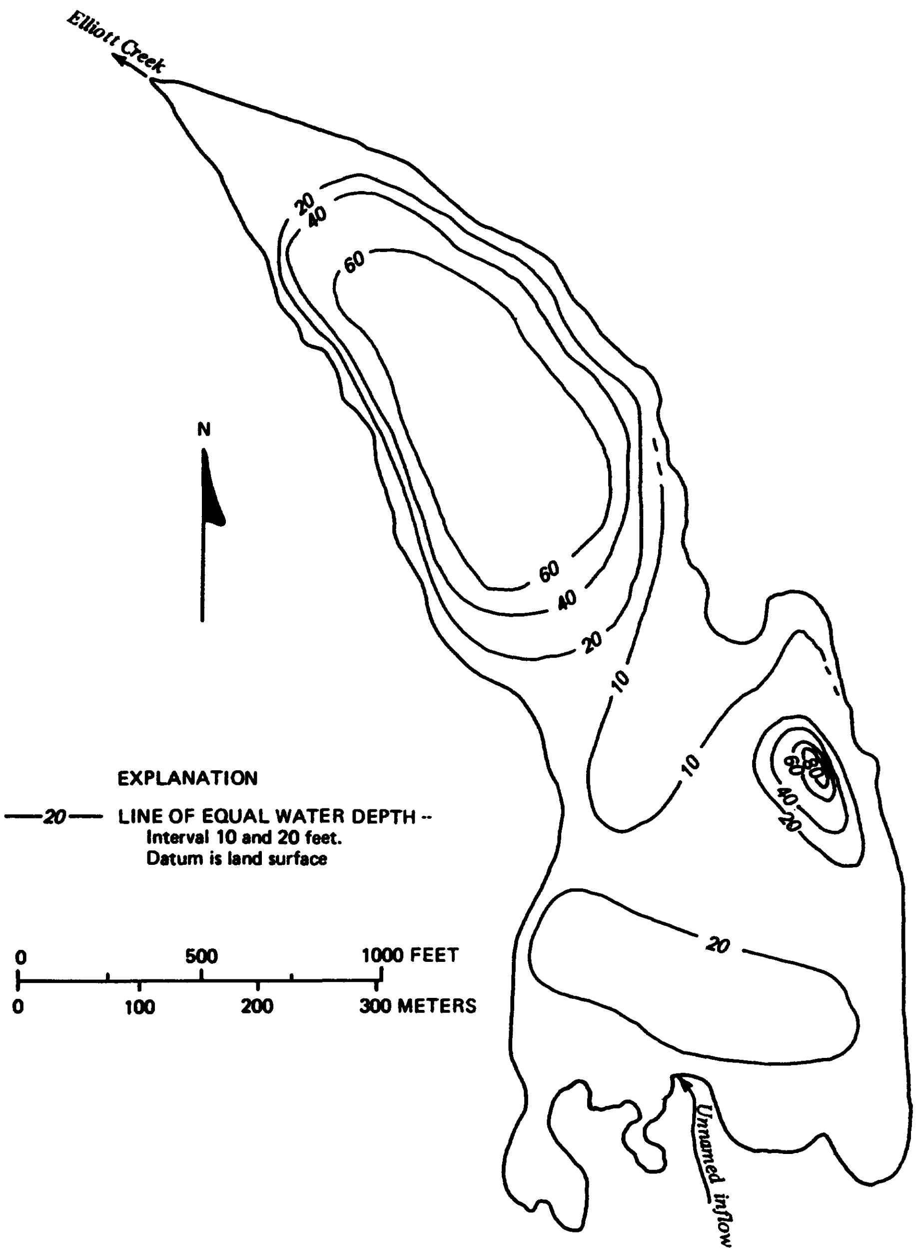

Figure 6.--Bathymetric map of Goat Lake (modified from Bortleson and others, 1976).

METHODS OF DATA COLLECTION

A long-term U.S. Geological Survey program of data collection began at Goat Lake in October 1982. At that time, a continuous discharge measuring station was constructed on the outlet by Geological Survey personnel, with the approval of the U.S. Forest Service. An automated stage recorder was housed in a 6-by-6-foot cedar-log shelter for protection against the elements and vandals. In spring 1984, a wet/dry precipitation sampler and a tipping-bucket precipitation gage were installed in the headwaters of the lake. The discharge and precipitation stations were visited and serviced about 12 times per year by helicopter. However, in July 1984 Congress and the President authorized creation of the Henry M. Jackson Wilderness Area, which encompassed the entire Goat Lake watershed. Because the new Wilderness status precluded visits by motorized vehicles and aircraft, the precipitation instruments were removed from the watershed and field personnel began hiking to the lake instead of flying.

Since July 1984, data collection has consisted of making a discharge measurement of the outlet stream (Elliott Creek), servicing the discharge recorder, and taking a water sample from the outlet stream for chemical analysis 10-12 times per year. When conditions permit, usually during the summer months, a measurement of water discharge is made and a water-quality sample is collected at the principal lake inlet (see fig. 2). On three occasions, water samples were collected from Goat Lake proper. In December 1985, a nonrecording precipitation gage was installed about 1.3 miles northwest of the lake outlet at an altitude of about 2,800 feet (see fig. 2). This precipitation gage is serviced each time the lake is visited.

Within about 2 hours of collection of water-quality samples, measurements of the specific conductance and pH are made. Since March 1986, part of the water sample is titrated incrementally for alkalinity within 2 hours, using a microburet graduated in 0.01 milliliter divisions.

The remainder of the sample is apportioned and preserved for later laboratory analyses of major ions, nutrients, dissolved organic carbon, aluminum, iron, manganese, silica, alkalinity, and acidity. The samples for major ion and nutrient analyses are filtered using a 0.45-micrometer filter; samples for aluminum, iron, and manganese are filtered using a 0.10-micrometer filter. The smaller pore size is preferable for metals because a significant fraction of the suspended metals in dilute waters may pass through a 0.45-micrometer filter. Samples for dissolved organic carbon analysis are filtered through a 0.45-micrometer silver filter housed in a stainless-steel holder. All other preservation methodology follows standard Geological Survey procedures (Skougstad and others, 1979; U.S. Geological Survey, 1977). Analyses for major ions, nutrients, dissolved organic carbon, and metals are done at the Geological Survey Laboratory in Arvada, Colo., using methods described in the two above references.

Samples of the phytoplankton and zooplankton in Goat Lake were collected in August 1982 and October 1985. Samples for phytoplankton density represent whole-water aliquots composited vertically across the photic zone, as approximated by the water layer bounded by the lake surface and the maximum depth of Secchi-disk transparency. Samples for zooplankton density were collected with a 153-micrometer cup screen and silk net in a single vertical tow through a 60-foot water column. Algae and zooplankton were identified to species when possible by Applied Biology, Inc., Decatur, Georgia.[1]

[1]Use of the firm name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Lake Inflow and Outflow Discharge

Discharge data have been collected on a continuous basis at the lake outlet, and intermittently at the principal lake inlet, since October 1982. A hydrograph of the monthly mean discharge of the Goat Lake outflow stream and of intermittent discharge measurements made of the inflow stream is shown in figure 7. For the 4-year period 1983-86, the mean annual discharge at the outlet was 33.3 ft^3/s. Precipitation during this period, as measured at the nearby Darrington Ranger Station (altitude 545 feet above sea level and 19 miles to the northwest, fig. 1), was 5.7 percent below long-term normal. By adjusting the observed outflow discharge by the same percentage as the precipitation deficit, the long-term mean annual discharge is estimated to be 35 ft^3/s.

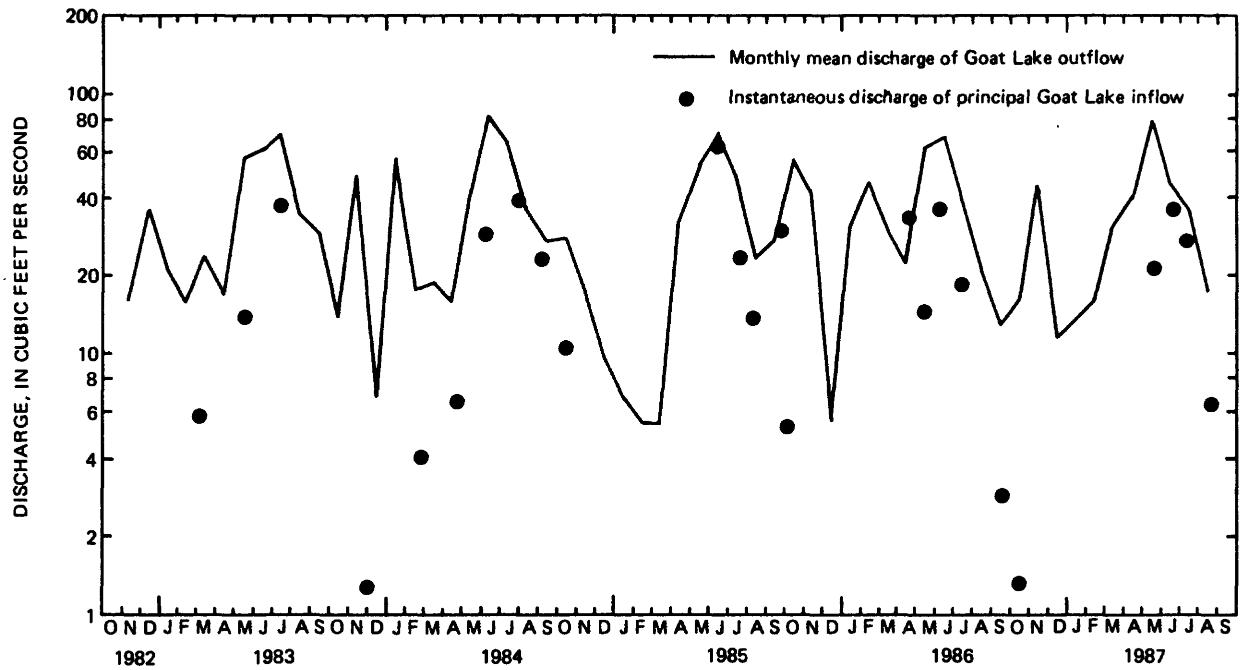

Figure 7.--Hydrograph of Goat Lake inflow and outflow streams.

A regression analysis of outflow and inflow discharge data indicates that, at the mean value of 35 ft^3/s, the inflow rate is 21 ft^3/s, or 60 percent of the outflow. The difference between the inflow and outflow rates represents ground-water inflow, surface-water inflow from the smaller, ungaged tributaries, and precipitation directly on the lake. The percentage of outflow accounted for by the principal, gaged inflow tributary ranges from 28 percent (at low flow) to 68 percent (at high flow).

Estimates of annual basin runoff and precipitation were made by using the average outflow rate of 35 ft^3/s. When applied to the 1,940-acre drainage basin, the outflow discharge value produced a mean annual runoff of 158 inches. If a conservative estimate of 12 inches of evapotranspiration is added to the runoff value (158 inches), the watershed likely receives an average annual precipitation amount of about 170 inches. This quantity would vary geographically within the watershed because of varying conditions of physiography, exposure, and altitude. The calculated values of runoff and precipitation compare favorably with those reported by Dethier (1979) for the Copper Lake basin, about 9 miles west of Goat Lake (see fig. 1) and at a similar altitude. By assuming a lake volume of 1,500 acre-feet (Bortleson and others, 1976), a total inflow to the lake of 35 ft^3/s (equal to the measured outflow) is sufficient to replace the entire contents of the lake on the average every 21.5 days, or 17 times per year.

Chemical Quality

Water samples for chemical analysis have been collected at the lake inlet and outlet (tables 6 and 7, respectively, at the end of the report) at regular intervals since October 1982. Samples were collected from the lake in August 1973, August 1982, and October 1985 (see table 8, at the end of the report).

Physical and Chemical Characteristics

Low-ionic-strength, calcium-bicarbonate type waters were observed at all sampling stations. Specific-conductance values in Goat Lake and its inlet and outlet are generally less than 20 $\mu S/cm$ (microsiemens per centimeter). The average concentrations (arithmetic mean) of major ions in the inflow, outflow, and the lake are summarized in table 1, and those concentrations are compared with waters in other North Cascades lakes above an altitude of 2,500 feet for which chemical data exist. Although Goat Lake is lower in altitude than most other lakes studied, its water is chemically similar to that of other North Cascades lakes. Goat Lake, therefore, can be considered chemically typical of North Cascades lakes above 2,500 feet altitude.

The chemical loads leaving the Goat Lake watershed (table 2) were calculated by using mean values of outflow discharge and concentrations of the principal chemical constituents in the outflow. It should be noted that some of the total load undoubtedly originates in precipitation that falls into the lake and not in the watershed proper.

A time-series analysis of chemical concentrations in the outflow of Goat Lake revealed no apparent trend for most constituents. Although a trend in alkalinity was suspected, it was found to be the result of erroneous data. Because of its potential significance with respect to acidification, this apparent trend was analyzed in detail as part of this study. A description of that analysis is presented in the next section of the report.

The lake is sufficiently deep to stratify thermally. When visited in August 1973, the lake was stratified (see fig. 8) and dissolved-oxygen concentrations in the hypolimnion (the bottom water layer) were depressed but not completely depleted. Whether the hypolimnion ever becomes depleted in oxygen (anaerobic) is unknown. When the lake was visited in October 1985, the

Table 1.--Physical and chemical data for Goat Lake and its inflow and outflow, and data collected in previous studies for North Cascades lakes above an altitude of 2,500 feet

[Physical and chemical values presented for multiple lakes or samples are means; mg/L, milligrams per liter; μS/cm, microsiemen per centimeter; --, data not available]

Reference or study	Time of data collection	Number of lakes or (samples)	Lake altitude (feet)	Lake area (acres)	Secchi-disc transparency (feet)	Chemical constituent: Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Alkalinity[1] (as $CaCO_3$) (mg/L)	Specific conductance (μS/cm)
Goat Lake inflow (this study)[2]	Jan. 1983-July 1987	(33)	--	--	--	1.79	0.45	0.39	0.22	0.30	1.36	5.4	15
Goat Lake outflow (this study)[2]	Jan. 1983-July 1987	(47)	--	--	--	1.95	.45	.50	.30	.37	1.40	6.1	16
Goat Lake (this study)[3]	Oct. 8, 1985	1	3,160	56	17	1.93	.46	.46	.30	.25	1.48	6.1	16
Landers and others (1987)	fall 1985	68	4,990	10	25	1.99	.20	.44	.18	.17	.84	5.7	15
Loranger (1986)	summer 1984	6	4,780	33	--	2.96	.18	.34	.14	.25	1.80	7.2	--
Brakke (1984)	summer-fall 1983	33	4,510	31	--	4.98	.21	.45	.39	.55	2.08	10	30
Welch and Spyridakis (1984)	summer-fall 1983	[4]12	--	50	--	.87	.12	.47	.37	1.06	.98	1.9	9.0
Logan and others (1982)	summer 1981	29	4,410	74	--	1.17	--	--	--	--	--	2.9	8.2
Welch and Chamberlain (1981)	summer 1980	19	4,020	74	--	1.35	--	--	--	--	2.35	2.0	--
Dethier and others (1979)	summer 1978	44	5,580	31	50	[5]1.70	[5].28	[5].92	[5].28	[5].53	[5]1.03	[5]4.8	[6]11
Bortleson and others (1976); Dion and others (1976)	summer 1974	74	4,010	41	[7]44	--	--	--	--	--	--	--	18

[1] Commonly referred to as ANC (or acid neutralizing capacity) in other reports.
[2] Samples collected and analyzed by U.S. Geological Survey.
[3] Lake sampled by U.S. Geological Survey; water analysis by U.S. Environmental Protection Agency.
[4] Total of 20 water samples collected and analyzed.
[5] Mean of 15 samples.
[6] Mean of 21 samples.
[7] Mean of 63 samples

upper water layer was only 3 °C (Celsius) warmer than the bottom water layer. Because of the climate of the watershed, Goat Lake is probably dimictic; that is, vertical mixing (turnover) probably occurs twice per year, in spring and autumn.

Table 2.--Annual chemical loads from the Goat Lake watershed

Chemical constituent	Mean concentration[1] in outflow (milligrams per liter)	Load[2] Tons	Load[2] Pounds per acre
Calcium	1.95	67	69
Magnesium	.45	16	16
Sodium	.50	17	18
Potassium	.30	10	11
Chloride	.37	13	13
Sulfate	1.40	48	50
Nitrate	.35	12	13
Alkalinity (as $CaCO_3$)	6.1	210	220

[1] Based on approximately 47 analyses for the period January 1983 to July 1987; see table 1.

[2] Based on a mean annual discharge of 35 cubic feet per second.

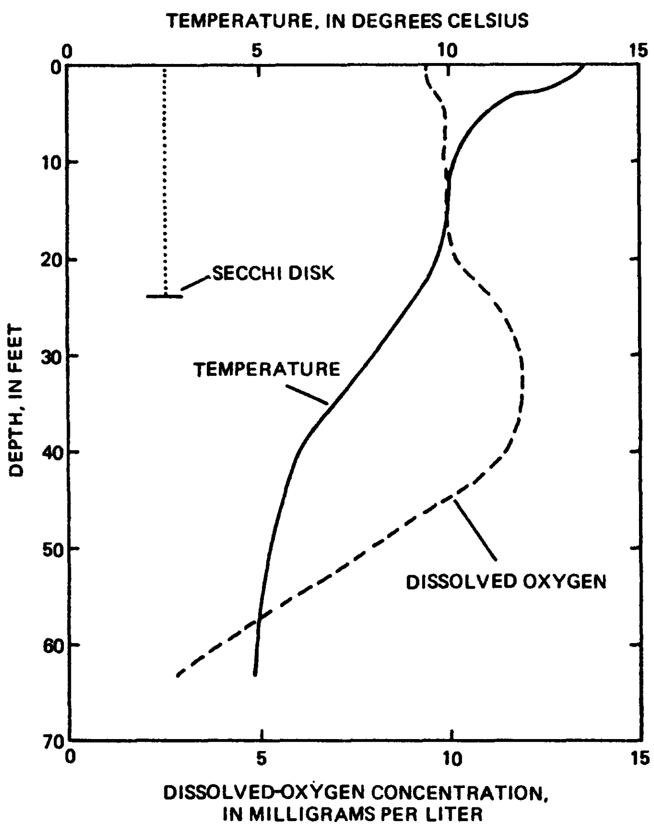

Figure 8.--Vertical profiles of temperature and dissolved-oxygen concentration for Goat Lake, August 1, 1973.

Nutrient (nitrogen and phosphorus) concentrations in the lake are relatively low and primary productivity most likely is limited by phosphorus. Water transparency in the lake, as measured by Secchi disk, has ranged from 17 to 29 feet. On the basis of values of nutrient concentrations and water transparency, which indicate that biological productivity in the lake is low, Sumioka and Dion (1985) assigned the lake a trophic level of oligotrophic.

The effects of residence time of water in Goat Lake on its chemistry was minimal; the chemical composition of the outflow water is essentially identical to the composition of the inflow and lake waters (table 1). However, outflow water tends to be somewhat warmer than inflow water as a result of residence time in the lake. The amount of warming varies seasonally and ranges from essentially zero in winter to as much as 7 °C in summer.

Concentrations of aluminum, an element known to be detrimental to the well-being of fish, are generally less than 10 μg/L (micrograms per liter) in Goat Lake. As such, aluminum most likely poses no threat to the lake's fishery.

Evaluation of the Alkalinity Data

A time-series plot of the alkalinities of the outflow samples from Goat Lake indicates a trend of generally decreasing values for the period from March 1983 to July 1985 (fig. 9). Because a concomitant change in the concentrations of other ions did not occur during the same period, it was necessary to evaluate the alkalinity data to determine the validity of the observed trend.

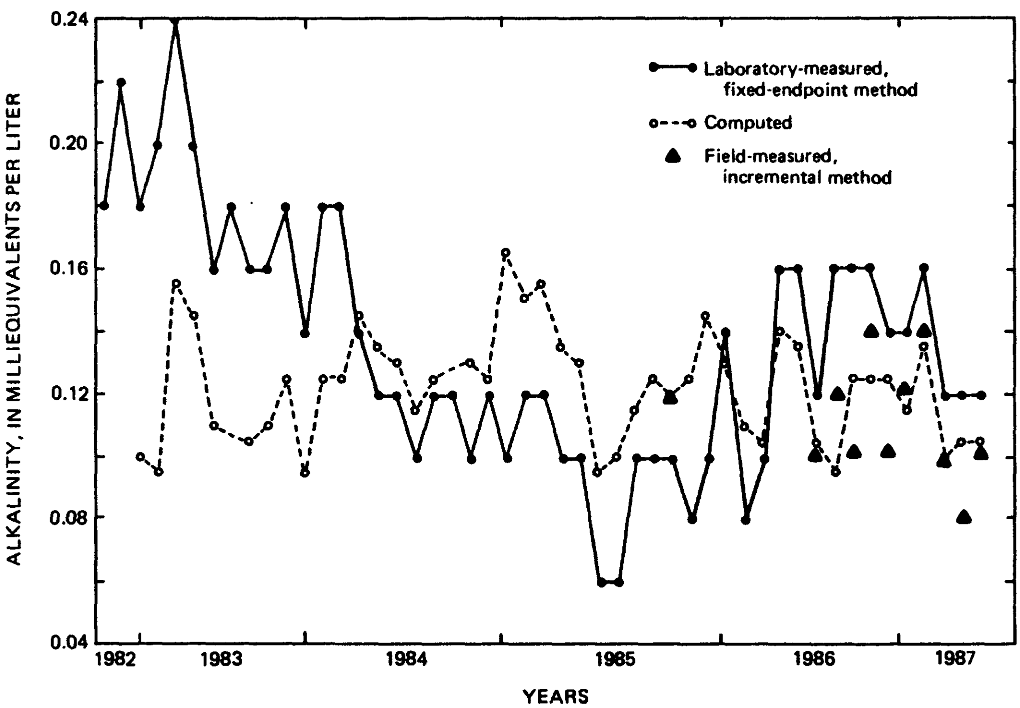

Figure 9.--Measured and computed alkalinities of Goat Lake outflow.

Prior to September 1987, the alkalinities of all samples collected at the inlet and outlet of Goat Lake were measured in the laboratory using a fixed-endpoint potentiometric titration to pH 4.5 (Fishman and Friedman, 1985). Beginning in March 1986, field measurements of alkalinity were begun in addition to the laboratory measurements (tables 6 and 7, end of report). For the field measurements, the endpoint of a potentiometric titration is determined by plotting the change in pH divided by the change in titrant volume against total titrant volume, and choosing the maximum in this curve as the endpoint (Barnes, 1964). This method is referred to as an incremental titration, and usually gives a more accurate measurement of the alkalinity of low ionic-strength water, such as that of Goat Lake, than the fixed-endpoint method (Yurewicz, 1981). Beginning in September 1987, an incremental titration is also being used for the laboratory determination of alkalinities of Goat Lake samples. The use of the fixed-endpoint titration to measure alkalinity during the initial phase of data collection at Goat Lake leaves open the possibility that the trend of decreasing alkalinity values observed in water collected at the outlet might not be real, but instead, an artifact of the analytical method used.

One method of examining the validity of the laboratory-measured alkalinities is to compare them with computed alkalinities. By assuming electroneutrality, alkalinity can be computed as,

Alkalinity = (sum of the concentrations of cations)
- (sum of the concentrations of anions not contributing to alkalinity),

where all concentrations are expressed in milliequivalents per liter. The alkalinities computed from the equation, as well as the field and laboratory determinations for Goat Lake samples, are total alkalinities. Total alkalinity also is referred to as acid-neutralizing capacity (Stumm and Morgan, 1981). The total alkalinity is the equivalent sum of all bases that can be titrated with a strong acid to an equivalence point of approximately pH 4.5. If the solution contains no protolytic systems other than that of aqueous carbonate, the total alkalinity is equivalent to the carbonate alkalinity. For practical purposes, only the concentrations of the major cations and anions need to be used in the equation. For this study, the constituents used to compute alkalinities included the cations calcium, magnesium, sodium, potassium, ammonium, aluminum, iron, and manganese; and the anions chloride, bromide, fluoride, sulfate, and nitrate. Unlike the laboratory-measured values, the computed alkalinities do not show a trend of generally decreasing values between March 1983 and July 1985 (fig. 9). A comparison of laboratory-measured and computed alkalinities of Goat Lake inflow (not shown in fig. 9) yielded similar results.

Differences between computed and measured alkalinities could also result from errors in the determination of cation or anion concentrations, or the presence of ions for which determinations were not made. If the concentrations of all ions in aqueous solution are accurately determined, then the difference between the sum of cation milliequivalents and the sum of anion milliequivalents (the ion-balance residual) should equal zero. A correlation between the residual, which was usually not equal to zero, and the concentration of a major ion provides a means to detect a persistent error in the analysis of that ion.

Pearson product-moment correlation coefficients between the ion-balance residual and the concentrations of all ionic species plus alkalinity were computed for the outlet. The correlation coefficient between the residual and alkalinity is -0.90, and the probability that the two variables are uncorrelated is less than 3 percent. Correlation coefficients between the residual and all other ionic species are less than 0.35. The correlation between the residual and alkalinity indicates a persistent error in the analysis of alkalinity.

The relation between measured alkalinity and ion-balance residual of analyses of the outflow is shown in figure 10. The slope and standard error of the slope of the regression line are -0.94 and 0.07, respectively. The slope is not significantly different from -1 (one cannot reject the hypothesis that the slope equals -1 even at a confidence level as low as 70 percent), indicating that the error in alkalinity can account for all of the residual.

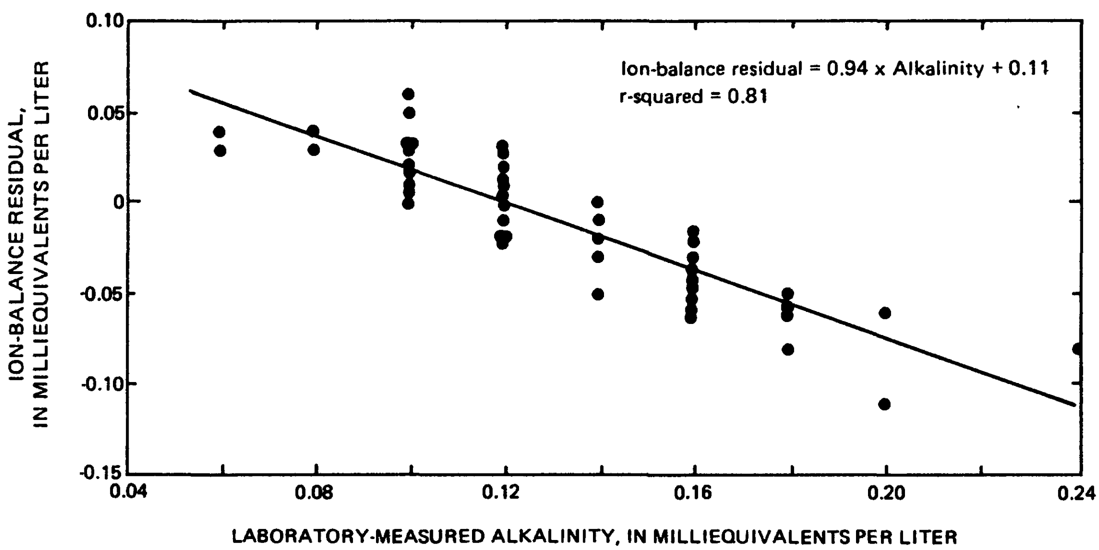

Figure 10.--Relation between measured alkalinity and the ion-balance residual of analyses of Goat Lake outflow.

The use of the incremental titration method to determine the alkalinity of Goat Lake samples has resulted in generally lower absolute values of ion-balance residual for chemical analyses. This indicates that, where available, the incremental determinations (or computed alkalinities) should be used in preference to the fixed-endpoint determinations for interpreting the chemistry of Goat Lake.

Biota

Samples of the phytoplankton and zooplankton in Goat Lake were taken in August 1982 and October 1985; the results of those analyses are presented in tables 3 and 4. The phytoplankton population was dominated by diatoms on both sample dates (table 3); no blue-green algae were observed in either sample, and densities of green algae were small. On August 6, 1982, a time of thermal stratification, the phytoplankton density was relatively small and the sample was dominated by the diatom Synedra radians. The water on that date was clear and the transparency, as measured by Secchi disk, was 29 feet. On October 8, 1985, shortly after autumnal mixing (turnover), the phytoplankton density was relatively large. The predominant alga was once again a diatom, Cyclotella glomerata. The water at this time was slightly turbid, most likely because of the increased algal density, and transparency was only 17 feet. The greater algal density in October may have been due to the transport of nutrients from the hypolimnion up into the photic zone at the time of turnover. The lake has few emersed, floating, or submersed aquatic macrophytes.

The total zooplankton densities on both sampling dates were almost identical (table 4). The predominant organism in each sample was Asplancha sp., a relatively large, predatory rotifer. No cladocerans were identified in either sample.

The biological data collected to date at Goat Lake are inadequate to permit a determination of how typical the lake is biologically. Because phytoplankton and zooplankton populations exhibit marked seasonal changes, two samples spaced more than 3 years apart are not adequate for a biological description or assessment of Goat Lake. In addition, the dearth of biological information for North Cascades lakes in general prevents a determination of how typical Goat Lake is biologically.

Goat lake is periodically stocked with game fish. The stocking history of the lake is as follows:

July 12, 1951	15,000	rainbow trout
August 12, 1955	6,000	eastern brook trout
July 11, 1961	2,500	Do.
September 19, 1966	5,000	cutthroat trout

Stocking in 1961 and 1966 was by airplane. The success of the stocking program is unclear, although campers familiar with the lake report that it currently has resident populations of rainbow and eastern brook trout.

Lake Sensitivity and Acidification

Even though there are numerous methods of assessing the sensitivity of water bodies to acidic inputs, most researchers now agree that pH, specific conductance, and alkalinity are the most useful indicators of sensitivity. The threshold levels below which a water can be considered sensitive, as proposed by the Ontario Ministry of the Environment (1979) and A.P. Zimmerman and H.H. Harvey (University of Toronto, written commun., 1979) are presented in table 5. Also included in the table are the ranges of the three constituents as measured in a water-sampling program of the Goat Lake watershed that began in October 1982. As shown in table 5, water from Goat Lake is considered sensitive with respect to specific conductance and alkalinity. For the most part, however, pH values were above the threshold level of 6.0 to 6.3.

Table 3.--Phytoplankton densities in Goat Lake

[--, none detected]

	Organisms per milliliter	
	August 6, 1982[1]	October 8, 1985[2]
Chlorophyta		
Cosmarium regnesi	6	--
Cosmarium sp.	--	5
Dictyosphaerium pulchellum	--	5
Oocystis parva	--	5
Chrysophyta		
Achnanthes minutissima	11	11
Cyclotella glomerata	30	1,026
Cyclotella kutzingiana	--	11
Cyclotella pseudostelligera	7	--
Cyclotella stelligera	--	93
Cyclotella sp.	1	--
Cymbella minuta	--	5
Dinobryn bavaricum	--	88
Fragillaria brevistriata	1	--
Fragillaria construens	--	11
Gomphonema sp.	3	--
Navicula sp.	3	5
Nitzschia sp.	1	--
Synedra amphicephala	31	22
Synedra incisa	1	--
Synedra radians	155	93
Synedra rumpens	31	27
Pseudokephrion sp.	--	411
Unidentified	--	55
Pyrrophyta		
Gymnodinium sp.	3	--
Unidentified phytoflagellates	50	82
Total	334	1,955

1 Secchi-disk depth = 29 feet.

2 Secchi-disk depth = 17 feet.

Table 4.--Zooplankton densities in Goat Lake

[--, none detected]

	Organisms per cubic meter	
	August 6, 1982	October 8, 1985
Rotifers		
Asplancha sp.	4,570	8,240
Filinia longiseta	2,710	190
Kellicotia longiseta	40	--
Keratella cochlearis	--	120
Keratella quadrata	40	--
Unidentified	40	--
Copepods, calanoid		
Limnocalanus macrurus	310	2,240
Unidentifed	150	150
Copepods, cyclopoid		
Orthocyclops modestus	540	190
Unidentified	2,900	150
Copepods, nauplii	1,660	40
Total	12,960	11,320

Table 5.--Comparison of pH, specific conductance, and alkalinity ranges of Goat Lake outflow with commonly referenced sensitivity thresholds of acidification

	pH (units)	Specific conductance (microsiemens per centimeter)	Alkalinity (milligrams per liter)	Reference
Sensitivity threshold	6.0	35	15	Ontario Ministry of Environment (1979)
Do.	6.3	30	15	A.P. Zimmerman and H.H. Harvey (University of Toronto, written commun., 1979)
Goat Lake outflow (January 1983-July 1987)	[1]6.1-7.2	[1]11-21	[2]4.6-8.1	This study

[1] Values measured in field.

[2] Calculated values.

Many factors contribute to Goat Lake's sensitivity. The drainage basin of the lake is underlain, for the most part, by weathering-resistant rock that has a thin soil cover. In addition, the lake's drainage basin is small compared to the size of the lake; precipitation in the basin either falls directly on the lake or travels only a short distance, in limited contact with surface rocks and soil on its way to the lake. Even water that flows through the coarse colluvium at the south end of the lake before seeping into the lake does so at a relatively fast rate, thereby minimizing the amount of time the water is in contact with rock surfaces. Lake water therefore is of low ionic strength, and chronically acidic precipitation could result in the eventual acidification of the lake.

Even though Goat Lake is sensitive to acidification, it is not necessarily acidified. The primary indicator of acidification is pH, but the pH level at which acidification occurs varies greatly. The natural dissolution of carbon dioxide in precipitation can result in a pH value as low as 5.6 (Galloway and others, 1976). For this reason, many researchers consider a lake with a pH of 5.5 and lower to be acidified. The pH of Goat Lake outflow to date has ranged from 6.1 to 7.2 (see table 7, end of report), suggesting that the lake is not acidified at this time. High altitude pristine lakes with pH values in this range may be common (Welch and Chamberlain, 1981).

Because acidic precipitation neutralizes the alkalinity in a lake, alkalinity concentrations that are low, or are known to have decreased with time, may indicate acidification. A temporal decrease of alkalinity often occurs before a substantial decline in pH is observed (Henriksen, 1980). As discussed previously, the false trend observed in the alkalinity concentrations of Goat Lake outflow are most likely an artifact of the analytical procedure. At this time, the Goat Lake alkalinity data alone do not indicate that the lake is acidified.

Henriksen (1980) proposed a method of assessing the degree of lake acidification when historical water-quality data are lacking. If one assumes that the original alkalinity of a lake water is proportional to the sum of the original calcium and magnesium concentrations, and that the calcium and magnesium concentrations are not affected by the acidification process, then the amount of calcium and magnesium currently present in the lake water is a reasonable measure of the lake's original alkalinity. Although acidification of the lake will reduce the alkalinity, the calcium and magnesium concentrations should remain essentially constant. This reasoning also assumes that calcium and magnesium are the major cations, ammonium and nitrate levels are negligible, and that there is no input of chloride from the watershed (Lung, 1984; Reuss and others, 1986).

A plot of calculated alkalinity as related to the sum of calcium and magnesium for Goat Lake outflow is shown in figure 11 for the period June 1982-July 1987. All concentrations were converted from units of milligrams per liter to microequivalents per liter for direct elemental comparison, and the concentrations of calcium and magnesium were adjusted (reduced) to remove the contribution of ions from sea spray. The sea spray fraction was subtracted under the assumption that all chloride in the Goat Lake outflow is of seawater origin and that other ions are proportional to the ionic composition of seawater (Kramer and Tessier, 1982; Wright, 1983).

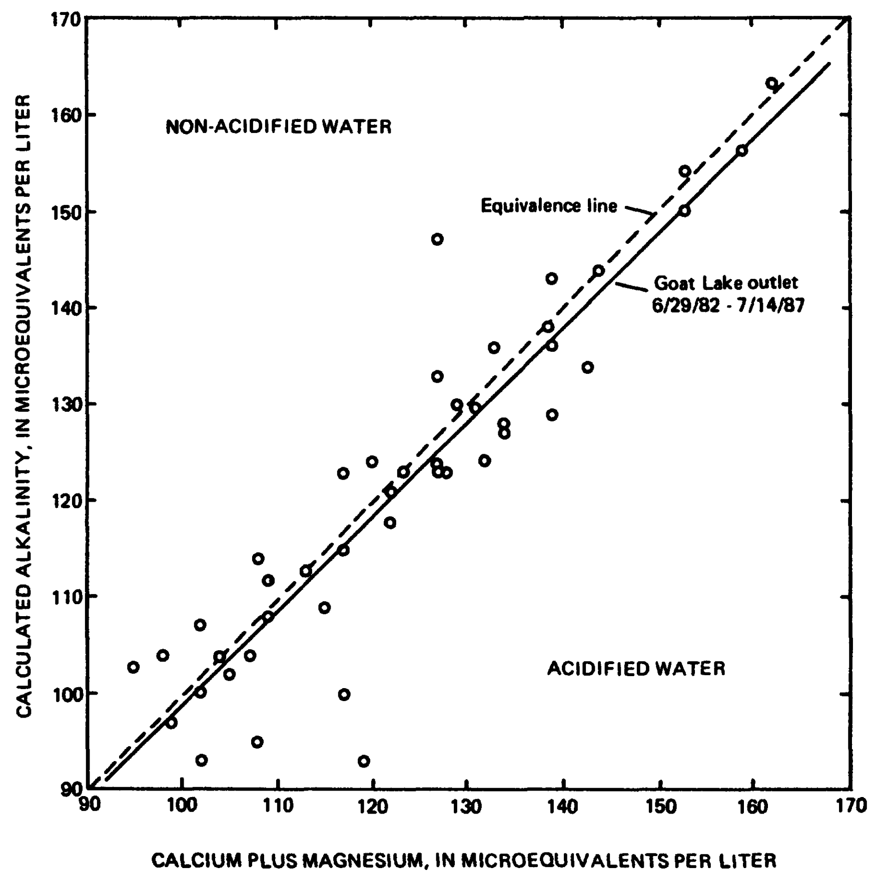

Figure 11.--Relation between alkalinity and the sum of calcium plus magnesium for the outflow of Goat Lake as an indicaiton of lake acidification (modified from Henriksen, 1980). (Calcium and magnesium concentrations have been adjusted for sea spray contribution.)

The dashed (equivalence) line in figure 11 represents a pristine, unacidified condition where alkalinity is equal to the sum of calcium and magnesium or, alternatively, where present-day alkalinity is equal to pre-acidification alkalinity. Points that plot beneath the equivalence line are interpreted as evidence of acidification, or the loss of alkalinity due to the input of acid. Individual analyses of Goat Lake outflow for the period June 1982-July 1987 plot both above and below the equivalence line, an indication that the lake is sensitive to acidic inputs. A least-square (solid) line of regression through the individual points falls below the equivalence line, suggesting that, on balance, Goat Lake is slightly acidified. However, because the deviation from the equivalence line is small and the scatter of data points about the regression line is large, a conclusion that Goat Lake is acidified may not be justified at this time.

ADDITIONAL STUDY NEEDS

Goat Lake is typical of numerous acid-sensitive lakes in the Washington Cascades; the lake and its watershed, therefore, offer the researcher an excellent environment in which to study the physical, chemical, and biological aspects of alpine hydrology in general, and the occurrence and effects of acidic precipitation on the water and biota of the lake.

Even though it has been shown that the Goat Lake watershed is likely to be receiving acidic precipitation and that the lake is sensitive to same, it is unknown if, in fact, the precipitation on the watershed at present is acidic. This determination, therefore, is the first priority of additional studies, and could be a part of a broader study to characterize the precipitation chemistry of the Goat Lake watershed. The precipitation sampler installed near the watershed in cooperation with WDOE has proved adequate for precipitation quantity, but inadequate for precipitation quality.

Some needed additional studies include:

* A more detailed description of the watershed, to include geologic materials, soils, vegetation, and climate.
* A water budget of the watershed and lake, including a more detailed calculation of lake water-renewal (hydraulic residence) time.
* A chemical budget of the watershed and lake, based on precipitation and outflow chemistry.
* Systematic monitoring, description, and interpretation of the physical, chemical, and biological processes operating within Goat Lake.

SUMMARY

In 1982, the Goat Lake watershed was selected as an "experimental watershed" to function as the focus for long-term studies to determine the effects of acidic precipitation on water resources. The mean annual discharge of the lake outflow is 35 ft^3/s; precipitation on the watershed is calculated to be about 170 inches per year. The inflow to Goat Lake is sufficient to replace the entire contents of the lake basin on an average every 21.5 days, or 17 times per year.

Water in Goat Lake and in the inlet and outlet is of low ionic strength and of calcium-bicarbonate type. A comparison of available chemical data indicates that Goat Lake is chemically typical of North Cascades lakes above 2,500 feet altitude. Although considered oligotrophic, the lake is sufficiently deep to stratify thermally, and summer dissolved-oxygen concentrations in the hypolimnion are depressed. Even though alkalinity and specific conductance at Goat Lake are in the range considered sensitive to acidic inputs, the pH of the lake has consistently ranged from 6.1 to 7.2, indicating that the lake is not acidified at this time.

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Table 6.--Chemical data for Goat Lake inflow

[μS/cm, microsiemens per centimeter at 25 °C; deg C, degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; ft^3/s, cubic feet per second; --, no data; <, less than]

Date	Time	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Water-Quality Data, Water Year October 1981 to September 1982								
Aug								
06...	1300	17	6.00	16.0	1.9	0.41	0.5	0.3

Date	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Aluminum, dissolved (μg/L as Al)	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)
AUG							
06...	<5.0	0.3	<0.1	2.2	<10	<3	3

Table 6.--Chemical data for Goat Lake inflow--continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Temper-ature (deg C)	Acidity (mg/L as H)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)
Water-Quality Data, Water Year October 1982 to September 1983												
JAN												
12...	0755	--	16	6.40	3.5	--	1.8	0.4	0.4	0.3	9.0	1.3
MAR												
07...	1105	5.8	18	6.10	3.5	--	1.9	0.44	0.4	0.3	9.0	2.8
31...	1035	--	18	6.40	3.5	--	2.0	0.51	0.4	0.3	11	1.3
APR												
21...	0945	--	13	6.80	3.0	0.6	2.0	0.5	0.4	0.31	9.0	1.3
MAY												
19...	1000	14	17	6.60	3.5	0.1	1.9	0.47	0.4	0.23	10	1.4
JUN												
09...	1100	--	16	6.50	4.0	<0.1	1.6	0.47	0.3	0.2	8.0	1.2
29...	0950	--	15	6.60	4.5	<0.1	1.6	0.39	0.3	0.17	8.0	1.3
JUL												
19...	1030	38	14	6.40	5.0	<0.1	1.5	0.35	0.5	0.15	8.0	1.3
AUG												
24...	1155	--	14	6.30	6.0	<0.1	1.7	0.42	0.3	0.31	8.0	1.5

Date	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Phos-phorus, ortho, dis-solved (mg/L as P)	Alum-inum, dis-solved (µg/L as Al)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Carbon, organic dis-solved (mg/L as C)
JAN											
12...	0.52	0.04	<0.05	2.4	0.13	--	<0.10	<10	3	3	--
MAR											
07...	0.36	0.01	0.05	2.7	0.03	--	<0.10	10	20	10	--
31...	0.37	0.01	<0.05	3.4	0.12	--	<0.10	<10	12	10	--
APR											
21...	0.37	0.03	<0.05	2.3	--	--	<0.10	<10	5	6	--
MAY											
19...	0.31	0.01	0.03	2.3	--	--	<0.10	<10	18	3	--
JUN											
09...	0.21	<0.01	<0.05	1.9	--	0.019	<0.10	<10	15	<1	0.5
29...	--	<0.01	<0.05	1.8	--	0.055	<0.10	20	5	2	0.6
JUL											
19...	0.16	<0.01	<0.05	1.8	--	0.056	<0.10	<10	12	2	0.3
AUG											
24...	0.13	<0.01	<0.05	2.1	--	0.033	<0.10	20	7	2	0.5

Table 6.--Chemical data for Goat Lake inflow--continued

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)
					Water-Quality Data, Water Year October 1983 to September 1984							
DEC												
02...	0840	1.3	17	6.80	2.5	--	2.1	0.47	0.4	0.31	9.0	1.5
JAN												
26...	0850	--	16	6.60	3.0	<0.1	1.7	0.38	0.5	0.24	7.0	1.2
FEB												
23...	1005	4.1	14	5.60	3.0	<0.1	1.8	0.49	0.4	0.21	8.0	1.3
MAR												
19...	0855	--	15	6.10	4.0	<0.1	1.9	0.49	0.4	0.26	8.0	1.2
APR												
23...	0840	6.5	15	6.00	2.5	<0.1	1.9	0.47	0.4	0.22	6.0	1.3
MAY												
22...	0835	--	13	6.00	2.5	<0.1	1.9	0.5	0.4	0.21	5.0	1.5
JUN												
12...	1000	29	14	6.80	3.0	<0.1	1.9	0.5	0.3	0.21	5.0	1.4
AUG												
02...	1115	40	12	6.10	5.5	<0.1	1.6	0.4	0.3	0.19	5.0	1.2
SEP												
10...	1105	23	15	6.20	6.0	<0.1	1.8	0.4	0.4	0.2	10	1.3

Date	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)
DEC											
02...	0.28	<0.01	<0.05	2.9	0.09	0.046	<0.10	10	9	6	1.0
JAN											
26...	0.46	<0.01	<0.05	2.8	0.14	0.025	<0.006	<10	12	11	0.4
FEB											
23...	0.36	0.06	<0.01	2.7	0.11	0.005	<0.01	<10	8	6	1.5
MAR											
19...	0.4	0.04	<0.01	2.7	0.11	0.029	<0.01	<10	27	9	0.4
APR											
23...	0.44	<0.01	<0.01	2.4	0.10	0.09	<0.01	10	12	5	0.7
MAY											
22...	0.41	0.02	<0.01	2.3	0.15	0.026	<0.01	10	14	3	0.7
JUN											
12...	0.35	<0.01	<0.01	2.1	0.11	0.057	<0.01	<10	5	2	0.5
AUG											
02...	0.2	0.01	<0.01	1.8	0.03	0.033	<0.018	10	3	4	0.8
SEP											
10...	0.2	<0.01	<0.01	2.1	--	0.028	<0.01	<10	3	4	0.4

Table 6.--Chemical data for Goat Lake inflow--continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Temper-ature (deg C)	Acidity (mg/L as H)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)
Water-Quality Data, Water Year October 1984 to September 1985												
OCT												
16...	1105	10	14	6.30	5.0	<0.1	1.9	0.5	0.4	0.21	5.0	1.4
JUN												
20...	0820	66	13	6.30	3.5	<0.1	1.8	0.4	0.4	0.2	3.0	1.2
JUL												
25...	1127	24	12	6.90	5.5	<0.1	1.5	0.4	0.3	0.12	3.0	1.3
AUG												
13...	1150	14	12	6.90	6.0	<0.1	1.7	0.41	0.4	0.19	4.0	1.4
SEP												
17...	0930	30	13	6.80	5.5	<0.1	2.0	0.44	0.4	0.17	4.0	1.3

Date	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Phos-phorus, ortho, dis-solved (mg/L as P)	Alum-inum, dis-solved (µg/L as Al)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Carbon, organic dis-solved (mg/L as C)
OCT											
16...	0.3	0.04	0.01	2.5	<0.01	<0.005	<0.002	20	9	6	0.9
JUN											
20...	0.33	0.02	<0.01	2.3	0.05	0.03	0.002	<10	21	5	1.1
JUL											
25...	0.21	0.04	<0.01	1.9	0.03	0.009	0.001	<10	5	1	2.1
AUG											
13...	0.23	0.02	<0.01	2.2	0.04	0.003	0.003	10	8	2	2.2
SEP											
17...	0.21	0.02	<0.01	2.0	0.06	0.026	0.001	<10	4	3	0.6

Table 6.--Chemical data for Goat Lake inflow--continued

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Alkalinity, carbonate IT-fld (mg/L-$CaCO_3$)
				Water-Quality Data, Water Year October 1985 to September 1986								
OCT												
08...	1030	5.4	14	6.90	4.0	<0.1	1.9	0.5	0.4	0.19	5.0	6.0
APR												
22...	0955	34	17	6.80	2.5	<0.1	1.9	0.5	0.4	0.17	7.0	--
MAY												
15...	1010	15	15	6.90	3.0	<0.1	1.8	0.42	0.4	0.19	6.0	--
JUN												
10...	1020	37	15	6.90	4.0	<0.1	1.5	0.44	0.4	0.19	6.0	5.0
JUL												
15...	1015	19	14	6.80	4.5	<0.1	1.7	0.48	0.5	0.24	7.0	5.0
SEP												
17...	0900	3.0	15	6.90	5.0	<0.1	1.8	0.49	0.4	0.3	7.0	5.0

Date	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)
OCT												
08...	1.4	0.28	0.04	<0.01	2.5	0.03	0.033	<0.01	20	100	7	0.4
APR												
22...	1.3	0.33	0.02	0.01	2.1	0.13	0.031	<0.01	<10	<3	<1	1.1
MAY												
15...	1.4	0.35	0.03	0.01	2.5	0.11	0.01	<0.01	<10	13	<1	0.9
JUN												
10...	1.2	0.23	0.01	<0.01	1.8	0.06	0.008	<0.01	<10	7	<1	0.9
JUL												
15...	1.2	0.3	0.02	<0.01	2.2	0.04	0.012	<0.01	<10	9	<1	0.7
SEP												
17...	1.4	0.21	0.01	<0.01	1.9	<0.01	<0.002	<0.01	<10	3	6	0.7

Table 6.--Chemical data for Goat Lake inflow--continued

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Alkalinity, carbonate IT-fld (mg/L-$CaCO_3$)
					Water-Quality Data, Water Year October 1986 to September 1987							
OCT												
15...	0910	1.4	18	6.90	4.0	<0.1	1.9	0.54	0.4	0.24	8.0	7.0
MAY												
19...	1015	22	15	7.20	--	<0.1	1.9	0.36	0.3	0.17	7.0	5.0
JUN												
22...	0905	37	14	6.80	4.5	<0.1	1.6	0.43	0.4	0.23	6.0	6.0
JUL												
14...	0900	28	13	6.80	5.0	<0.1	1.6	0.38	0.4	0.28	6.0	5.0

Date	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)
OCT												
15...	1.5	0.22	0.02	<0.01	2.8	0.05	0.004	<0.01	<10	4	5	1.2
MAY												
19...	1.3	0.35	0.02	<0.01	2.4	0.06	0.014	<0.01	<10	11	4	0.6
JUN												
22...	1.1	0.26	0.01	<0.01	2.1	0.04	0.034	<0.01	<10	4	2	4.7
JUL												
14...	1.2	0.24	0.03	<0.01	2.0	0.03	0.04	<0.01	20	15	4	1.4

Table 7.--Chemical data for Goat Lake outflow

[µS/cm, microsiemens per centimeter at 25 °C; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; ft^3/s, cubic feet per second; --, no data; <, less than]

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Water-Quality Data, Water Year October 1981 to September 1982									
JUN									
29...	1250	--	15	6.00	9.0	2.3	0.36	0.5	0.4
AUG									
06...	1245	36	16	6.00	10.5	1.7	0.33	0.5	0.4

Date	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
JUN									
29...	9.0	<5.0	0.3	<0.1	2.4	<0.01	10	13	7
AUG									
06...	11	<5.0	0.3	<0.1	2.0	--	10	<3	5

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Temper-ature (deg C)	Acidity (mg/L as H)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)
					Water-Quality Data, Water Year October 1982 to September 1983							
JAN												
12...	0845	40	17	6.30	2.5	--	1.9	0.4	0.5	0.4	9.0	1.5
MAR												
07...	1145	20	16	6.30	3.0	--	1.9	0.43	0.6	0.4	10	1.4
31...	1040	12	21	6.20	4.0	--	2.5	0.6	0.6	0.4	12	1.8
APR												
21...	0955	22	17	7.00	8.0	1.0	2.3	0.52	0.7	0.41	10	1.6
JUN												
09...	0950	79	16	6.50	7.5	<0.1	1.7	0.41	0.4	0.28	8.0	1.3
29...	1005	54	16	6.60	9.0	<0.1	1.7	0.36	0.4	0.23	9.0	1.4
JUL												
19...	1125	60	14	6.40	9.0	<0.1	1.5	0.36	0.5	0.21	8.0	1.2
AUG												
24...	1205	25	13	6.40	12.5	<0.1	1.7	0.42	0.4	0.32	8.0	1.5

Date	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Phos-phorus, ortho, dis-solved (mg/L as P)	Alum-inum, dis-solved (µg/L as Al)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Carbon, organic dis-solved (mg/L as C)
JAN											
12...	0.63	0.05	<0.05	3.1	0.14	--	<0.10	10	12	22	--
MAR											
07...	1.1	0.13	<0.05	3.3	0.11	--	<0.10	10	10	30	--
31...	0.39	0.01	<0.05	5.5	0.11	--	<0.10	<10	6	28	--
APR											
21...	0.4	0.03	0.09	3.6	--	--	<0.10	<10	10	20	--
JUN											
09...	0.24	0.01	<0.05	2.5	--	0.022	<0.10	<10	<3	3	0.5
29...	--	0.05	<0.05	2.4	--	0.036	<0.10	<10	14	6	0.4
JUL											
19...	0.17	<0.01	<0.05	2.2	--	0.053	<0.10	10	6	4	0.4
AUG											
24...	0.15	<0.01	<0.05	2.1	--	0.041	<0.10	10	11	8	0.5

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)
Water-Quality Data, Water Year October 1983 to September 1984												
DEC												
02...	0905	8.5	16	6.90	1.5	<0.1	2.0	0.47	0.5	0.4	9.0	1.5
JAN												
26...	0903	49	17	6.50	2.0	<0.1	1.6	0.38	0.4	0.34	7.0	1.3
FEB												
23...	1030	15	15	5.80	2.5	<0.1	2.0	0.47	0.5	0.33	9.0	1.3
MAR												
19...	0905	14	16	6.00	2.5	<0.1	2.1	0.48	0.5	0.37	9.0	1.5
APR												
23...	0910	19	18	6.00	4.0	<0.1	2.2	0.5	0.5	0.33	7.0	1.5
MAY												
22...	0850	58	17	5.90	5.5	<0.1	2.2	0.5	0.5	0.34	6.0	1.5
JUN												
12...	1055	47	15	6.70	7.5	<0.1	2.0	0.5	0.5	0.29	6.0	1.4
AUG												
02...	1245	64	11	6.20	11.0	<0.1	1.7	0.4	0.5	0.31	5.0	1.2
SEP												
10...	1230	42	15	6.20	10.0	<0.1	1.9	0.4	0.5	0.26	6.0	1.4

Date	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (μg/L as Al)	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)	Carbon, organic dissolved (mg/L as C)
DEC											
02...	0.37	0.01	<0.05	3.1	0.09	0.003	<0.10	<10	15	9	1.3
JAN											
26...	0.41	<0.01	<0.05	2.2	0.12	0.055	<0.10	<10	3	3	1.0
FEB											
23...	0.36	0.07	<0.01	3.4	0.10	0.018	<0.01	10	12	12	0.8
MAR											
19...	0.41	0.05	<0.01	3.6	0.10	0.029	<0.01	<10	18	21	0.9
APR											
23...	0.39	<0.01	<0.01	3.5	0.08	0.086	<0.01	<10	23	65	1.6
MAY											
22...	0.39	0.02	<0.01	3.4	0.08	0.031	<0.01	<10	35	23	0.7
JUN											
12...	0.38	<0.01	<0.01	2.9	0.09	0.062	<0.01	<10	15	8	0.9
AUG											
02...	0.28	0.03	<0.01	1.8	0.02	0.015	<0.01	20	19	4	0.5
SEP											
10...	0.2	<0.01	<0.01	2.0	--	0.012	<0.01	<10	8	8	0.4

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Temper-ature (deg C)	Acidity (mg/L as H)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)
					Water-Quality Data, Water Year October 1984 to September 1985							
OCT												
16...	1225	28	16	6.20	6.5	<0.1	2.0	0.4	0.4	0.31	6.0	1.5
NOV												
14...	1210	24	16	6.10	2.5	<0.1	2.1	0.51	0.5	0.28	5.0	1.6
DEC												
31...	0910	6.1	18	6.10	0.5	<0.1	2.1	0.5	0.5	0.29	6.0	1.5
JAN												
30...	0920	7.2	19	6.10	1.5	<0.1	2.3	0.8	0.6	0.33	5.0	1.6
FEB												
21...	0840	4.6	19	6.10	0.0	<0.1	2.5	0.5	0.6	0.36	6.0	1.6
MAR												
19...	0835	6.8	20	6.10	1.0	<0.1	2.5	0.5	0.7	0.52	6.0	1.6
APR												
25...	0935	15	18	6.00	2.5	<0.1	2.3	0.5	0.5	0.27	5.0	1.4
MAY												
21...	1030	78	18	6.10	4.0	<0.1	2.2	0.5	0.5	0.3	5.0	1.5
JUN												
20...	0955	98	12	6.10	8.0	<0.1	1.7	0.4	0.3	0.18	3.0	1.2
JUL												
25...	1235	39	11	6.90	12.5	<0.1	1.6	0.38	0.4	0.2	3.0	1.2
AUG												
13...	1252	22	12	6.90	13.0	<0.1	1.7	0.48	0.4	0.21	5.0	1.3
SEP												
17...	1050	39	14	6.90	9.5	<0.1	2.0	0.43	0.4	0.22	5.0	1.3

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)
Water-Quality Data, Water Year October 1984 to September 1985--continued											
OCT											
16...	0.3	0.04	<0.01	2.2	<0.01	0.008	0.002	20	14	14	0.7
NOV											
14...	0.48	0.02	<0.01	2.7	0.04	0.018	<0.002	30	18	11	1.3
DEC											
31...	0.45	0.02	<0.01	3.4	0.09	0.039	<0.002	<10	13	5	0.5
JAN											
30...	0.47	0.01	<0.01	0.5	0.11	0.018	0.002	<10	13	12	0.7
FEB											
21...	0.46	0.03	0.02	3.9	0.13	0.051	0.002	20	15	35	0.2
MAR											
19...	0.59	0.03	<0.01	4.0	0.12	0.028	0.003	10	14	36	0.2
APR											
25...	0.5	0.01	<0.01	3.4	0.15	0.028	0.001	10	13	26	1.1
MAY											
21...	0.44	0.02	<0.01	3.2	0.13	0.026	0.001	<10	10	21	0.4
JUN											
20...	0.32	0.02	<0.01	1.9	1.10	0.029	0.002	<10	6	2	0.6
JUL											
25...	0.26	0.03	0.01	1.8	0.02	0.011	0.036	<10	9	4	1.9
AUG											
13...	0.28	0.01	<0.01	2.0	0.01	0.023	0.002	10	13	4	0.4
SEP											
17...	0.28	0.02	<0.01	2.1	0.03	0.033	0.002	<10	17	8	0.6

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Alkalinity, carbonate IT-fld (mg/L-$CaCO_3$)
				Water-Quality Data, Water Year October 1985 to September 1986								
OCT												
08...	1130	11	16	6.80	8.0	<0.1	2.0	0.4	0.4	0.27	5.0	6.0
NOV												
13...	0840	15	14	6.80	2.0	<0.1	2.0	0.43	0.5	0.26	4.0	--
DEC												
10...	0915	5.1	17	6.90	1.5	<0.1	2.0	0.48	1.0	0.34	5.0	--
JAN												
14...	0930	9.8	20	6.80	1.5	<0.1	2.1	0.46	0.6	0.35	7.0	--
FEB												
12...	0840	9.2	16	6.60	2.0	<0.1	1.9	0.37	0.5	0.26	4.0	--
MAR												
12...	0845	32	15	6.70	2.5	<0.1	1.7	0.39	0.5	0.26	5.0	--
APR												
22...	1120	42	21	6.70	5.5	<0.1	2.2	0.5	0.6	0.36	8.0	--
MAY												
15...	1215	36	19	7.00	6.0	<0.1	2.1	0.49	0.6	0.33	8.0	--
JUN												
10...	1200	51	13	6.80	9.0	<0.1	1.5	0.4	0.5	0.22	6.0	5.0
JUL												
15...	1140	36	13	6.80	9.0	<0.1	1.6	0.34	0.4	0.25	8.0	6.0
SEP												
17...	1012	7.4	16	6.90	10.5	<0.1	2.0	0.49	0.4	0.28	8.0	5.0

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)
Water-Quality Data, Water Year October 1985 to September 1986--continued												
OCT												
08...	1.4	0.28	0.02	0.01	2.2	--	0.025	<0.01	<10	<3	7	0.5
NOV												
13...	1.3	0.38	0.02	<0.01	3.0	0.07	0.021	<0.01	<10	47	8	0.6
DEC												
10...	1.4	0.41	0.03	<0.01	3.3	0.08	0.035	<0.01	<10	17	7	1.3
JAN												
14...	1.5	0.4	0.02	0.01	3.6	0.08	0.009	<0.01	<10	19	13	0.9
FEB												
12...	1.4	0.4	<0.01	0.01	3.0	0.10	0.025	<0.01	<10	17	9	1.1
MAR												
12...	1.3	0.34	0.02	<0.01	3.0	0.09	0.005	<0.01	<10	14	8	1.2
APR												
22...	1.6	0.41	0.03	0.01	3.8	0.07	0.026	<0.01	<10	14	16	1.1
MAY												
15...	1.5	0.39	0.02	<0.01	3.5	0.06	0.026	<0.01	<10	30	12	1.1
JUN												
10...	1.1	0.26	<0.01	<0.01	2.1	0.04	0.016	<0.01	<10	20	4	1.0
JUL												
15...	1.3	0.28	0.01	0.01	2.0	0.02	0.019	<0.01	<10	13	3	0.8
SEP												
17...	1.5	0.26	0.02	<0.01	2.6	0.04	<0.002	<0.01	20	11	6	0.4

Table 7.--Chemical data for Goat Lake outflow--continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Temper-ature (deg C)	Acidity (mg/L as H)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Alka-linity, carbon-ate IT-fld (mg/L-$CaCO_3$)
				Water-Quality Data, Water Year October 1986 to September 1987								
OCT												
15...	1015	6.0	17	6.80	8.0	<0.1	1.9	0.45	0.5	0.26	8.0	7.0
DEC												
09...	0900	8.2	12	6.70	2.0	<0.1	1.9	0.5	0.5	0.31	7.0	5.0
JAN												
13...	0825	29	14	6.70	2.5	<0.1	1.9	0.4	0.6	0.3	7.0	6.0
FEB												
10...	0830	18	15	6.60	2.5	<0.1	2.1	0.4	0.5	0.33	8.0	7.0
MAY												
19...	1145	43	14	7.00	--	<0.1	1.7	0.36	0.4	0.21	6.0	5.0
JUN												
22...	1030	55	14	6.80	9.0	<0.1	1.6	0.39	0.5	0.23	6.0	4.0
JUL												
14...	1024	39	13	6.90	12.0	<0.1	1.6	0.42	0.3	0.28	6.0	5.0

Date	Sul-fate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Phos-phorus, ortho, dis-solved (mg/L as P)	Alum-inum, dis-solved (µg/L as Al)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Carbon, organic dis-solved (mg/L as C)
OCT												
15...	1.4	0.26	0.01	0.01	2.2	0.01	0.013	<0.01	<10	7	9	1.2
DEC												
09...	1.3	0.4	<0.01	<0.01	3.2	0.08	0.022	<0.01	<10	20	11	0.8
JAN												
13...	1.5	0.4	0.03	<0.01	3.4	0.08	0.017	<0.01	<10	19	19	0.9
FEB												
10...	1.4	0.46	0.03	<0.01	3.6	0.09	0.183	<0.01	<10	19	20	0.7
MAY												
19...	1.2	0.35	0.03	<0.01	2.6	0.04	0.035	<0.01	<10	15	9	0.5
JUN												
22...	1.2	0.29	<0.01	<0.01	2.2	0.02	0.015	<0.01	<10	11	6	4.9
JUL												
14...	1.2	0.26	0.03	<0.01	2.0	<0.01	0.04	<0.01	<10	7	3	1.0

Table 8.--Chemical data for Goat Lake

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

Date	Time	Sampling depth (feet)	Temperature (deg C)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic dissolved (mg/L as C)
AUG 1973											
01...	1315	3.00	12.0	0.04	0.006	0.03	--	0.03	0.002	0.002	--
01...	1320	60.0	5.0	0.09	0.004	0.10	--	0.12	0.007	0.001	--
AUG 1982											
13...	1252	5.00	--	--	--	--	0.023	--	--	0.002	0.4

Date	Time	Sampling depth (feet)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Color (platinum-cobalt units)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Acidith (mg/L as H)	Calcium, dissolved (mg/L as Ca)
OCT 1985										
08...	1100	5.00	16	6.80	8.0	3	5.5	9.7	<0.1	2.1

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Alkalinity, carbonate IT-FLD (mg/L - ($CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as (SiO_2)
OCT 1985										
08...	0.5	0.5	0.28	6.0	8.0	1.4	0.3	0.02	<0.01	2.4

Date	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Carbon, organic dissolved (mg/L as C)	Carbon, inorganic, dissolved (mg/L as C)
OCT 1985									
08...	0.03	0.044	<0.01	<0.01	10	<3	14	0.4	1.6