WATER INVESTIGATIONS BRANCH
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DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES
PARLIAMENT BUILDINGS
VICTORIA, BRITISH COLUMBIA

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AN INVESTIGATION OF THE CONDITION OF KATHLYN LAKE, WITH SUGGESTIONS FOR REHABILITATION

September, 1974
File: 0290862-Gen.

B.R. Baillie, B.Sc.
R.J. Buchanan, Ph.D.

E H Vernon File

DEPARTMENT OF RECREATION AND CONSERVATION

FISH AND WILDLIFE BRANCH

MEMORANDUM

G.D. Taylor, R/F/B., Fish and Wildlife Branch, P.O. Box 127, Smithers, B.C.	FROM L. J. Cox,
	DATE September 28/67 FILE No. 48-01-7

WATER LICENCES - Lake Kathlyn

Lake Kathlyn is approximately 3/4 miles long and ½ miles wide. It is quite shallow over most of its area with a maximum depth of 31 feet and mean depth of 15 feet. The only continuous flowing inlet stream is an unnamed stream, locally called Club Creek, which flows into the lake on the west side. The Bulkley Valley Rod and Gun Club own property near Lake Kathlyn through which Club Creek flows. The Rod and Gun Club own and operate a fish hatchery on ~~kk~~ its property and water for same is obtained from the Creek under conditions of a Water Licence held by the Fish and Wildlife Branch.

Lake Kathlyn is almost completely surrounded by private property which contain some permanent residences and many summer homes. A large percentage of the land around the Lake that is in use is partly inundated during the spring freshet each year.

Some years ago (1955?) the B.C. Game ~~Department~~ Commission made a study of Lake Kathlyn with the intention of attempting a rehabilitation program. The only reasonable location for a barrier to prevent reintroduction of undesireable fish species was at or near the outlet in Kathlyn Creek (Chicken Creek). This would have meant raising the water level in the Lake by three or four feet and permanently inundating a number of acres of privately owned land around the lakeshore. Some of the land owners were contacted but none would allow the flooding of their land.

In the present water use controversy it seems that a number of homeowners around Lake Kathlyn and along Kathlyn Creek are seeking authority to divert water from Glacier Gulch Creek, tributary to Tobaggan Creek, into Lake Kathlyn through Club Creek. The idea here is that this flow of cold water from the glacier would ~~xxxxx~~ lower the water temperature in Lake Kathlyn, raise the water level throughout the system and stop the growth of weeds. I believe this is a falicy. For one reason, the inlet of Club Creek to the Lake and the outlet of Kathlyn Creek from the Lake are directly across the lake from one another, near the west end of the Lake and the deep part of the Lake connects them so there would be little, if any, mixing of water unless a barrier was placed to raise the water level of Lake Kathlyn.

The introduction of too much cold water to Club Creek would have ill effects on the production of fish in the Rod & Gun Club Hatchery but I doubt that it would have any effect on the remainder of this system. Too much water takeoff from Glacier Gulch Creek would have a detrimental affect on the Tobaggan Creek fishery which containd game fish, steelhead and salmon spawning facilities.

There is the legal aspect of flooded land which need not concern us.

L. J. Cox

L. J. Cox

1866 CENTENARY OF THE UNION OF THE COLONIES OF VANCOUVER ISLAND AND BRITISH COLUMBIA UNDER THE NAME BRITISH COLUMBIA.
1967 CENTENARY OF THE CONFEDERATION OF CANADA.

Interior News (Smithers, B.C.)
AUG 2 4 '83

More information required before trying creek diversion

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SMITHERS — The amount of water disappearing from the Glacier Gulch Creek system must be determined before any Lake Kathlyn diversion plan is approved, says regional water manager ~~Will~~ Dreher.

Dreher says beaver dams and underground seepage are removing an unknown quantity of water from the creek system each year.

"It's difficult for us to come up with an acceptable diversion rate for Lake Kathlyn and Toboggan Lake until the question of creek flow losses is dealt with," said Dreher.

He said the main concentration of beaver dams is located about .5km past the present diversion point of Glacier Gulch Creek into Club Creek.

"Those beaver dams are presently storing a considerable amount of water and would have to be removed," he said. "That, in turn, may also cause flooding problems for people living along the shoreline of the creek system."

The destination of the creek flow escaping underground, he said, is "anybody's guess".

"We have to know where that groundwater is going before implementing a diversion into Lake Kathlyn."

Dreher says he hasn't yet received any information regarding a Glacier Gulch Creek preliminary water diversion proposal for Lake Kathlyn by a Prince Rupert consulting firm.

The plan, drawn up by Ker Priestman and Associates Ltd., calls for a cement structure to be installed below the water table of Glacier Gulch Creek at a cost of $100,000.

Dreher says he won't dispute the technical aspects of any proposal if the steelhead fishery at Toboggan Lake receives the required flow rates.

"We've started a study this summer to find out what percentage of the water volume in Toboggan Lake comes from the Glacier Gulch Creek system," he said.

The steep gradient of the creek, he says, will make it very unmanageable.

"It's a raging stream which carries with it a considerable bedrock load, so any diversion structure will have to encompass the entire width of the channel," said Dreher.

He claims it's still a guessing game in determining if the diverted creek water will have an effect on Lake Kathlyn.

"It would be an ideal system for the lake because the creek water flow is at its highest during hot climate periods when the cold water influx is needed most," said Dreher. "There are still, however, a lot of stored nutrients in the lake bottom."

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Interior News (Smithers, B.C.)
AUG. 19 1987

Lake Kathlyn

371PR

Diverting creek could solve lake weed problems

SMITHERS — Following a meeting with representatives from the ministry of environment and lands, the Lake Kathlyn Protection Society has decided on a scheme to rid Lake Kathlyn of its weed problem.

Society president Dr. Mitch Greene says the society has begun working toward getting an approval to divert Glacier Creek so it will flow through Lake Kathlyn.

According to Greene, Mel Maxnuk, a Vernon-based biologist with the ministry's water management branch who specializes in weed control, suggested to the society that "every attempt be made" to flush the lake continuously with cold water, a method which has proven to keep weed growth down.

Provincial biologist Brian Wilkes reported at the meeting that the water in Lake Kathlyn is clearer this year, algae growth is down and there is less waste and pollution in the lake as a whole.

"The executive felt there was less weed growth this year due to a higher lake level of cold water," said Greene.

Of the six options discussed at the July 21 meeting between the society's executive and representatives from the environment and parks ministry and the regional district, Greene said the executive decided the cold water flushing method would be the most effective in ridding the lake of its weed problem.

The Lake Kathlyn Protection Society was formed by lakeside property owners four years ago to look at the question of weed growth in the lake.

Aside from being unsightly, the weeds make boating difficult or impossible, and they prevent swimming and fishing in the lake.

A three-year-old engineering study shows the cost of putting in a silo with exit valve on the creek for selective water release into the lake at between $75,000-$100,000, according to Greene.

He said regional district administrator Gary McIntyre and regional district rural area "A" representative, Art Mortensen, were enthusiastic about the cold water diversion proposal.

The formal diversion of Glacier Creek could be extended for a permanent drinking water supply and to provide a firefighting supply, thus bringing insurance rates down for properties in the Lake Kathlyn area, said Greene.

Greene said the July 21 meeting was the society's first opportunity to meet with ministerial representatives.

Other methods looked at, but rejected, included:

- mechanical harvesting of the weeds — considered cosmetic and ineffective because it leaves the roots behind and regrowth will occur;
- mechanical de-rooting — considered unsuitable to the weeds in Lake Kathlyn because, when cut, they would simply sink to the bottom and regrow;
- bottom barriers — materials are specially woven on the lake bottom to occlude sunlight, but although it is effective, the method is very expensive;
- herbicides — commonly used in the U.S., yet very controversial; rejected because Lake Kathlyn's water is a source of drinking water, making an application for a herbicide use licence from the pesticide control branch difficult if not impossible;
- drainage of lake — a 1970s study showed that weed growth could be stopped by having the lake's water level lowered in the winter to allow the algae roots to freeze and die; rejected because recent studies show not all weeds would be killed off, and because there would be a loss of fish and an absence of drinking water.

Glacier Creek already flows partially into Lake Kathlyn, where it continues on to the Bulkley River down Chicken Creek, but part of the glacier stream also drains into Toboggan Lake and the salmon and steelhead bearing Toboggan Creek.

"Our basic question is: 'what can be done about the weeds in Lake Kathlyn?' " asks Greene.

The next annual meeting of the society will be held in mid-October.

Mr. Maxnuk RB 87.09.01

Dr. Buchanan + file

CORRECTION:

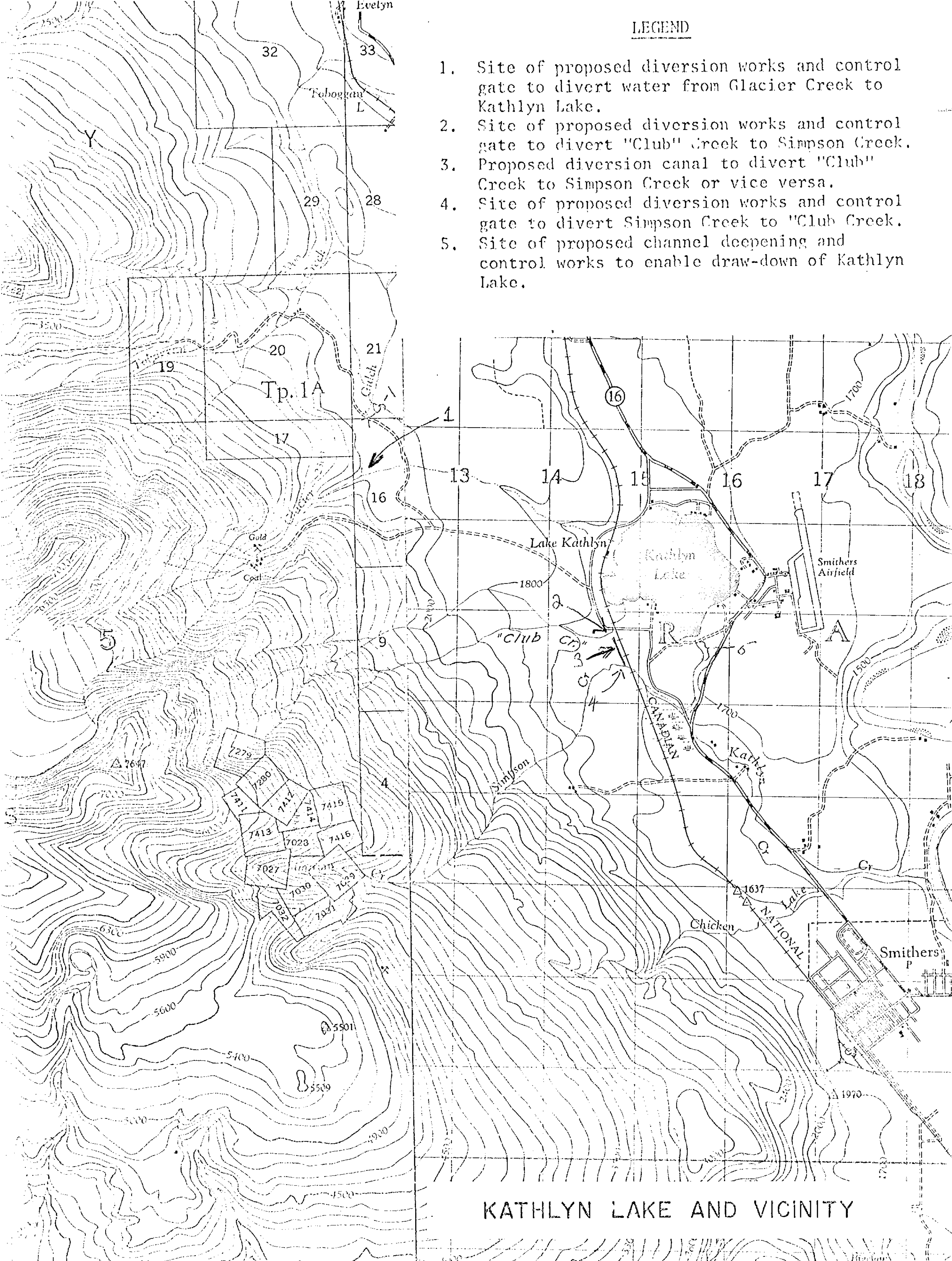
Since completion of the following report, it has come to our attention that the names given to some streams in this report do not conform to official names. The stream labeled and referred to as "Club Creek" is officially known as Kathlyn Creek, and the water course left unnamed but referred to as the "Diversion channel from Glacier Creek" in the report is officially known as Club Creek.

B.R. Baillie

R.J. Buchanan

LEGEND

1. Site of proposed diversion works and control gate to divert water from Glacier Creek to Kathlyn Lake.
2. Site of proposed diversion works and control gate to divert "Club" Creek to Simpson Creek.
3. Proposed diversion canal to divert "Club" Creek to Simpson Creek or vice versa.
4. Site of proposed diversion works and control gate to divert Simpson Creek to "Club Creek.
5. Site of proposed channel deepening and control works to enable draw-down of Kathlyn Lake.



KATHLYN LAKE AND VICINITY

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ACKNOWLEDGEMENTS

Several individuals and organizations contributed significantly to the successful completion of this study. Mr. R.S. Hawthorn assisted in the lake sampling and the identification of aquatic plants. Identities of plant specimens were confirmed by Dr. P.R. Newroth. The August 1972 survey was made possible by the kind loan of a suitable boat and trailer from Mr. L. Cox, Senior Conservation Officer, Fish and Wildlife Branch, Smithers. His colleague, Mr. G. Smythe, Conservation Officer, Terrace, provided a truck for launching the boat. The highly skilled and dedicated staff of the Water Resources Service Chemistry Laboratory executed the chemical analyses on which the entire ecological interpretation rests. Their contribution was indispensable. The illustrations were prepared by Mr. R. Dabrowski, and the text and tables were typed by Miss Karen Thokle, Miss June Seto and Mrs. G. Bellavance.

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RESUME

A field survey of the physical, chemical and biological condition of Kathlyn Lake was carried out in August 1973. The distribution of various species of weeds around the margin of the lake was determined. The predominant species were found to be Nuphar sp., Potamogeton pectinatus, and Ranunculus sp. The greatest number of species were encountered in the east and the northeast bays, while the south bay and the region of the municipal beach had the least number of species. No measurements of biomass per unit area were attempted.

The theoretical aspects and the ecological implications of the various physical and chemical variables is discussed in some detail, with particular reference to Kathlyn Lake.

The plankton algae were sampled in Kathlyn Lake at five depths. The numbers of each species per millilitre and the total number of specimens per millilitre were determined by microscopic counting. The algal species in Kathlyn Lake are more or less typical of eutrophic lakes, but the abundance of algae was lower than commonly found in eutrophic lakes. This may be a result of limiting growing conditions or of intense feeding by planktonic animals.

It is concluded that Kathlyn Lake is eutrophic. The alternative means of aquatic weed control are considered with respect to their appropriateness for Kathlyn Lake. Herbicides, harvesting and biological control are rejected for various reasons. While flushing would be effective in

the control of algae, it is not expected to reduce established rooted weed populations, and it has the potential for cooling the lake more than desired and increasing surface turbidity if flushing is continuous. The most promising method appears to be a combination of spring and fall flushing and winter drawdown. This method would be expected to control both algae and rooted plants and would give positive operator control. It suffers, however, in necessitating reconstruction of numerous domestic water intakes, and sizable expenditures on hydraulic control works. The effects along the streams whose flows would be altered have not been estimated either. Dredging is briefly considered as a purely weed control measure. It was judged to be inferior to drawdown and flushing. It would entail both reconstruction work for domestic water intakes, and interruption of service during dredging while creating spoil disposal problems and not affecting algal proliferation. Dredging is considered to be a viable alternative for purely weed control if drawdown and flushing is rejected. The relative costs of the two best options is not known.

An Investigation of the Condition of Kathlyn Lake, with Suggestions for Rehabilitation

1. INTRODUCTION

As early as 1970, and continuing into the year 1973, concerned citizens of the Smithers area brought to the attention of the Water Resources Service the fact that nuisance weed growths were occurring (and increasing) in Kathlyn Lake. In response to this concern, two biologists from the Ecology Division, Water Investigations Branch, visited Kathlyn Lake in August 1973. This report is an analysis of the data collected.

2. OBSERVATIONS

2.1 Morphometry

The following statistical data were obtained from maps of Kathlyn Lake supplies by the Fish and Wildlife Branch, Department of Recreation and Conservation:

Elevation	1,545 feet
Surface area	420 acres
Volume	6,300 acre-feet
Mean depth	15 feet
Maximum depth	31 feet
Perimeter	20,064 feet

Figure 1 indicates the number of acres between various water depths in Kathlyn Lake. Figure 1 also includes a plot of depth against the total area (acres) to that depth.

Kathlyn Lake is fed by Club Creek which begins at approximately the 5,000-foot elevation on Hudson Bay Mountain. There have been occasions when Glacier Creek has been diverted into Kathlyn Lake but these were temporary diversions only. Kathlyn Lake is drained by Kathlyn Creek which flows ultimately into the Bulkley River. Simpson Creek flows from the slopes of Hudson Bay Mountain into Kathlyn Creek downstream from Kathlyn Lake.

Water temperatures in Kathlyn Lake range from 0°C (in winter) to at least 19°C (in summer). During the summer, the lake becomes typically stratified; the thermocline occurring between three and five meters in depth. Approximately 54% of the total area within the lake lies above the five-meter (16.4 feet) contour.

2.2 Weed Distribution

The following plants were collected from Kathlyn Lake on August 13, 1973:

Brasenia sp.	*Potamogeton* sp.
Ceratophyllum demersum	*Ranunculus aquatilis*
Nitell sp.	*Ranunculus* sp.
Potamogeton berchtoldii	*Sagittaria latifolia*
Potamogeton gramineus	*Sparganum* sp.

Potamogeton natans *Typha* sp.

Potamogeton nodosus

These plants were identified by Dr. P.R. Newroth of the Environmental Studies Division. Three other specimens were tentatively identified by Dr. Newroth as *Isoetes* sp., *Juncus* sp. and *Lilaea* sp.

Table I shows the plant species distribution throughout the stations samples. Species included in Table I but not included in the list above, were seen and tentatively identified by Dr. R.J. Buchanan. The location of each station is indicated on the map of Kathlyn Lake (see Figure 14).

From Table I it is seen that *Nuphar* sp. and *Potamogeton pectinatus* are the two plant species most widely distributed in the lake. Each occurs at seventeen of the twenty-five stations sampled. The genus *Potamogeton* is found at all but two stations. The genus *Ranunculus* is also well represented, occurring at nineteen of the twenty-five stations. The other species listed occur at one or more stations.

There is no obvious distribution pattern and in all probability, most species occur at most stations in this small lake. The species most frequently encountered are *Nuphar* sp., *Potamogeton pectinatus* (or some other species of *Potamogeton*) and *Ranunculus* sp.

Stations 8 and 12 have the greatest number of species whereas stations 4 and 25 have the least number. All other stations show varying numbers of species present.

2.3 Water Quality

Figures 2, 8, 9 and 10 show the variation with depth of the various chemical variables in Kathlyn Lake. It should be noted that there is a considerable change in scale of the four graphs.

Table II compares the water chemistry of Kathlyn Lake with that of Kathlyn Creek, Simpson Creek, Glacier Creek and Club Creek.

2.3.1 Temperature

Figure 2 indicates that Kathlyn Lake becomes typically stratified in the summer; the thermocline occurring between three and five meters in depth. The waters above the thermocline (epilimnion) are warmed by the sun, thus they become less dense. The waters below the thermocline (hypolimnion) are colder and therefore more dense than the waters in the epilmnion. Thus the waters of Kathlyn Lake become stratified into an upper region of warm, circulating water (free to carry on gas exchange with the atmosphere) and deeper, colder, relatively uncirculating water (which cannot carry on gas exchange with the atmosphere). The region of rapid decrease in temperature separating the epilimnion from the hypolimnion is called the thermocline (see Figures 2 and 3).

The establishment of the thermocline is very important to the understanding of the various processes occurring in Kathlyn Lake.

2.3.2 Dissolved Oxygen

Figure 2 indicates the dissolved oxygen concentration of Kathlyn Lake remains relatively constant throughout the epilimnion, then decreases rapidly through the thermocline to less than one part per million (ppm) in the hypolimnion. This has three effects of immediate concern; one is to restrict most animal life (especially fish) to the epilimnion (most fish require at least 4.0 ppm of oxygen (McCarren, 1972 p.14); the second is that of necessity, these must be warm-water fish; the third is to restrict plant growth to those areas above the five meter (probably above the three meter) contour.

The epilimnion receives oxygen from the atmosphere and also as a by-product of photosynthesis by the phytoplankton. The warm temperatures and abundant sunlight of the epilimnion stimulate phytoplankton growth and photosynthesis. Any oxygen deficiencies which might occur in the epilimnion can be removed by diffusion of oxygen from the atmosphere into the water.

The oxygen in the waters of the hypolimnion is constantly removed by respiration of plants and animals and by organic decomposition. It is rarely renewed until the fall turn-over. Eventually, these processes will remove all the oxygen from the hypolimnion.

The thermocline prevents the oxygen-rich epilimnion waters from mixing with the oxygen-deficient hypolimnion waters.

2.3.3 Specific Conductance

Specific Conductance is a measure of the ability of water to conduct electricity. This ability increases as the ionic salt concentration increases. The specific conductance is directly related to the dissolved solids content of the water. It indicates neither the ions present nor that the ions are nutrients. Because natural waters contain a variety of both ionic and undissociated species (the amounts and proportions of which may vary greatly) the conductance is not related in a simple manner to ion concentration or to total dissolved solids. It gives only a general indication of the dissolved solids concentration (see Figures 4-7).

Phytoplankton growth in the epilimnion reduces the concentration of nutrients above the thermocline (which prevents the replenishment of nutrients to the epilimnion from the hypolimnion). The decomposition of dead and dying organic matter (detritus) "raining" down from the epilimnion (e.g., phytoplankton, zooplankton, fish etc.) or in the sediments may also increase the concentration of ions in the hypolimnion.

Thus, the specific conductance in the epilimnion should be lower than that of the hypolimnion because those ions (used as nutrients) removed by the phytoplankton will be more abundant in the hypolimnion. The production of carbon dioxide in the hypolimnion also contributes to the ionic content of this water layer.

Figure 2 shows the specific conductance profile of Kathlyn Lake in August 1973. The profile is not unusual. "The conductance of surface and groundwaters has a wide range, of course, and in some areas may be as low as 50 micromhos, where precipitation is low in solutes and the rocks are resistant to attack. In other areas conductances of 50,000 or more may be reached; this is the approximate conductance of sea water". (Hem, 1970, p.102). By this criterion, it would appear that the specific conductance (and thus the total dissolved solids generally) of Kathlyn Lake is low to moderate. The conductances of Kathlyn Creek, Simpson Creek, Glacier Creek and Club Creek would be considered low by the same criterion.

The total dissolved solids content of water indicates the amount of inorganic chemicals in solution. Dissolved solids in excess of 1,000 mg/l may have undesirable cooking characteristics or may cause adverse physiological effects if consumed and thus such water is considered unfit for consumption by humans. In the United States, the guidelines of the U.S. Public Health Service and most state agencies restrict the concentration to 500 mg/l (McCarren, 1972, p.11). However, more than one hundred public water supplies in the U.S. contained 2,000 mg/l dissolved solids without apparent harm to the users (McCarren, 1972, p.11).

Because the specific conductance of the waters of Kathlyn Lake, Kathlyn Creek, Simpson Creek, Glacier Creek and Club Creek, are low to moderate, it is probable that the total dissolved solids content is similarly low.

2.3.4 Turbidity

Turbidity is an optical property of water; it does not accurately indicate the weight of suspended material in a given volume of water because suspended particles show varying properties. It is expressed in turbidity units.

Figure 2 indicates that the turbidity of the epilimnion is relatively constant. The turbidity begins to increase at the top of the thermocline. Below the thermocline, the turbidity increases rapidly, eventually reaching approximately sixteen

There are indications of a large population of planktonic algae in the thermocline. This would produce an increase in turbidity. Also, algae and other particulate matter "raining" down into the hypolimnion from the epilimnion may contribute to the observed turbidity profile. In addition, bacterial growth (which results in organic decomposition and the release of dissolved solids) may effect the turbidity.

Sulphate and iron ions, in the absence of oxygen, may combine to form ferrous sulphide particles in the water. As the particles increase in size, some may settle out into the sediments, imparting a black colour to them. Before settling, however, these particles may contribute to increased turbidity.

Analysis of samples from Kalamalka Lake in the Okanagan Valley of British Columbia in 1972 resulted in turbidity values of 2.1 to 2.3 at a depth of 1 meter and 0.8 to 2.4 at a depth of 33 meters (Kalamalka Lake file, Ecology Division). Kalamalka Lake is considered to have clear water by most people. By comparison, the epilimnion of Kathlyn Lake is even clearer than that of Kalamalka Lake. At and below the thermocline, however, Kathlyn Lake is more turbid than Kalamalka Lake.

It should be noted that the increased turbidity of the thermocline and hypolimnion could decrease the rate of photosynthesis (and thus the production of oxygen) by scattering and absorbing the light reaching it. Thus oxygen deficiency would be enhanced by increased turbidity while there is a large oxygen demand from decaying materials.

2.3.5 Total Alkalinity

The alkalinity of water is the capacity to neutralize acid. It is the equivalent sum of bases that are titratable with strong acid. In most cases, the main form of alkalinity is carbonate and bicarbonate ions, which are theoretically in equilibrium with carbon dioxide or carbonic acid.

Carbon dioxide, on solution in water can undergo two possible reactions:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \quad \text{carbonic acid (1)}$$

or $$CO_2 + OH^- \rightleftharpoons HCO_3^- \quad \text{bicarbonate (2)}$$

The first (1) reaction is practically the only significant reaction occurring below pH 8.0. The second reaction (2) is practically the only significant reaction occurring above pH 10.0. In most natural waters the alkalinity is practically all produced by dissolved carbonate and bicarbonate ions.

Carbonic acid dissociates

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^= \quad (3)$$

Alkalinity is:

(Alkalinity) = (HCO_3^-) + $(CO_3^=$ + (OH^-) - (H^+) (Stumm and Morgan, 1970, p. 132.)

It should be remembered, however, that other acids (e.g., silicic, phosphoric, boric, organic acids, etc.) may contribute to the titratable alkalinity. The tritrated alkalinity is a result of the total effect of all the anions which may react on the addition of strong acid. Thus alkalinity values may not accurately represent the actual ionic species present.

In the epilimnion of Kathlyn Lake, the pH is relatively constant (7.6 at the surface to 7.4 at 2.5 meters depth). At this pH, most of the carbon dioxide is present as HCO_3^- (90-94%). Some is present as H_2CO_3 (10-6%). None is present as $CO_3^=$. The epilimnion contains carbon dioxide from two major sources; the atmosphere and respiration. The carbon dioxide is removed from the epilimnion mainly by photosynthesis and by release into the atmosphere.

Below the thermocline, respiration results in the production of carbon dioxide (and the utilization of oxygen) which is incapable of reaching equilibrium with the atmosphere (until the fall turnover). As more carbon dioxide is produced, more carbonic acid (which dissociates to form H^+ and HCO_3^- ions) forms. Thus in the hypolimnion the pH decreases and the total alkalinity increases.

Warren (1971) stated, "Total alkalinities of natural waters, expressed as chemically equivalent concentrations of calcium carbonate, vary from almost zero to several hundred milligrams per liter." Allen (1972) considered low alkalinities to be less than 10-20 mg $CaCO_3$ per liter. Maloney <u>et al.</u> (1972) measured the alkalinity (as $CaCO_3$) of nine Oregon lakes and found that it varied from 2 ppm to 54 ppm. Table II shows that only in Kathlyn Lake itself did the total alkalinity exceed 20 mg/l. Kathlyn Creek, draining Kathlyn Lake, had a higher alkalinity than any of the other three creek samples. Club Creek, Glacier Creek, and Simpson Creek had very low alkalinities. By comparison, Kathlyn Lake, with alkalinities ranging from 15.8 to 23.9 mg/l is not unusual.

2.3.6 Hardness

The hardness of a water is the sum of the concentrations of all the metallic cations (except the alkalies) expressed as the equivalent calcium carbonate concentration. The actual presence, however, of the indicated number of milligrams per liter in the form of $CaCO_3$ should not be assumed. The hardness of waters vary due to the varying proportions of the different cations which constitute this property.

In most waters calcium and magnesium ions contribute practically all the hardness. In some waters iron, aluminum, manganese, strontium and other ions may have to be considered. Hydrolysis reactions (with decreasing pH) such as

$$CaCO_3 + H_2O \rightleftharpoons Ca^{++} + OH^- + HCO_3^- \qquad (4)$$

may influence total hardness, pH and the total alkalinity of water. Calcium is a common constituent of igneous and metamorphic rocks; thus water in contact with such rocks commonly carries calcium. Calcium is also found in the skeletal structures of such animals as Foraminifera and fresh water Mollusca.

In Kathlyn Lake, the hardness remains constant throughout the epilimnion, then increases with increasing depth to the bottom. As the concentration of carbon dioxide in solution increases, the pH decreases. This increased acidity results in increased solubility of both calcium and calcium carbonate. As the temperature of water decreases, the solubility of $CaCO_3$ increases. Thus it may be that in the colder, more acidic regions of the lake (i.e., the hypolimnion), more calcium ions (as well as others such as Fe, Mg etc.) go into solution.

In the epilimnion cations are effectively removed from solution by incorporation into biological systems, by sorption onto particles and by certain precipitation reactions. In the hypolimnion, seston "raining" down from above and undergoing decomposition may return various cations to the water. It should be remembered that magnesium is an essential part of the chlorophyll molecule and that photosynthesis is impossible without chlorophyll. The magnesium concentrations (and therefore water hardness) would be somewhat lower in the epilimnion where there is much photosynthesis and higher in the hypolimnion where (due to decreased temperatures and increased turbidity) there is little or no photosynthesis. The actual magnitude of this partitioning effect of chlorophyll is not certain, and may in fact be insignificant.

According to McCarren (1972, p.12), "up to and including concentrations of 60 mg/l of hardness, water is rated as soft; from 61 to 120 mg/l, moderately hard; from 121 to 180 mg/l, hard; and over 180 mg/l, very hard". By this criterion, all waters listed on Table III are soft.

2.3.7 Total Organic Carbon

Organic carbon is carbon incorporated into living (or once-living) material. It is measured directly by infrared carbon analyzer after removing inorganic carbon from a water sample with acid.

The total organic carbon concentration in Kathlyn Lake remains constant through the epilmnion, then essentially increases with depth to the bottom. Seston "raining" down into the hyplimnion probably gradually increases the organic carbon concentration. Bacterial action of both autochthonous (local origin) and allochthonous (imported) organic matter in the sediments may release organic matter into the water. Hutchinson (1957, p.882) states,"In view of the considerable diversity of the sources of allochthonous organic matter even in basins not subject to human contamination, and also in view of the possibility that the autochthonous organic matter varies from lake to lake, according to whether it is produced by phytoplankton or by rooted vegetation and according to the species of either involved, there is every reason to expect considerable diversity in the composition as well as the quantity of the dissolved organic matter of lake water". The same author, citing Birge and Juday (1934) produces a table showing the total organic carbon content of waters from northeastern Wisconsin to vary from 1.0 to 25.9 mg/l. Jaworski et al. (1972) studied a noneutrophic estuary in Virginia and found "relatively high" concentrations of both organic carbon (5.0 to 18.0 mg/l) and inorganic carbon (4.0 to 10.0 mg/l).

The maximum total organic carbon content of Kathlyn Lake was 11.0 mg/l while that of Kathlyn Creek was 8 mg/l. Club Creek, Glacier Creek and Simpson Creek had 2.0 mg/l, less than 1.0 mg/l, and 1.0 mg/l. respectively of total organic carbon. Table VII gives the average total organic carbon (and total inorganic carbon) concentrations of Kalamalka Lake, Okanagan Lake (Vernon Arm), Langford Lake and Wood Lake. These data were obtained from Ecology Division files. The samples were obtained at various locations in the lakes and at various times throughout the years 1972-1974.

By comparison, Kathlyn Lake and Kathlyn Creek could be considered to have moderate to high concentrations of total organic carbon. Simpson Creek, Glacier Creek and Club Creek would be considered to have low concentrations of organic carbon.

2.3.8 Total Inorganic Carbon

Inorganic Carbon is the carbon present as free CO_2, HCO_3^- ions, $CO_3^=$ ions and H_2CO_3. Over the pH range encountered (6.4 to 7.6), most of the inorganic carbon is present as HCO_3^- ions. Inorganic carbon is the difference between total carbon and total organic carbon, as measured by infrared carbon analyzer.

The total inorganic carbon concentration in the epilimnion of Kathlyn Lake remains relatively constant (2.0 mg/l). Beginning at the thermocline, however, the total inorganic carbon concentration essentially increases with depth. The reasons for this increase have been discussed previously (see Total Alkalinity). Below the thermocline, respiration results in an excess of CO_2 which forms H_2CO_3 and HCO_3^- ions (which are inorganic forms of carbon). In the epilimnion, inorganic carbon is being used by the phytoplankton in photosynthesis (thus removing HCO_3^- ions from the water). In the epilimnion CO_2 may also be lost to (or received from) the atmosphere.

Deevey (1972) gives the mean HCO_3^- content of the rivers of the world as 58.4 ppm. Maloney et al. (1972) studied nine Oregon lakes and found soluble inorganic carbon values to vary from 1.0 ppm to 13.0 ppm. Edmondson (1972), studying Lake Washington, found the HCO_3^- concentrations to vary from 22 to 45 ppm at various sites and times. Jaworski et al. (1971) studying a noneutrophic estuary in Virginia considered inorganic carbon concentrations of 4.0 to 10.0 mg/l to be "relatively high".

The inorganic carbon content of Kathlyn Lake and Kathlyn Creek could be considered moderate to relatively high. Simpson Creek, Glacier

Creek and Club Creek waters have probably reached equilibrium with the atmosphere. In addition, photosynthesis in these waters would tend to remove inorganic carbon from them more rapidly than respiration could produce it (during sunlight hours only).

2.3.9 Dissolved Calcium

Calcium is a common constituent of both igneous and metamorphic rocks (e.g., feldspar, silicate minerals) and in sedimentary rocks as $CaCO_3$. Limestone consists mostly of $CaCO_3$. Other common calcium sediments are gypsum and fluorite. Calcium carbonate is also common in sandstone. Negatively charged mineral surfaces of soil and rocks may adsorb calcium ions. Calcite (a form of $CaCO_3$) forms the skeletal structures of the Foraminifera and aragonite (another form of $CaCO_3$) is found in the shells of most fresh water molluscs.

Hydrolysis reactions (under acid conditions) such as (4) would tend to influence the level of calcium in the water. Calcium is a major constituent of water hardness and the reasons for its increase with depth are discussed there.

The slightly more acidic, colder conditions of the hypolimnion favour the solution of $CaCO_3$ from skeletons, shells, sediments, rocks etc. This could cause the concentration of dissolved calcium to increase with depth. Any calcium contained in seston "raining" down from the epilmnion could increase the amount of both dissolved and total calcium. From Table II it is obvious that most of the calcium is present as dissolved calcium. Deevey (1972), citing Livingstone (1963), states that the mean concentration of Ca^{++} in the rivers of the entire world is 15 ppm.

By the same criteria used to determine hardness (because the Ca^{++} concentration is a major constituent) it can be assumed that the calcium concentrations found in the waters listed on Table II are also low. Low calcium concentrations are characteristic of soft waters. Since high concentrations of calcium tend to reduce the availability of phosphorus, calcium concentrations have a bearing on the productivity of aquatic plants in a lake.

2.3.10 Dissolved Magnesium

Magnesium is a common constituent of both igneous and sedimentary rocks. Most limestone contains moderate amounts of magnesium. In lakes, it is normal for magnesium to be much less abundant than calcium.

Magnesium is an essential micronutrient element for plant growth. It is a coenzyme necessary for certain enzymatic reactions and in addition, it is an essential part of the chlorophyll molecule. Like calcium, magnesium concentrations affect the availability of phosphorus, and the growing conditions for plants.

In Kathlyn Lake the magnesium concentration in the epilimnion is essentially constant and lower than that of the hypolimnion. In the hypolimnion, the magnesium concentration increases slightly.

The phytoplankton in the epilimnion incorporate magnesium from the water into their cells to form coenzymes and chlorophyll. This reduces the concentration of magnesium. In the hypolimnion, phytoplankton decompose, releasing magnesium into the water. This constant "rain" of seston from the epilmnion into the hypolimnion results in the magnesium being slowly removed from the epilimnion and concentrated in the hypolimnion.

2.3.11 Phenolphthalein Alkalinity

The phenolphthalein alkalinity is a measure of the carbonate ($CO_3^{=}$) fraction of alkalinity. For $CO_3^{=}$ to exist (at normal temperatures and pressures) the pH must exceed 8.3. This criterion was not fulfilled in Kathlyn Lake (maximum pH was 7.6). Most of the carbonate present was in the HCO_3^- form. Thus the phenolphthalein alkalinity is zero.

2.3.12 Nitrogen

An explanation of the complexities of the aquatic nitrogen cycle is beyond the scope of this report. Most libraries contain excellent source material for interested individuals.

Nitrogen is found in rocks, organic material and the atmosphere. Atmospheric nitrogen can be fixed by the action of some blue-green algae and some bacteria to form protein. Organic material and fertilizers can also contain nitrogen which can be carried into lakes and streams by run-off waters. The oxidized, nitrate, form is especially mobile in surface and ground waters.

Practically all heterotrophic bacteria produce ammonia as a result of organic decomposition of proteins (by deamination). A considerable part of the ammonia produced (in the presence of oxygen) is nitrified (oxidized) in two stages to nitrite (formed first) then to nitrate. This oxidation process is accompanied by a reduction in free energy, and is therefore a possible energy source for nitrifying bacteria. Ammonia, nitrite and nitrate are all possible nitrogen sources for most green plants (e.g., phytoplankton) and uptake by such organisms prevents accumulation in the environment.

In lake water, nitrogen is present as

1) Molecular nitrogen gas (N_2)
2) Organic nitrogen compounds - e.g., urea, proteins and amino acids
3) Ammonia, mainly as NH_4^+ (ammonium ion) and NH_4OH
4) Nitrite, mainly as NO_2^-
5) Nitrate, mainly as NO_3^-

Because nitrogen, like phosphorus, is an essential nutrient for plant growth, it is possible that low levels may inhibit such growth.

2.3.12.1 Total Nitrogen

Total nitrogen is the sum of ammonia (N), organic (N), nitrate (N) and nitrite (N) or the sum of the total Kjeldahl (N) and nitrate (N) and nitrite (N). Total Kjeldahl nitrogen measures the ammonia and organic nitrogen but does not include nitrate or nitrite nitrogen.

Total nitrogen in Kathlyn Lake increases with depth from the surface to seven meters. From seven meters to eight meters in depth there is a slight decline in total nitrogen. From Figure 9 it can be seen that ammonia nitrogen remains at or near the detection limit from zero to five meters, then increases rapidly with depth. Organic nitrogen generally increases with depth to five meters, then decreases rapidly with depth. The increased ammonia nitrogen and decreased organic nitrogen results in the total Kjeldahl nitrogen profile found in Figure 9.

From zero to two and one-half meters depth, organic nitrogen is the largest component of total nitrogen. From two and one-half meters to five meters in depth, the amount of organic nitrogen increases, probably due to "raining" of seston from the epilimnion into the hypolimnion. At a depth of five meters, there is a dramatic increase in organic nitrogen coincident with a dramatic increase in ammonia nitrogen. This is probably the result of the decomposition of organic material by heterotrophic bacteria which results in the production of ammonia.

Nitrogen in the form of ammonia (NH_3) is very low in concentration from the surface to a depth of five meters. The ammonia produced in the epilimnion is either incorporated into living organisms, converted to nitrate and then used by plants or exchanged with the atmosphere. It has most probably been exhausted by algae in the epilimnion.

From seven meters to eight meters in depth, the rate of ammonia concentration decreases. It is possible that on reaching eight meters in depth, an organism has lost most of its organic nitrogen (due to the action of bacteria) hence a slight decline in the rate of ammonia production. The increased turbidity below five meters (due to organic residue and bacterial populations) further supports this hypothesis.

2.3.12.2 Dissolved Nitrate plus Nitrite

From Figure 9 it is seen that the nitrate plus nitrite fraction of the inorganic nitrogen content of the water remains at or near the detection limit through the entire depth of the lake.

Although there are high concentrations of ammonia below five meters in depth, there is no oxygen, thus the ammonia cannot be oxidized (nitrified) to nitrite and nitrate. Thus, below five meters, although the ammonia concentration increases, the nitrate plus nitrite concentration does not.

In the epilimnion, the nitrate and nitrite are used for metabollic processes by phytoplankton. This consumption by plants has probably exhausted the supply.

2.3.13 Phosphorus

Total phosphorus (all the phosphorus in a sample) is composed mainly of:

1) Organic, particulate, unreactive phosphorus - particulate phosphorus organically combined in either living or dead material.
2) Organic, soluble, unreactive phosphorus - phosphorus in solution which is organically combined (e.g., sugars, A.T.P. (the "energy-converting" molecules of cells) or chelated.
3) Inorganic soluble reactive phosphorus - may be present as H_3PO_4, $H_2PO_4^-$, $HPO_4^=$ or $PO_4^{\equiv}$ depending upon the pH of the solution ("orthophosphate" - see Figure 10). In Kathlyn Lake, $H_2PO_4^-$ would be the most common form

but some would be present as $HPO_4^{=}$.

Total soluble phosphorus is composed of inorganic soluble reactive phosphorus plus the organic soluble unreactive phosphorus. To some extent, the increase in total soluble phosphorus with depth is due to the decomposition of seston and the subsequent liberation of inorganic and organic soluble phosphorus. Another important possible cause, however, of the increase in total soluble phosphorus with depth is the liberation from the sediments of inorganic, soluble, reactive phosphorus. Figure 10 shows that the concentration of organic, soluble, unreactive phosphorus remains almost constant with depth. This fraction is probably not very active biologically.

The oxygen deficiency in the hypolimnion would result in the disappearance of the oxidized microzone at the mud-water interface. When present, this microzone prevents the free passage of phosphate ions into the water; when removed, diffusion of phosphate from the mud can occur. Disturbances of the mud may also release phosphorus into the water under these conditions. Thus, the concentration of soluble reactive phosphorus would increase. In addition, some phosphorus released from decomposing seston may be included in this fraction on analysis. The biologically active forms of soluble phosphorus tend to be consumed in the surface waters of the lake.

Thus, total soluble phosphorus increases with depth; the concentration of inorganic, soluble, reactive phosphorus increases while the concentration of organic, soluble, unreactive phosphorus remains constant.

Phosphorus concentrations in the epilmnion are generally lower than those in the hypolimnion because in the epilimnion, phosphorus is removed by incorporation into biological systems and also by the sinking of seston into the hypolimnion. In the hypolimnion phosphorus is released from the seston (by decomposition) and from the sediments (under proper conditions).

Seston "raining" from the epilimnion (where phosphorus was removed from solution) causes the concentration of organic, particulate, unreactive phosphorus to increase with depth. The total soluble phosphorus increases with depth (for reasons already given). Because total phosphorus is the sum of the organic, particulate, unreative phosphorus and the total soluble phosphorus, it increases with depth also.

The total phosphorus concentrations in lake waters vary from undetectable amounts (less than 0.01 ppm) to immense quantities (78 ppm in Owens Lake, California or 208 ppm in Goodenough Lake, British Columbia) according to Hutchinson (1957). Phosphorus is common in igneous and sedimentary rocks, fertilizers, sewage and detergents. Like nitrogen, it is an essential element for plant growth and may limit growth under certain conditions. Powers *et al*. (1971) studied various lakes in Minnesota and Oregon to determine algal response to nutrient additions in natural waters. They state "We believe our data illustrate that, in a variety of lakes, in widely different geographical areas, phosphorus was the element most often critical to primary production and that carbon was rarely, if ever, limiting".

In 1970, Powers *et al.* studied three lakes of varying trophic levels. Waldo Lake in the Cascade Mountains was an alpine lake with extremely low primary productivity. Triangle Lake in the Oregon Coast mountains was moderately productive. Cline's Pond in the Willamette Valley, Oregon, was highly eutrophic. The chemical analysis of the three lakes is included in Tables III, IV and V.

A comparison of Kathlyn Lake and three lakes studied by Powers *et al.* (1971) indicates that:

1) With respect to both nitrogen levels and total inorganic carbon levels, Kathlyn Lake most closely resembles the moderately eutrophic Triangle Lake (see Tables III, IV and V)
2) With respect to both phosphorus levels and total organic carbon levels, Kathlyn Lake most closely resembles the highly eutrophic Cline's Pond.

In conclusion, it would seem that Kathlyn Lake has moderate to high levels of both nitrogen and phosphorus.

Comparing Club Creek chemical properties with those of Glacier Creek and Simpson Creek (Table II) it is seen that Club Creek has the lowest ammonia nitrogen level and the highest nitrate plus nitrite nitrogen levels, organic nitrogen levels and total nitrogen levels. The dissolved orthophosphate of Club Creek is very low but the total phosphorus (0.10 ppm) is very high; just slightly less than the maximum phosphorus levels found in Cline's Pond (0.16 ppm) by Powers *et al.* (1971). It is probable that most of this phosphorus is in particulate form, being carried from the mountains as rock particles. On reaching Kathlyn Lake, these particles would rapidly sink to the bottom unless they are extremely small (e.g., clay-size).

3. STREAM FLOW AND LAKE LEVELS

Figure 11 shows the monthly mean discharge (c.f.s.) of Kathlyn Creek above Simpson Creek for the years 1967 to 1972. In general, high discharges occur in Simpson Creek and Kathlyn Creek in May to July, with peak flows in June. The water level record for Kathlyn Lake (Figure 13) shows the maximal inflow occurs in March or April, with a second peak during October of some years.

4 PHYTOPLANKTON

Plankton is the assemblage of micro-organisms, both plant and animal, which live (floating, drifting or swimming) in the open water region of lakes and rivers. Phytoplankton is the plant portion of the plankton (unicellular algae of various kinds). (Campbell, (ed.), 1969).

Table VIII is a list of the class, genus and species (where possible) of the phytoplankton found at various depths in Kathlyn Lake on August 13, 1973. This table also includes the number of each per milli-meter of water. The algal species found are more or less typical of a eutrophic lake. However, the numbers recorded are relatively low in comparison with many eutrophic lakes. This may be a manifestation of limitations in growing conditions (e.g., nutrients, light, etc.) or of intense grazing by herbivorous animals (zooplankton).

5. DISCUSSION

It is the considered opinion of the authors that Kathlyn Lake is in a eutrophic state. This problem has a number of possible solutions. The ultimate choice of which solution to employ will depend upon several factors such as cost, ecological consequences and the effectiveness of the method. Selection of the desired characteristics the lake should have following treatment is also an important consideration when choosing treatments. This selection is probably best made by the users, after having considered the alternatives available and the users' means.

5.1 Weed Control Methods

5.1.1 Herbicides

Several different types of herbicides (varying in specificity, toxicity and effectiveness) are available commercially. Factors to be considered when selecting chemicals are costs of treatment, danger to the applicator, long-range effects on non-target organisims (including domestic water users) and the effectiveness of the chemical on the target plant.

Before any herbicide (or any other chemical) can be added to natural waters, several government agencies must be consulted and an application permit must be obtained.

It is not recommended that chemicals be used in Kathlyn Lake at this time, unless interagency co-operation can be secured for small-scale experimental herbicide applications. Such experiments would be necessary before any large-scale application were attempted. Administrative complications also make this an unattractive alternative at this time.

5.1.2. Harvesting

Excessive growth of aquatic plants (e.g., *Myriophyllum* sp., *Ceratophyllum* sp.) can be overcome (temporarily) by the use of weed harvesters which cut and remove the plants from the water, in a manner analagous to mowing a lawn.

Unfortunately, the initial (and operating) cost of the harvester is high. It does not cut all the weeds - some are invariably missed - nor remove all of the weeds it does cut. The roots of the cut weeds are left in the mud. The operation of the machine produces many plant fragments capable of recolonizing an area once it has been cleared. Harvesters can only remove those plants growing above approximately two meters in depth because the cutting bar cannot reach much deeper. Thus, shallow areas may become re-populated from surrounding deeper areas. Experiments with weed harvesters in Okanagan Lake have shown that the stature of weeds in harvested areas can be substantially greater than in unharvested areas, in the growing season following harvesting.

Harvesting rooted plants would have little effect on algae.

5.3.3. Flushing

Temporary diversions of Glacier and Simpson Creeks into Kathlyn

Lake could be used to "flush" the lake with low-nutrient water.

This would:

1) reduce the nutrient levels in the lake - particularly the level of nitrogen and phosphorus, and perhaps also trace element (s) to the point where they limit algal growth.
2) cause some of the algae to be removed from Kathlyn Lake more rapidly, thus reducing the standing crop.

A similar project carried out on Green Lake in Seattle, Washington by Oglesby from 1962 to 1967 determined,"..it is apparent that generally more phosphate phosphorus was present in 1959 than in 1965 or 1966,..." The same author states,"Variations in nitrate nitrogen between the years under comparison are even more striking." (Oglesby, 1969). He also reports that,"... with the exception of the months of September and October, the transparency has improved significantly since the addition of dilution water."

Because Glacier Creek is very cold and very turbid, it may not be considered desirable to divert water from it into Kathlyn Lake continuously. Alternatively, it may be desirable to divert it for only a very short period of time. It is conceivable that if Glacier Creek water is diverted into Kathlyn Lake continuously, the lake may become too cold for swimming. However, decreased temperatures would probably be beneficial to sport fish, and may impede the growth of rooted plants.

Flushing would not, however, be likely to eradicate the established population of rooted plants, since they would have access to the pool of nutrients in the sediments. The best that could be hoped for would be a reduction in algae due to reduced nutrients and low temperatures, and reduced growth rate by rooted plants due to lower temperatures and reduction in dissolved nutrients.

5.1.4 Drawing Down

It appears possible to eliminate the aquatic weed from large areas of Kathlyn Lake by lowering the water level of the lake, exposing the roots of the plants to drying and/or frost. The existing band of barren sediments along the shallow of much of the eastern shore may be attributable to normal drawdown effects. The best time for such a drawdown would be in the fall just prior to the onset of severe frost. By freezing the roots of the plants in the sediments, the plants can be effectively killed.

The drawing-down of Kathlyn Lake could be accomplished by:

1) Temporarily diverting Club Creek elsewhere and
2) Pumping water from Kathlyn Lake into Kathlyn Creek, or
3) Deepening the outflow of Kathlyn Lake and installing control works.

Rapid refilling of the lake in spring could be accomplished by

1) Returning Club Creek to its original course
2) Temporarily diverting Glacier Creek into Kathlyn Lake
3) Temporarily diverting Simpson Creek into Kathlyn Lake (via Club Creek).

It must be pointed out, however, that when the lake is refilled in the spring, the nutrients released from the dead and decaying plants will be incorporated into the water. Table VI shows the total nitrogen and phosphorus content (measured in Wisconsin) of some of the species of aquatic plants found in Kathlyn Lake. Naturally, the decay of these plants would release nutrients to the water whether or not the lake was drawn down.

It is likely that dewatering sediments would promote the release of some nutrients from that source also. Consequently, it may be advisable to flush the lake after drawdown and again prior to refilling.

If, after the drawdown has been accomplished, a heavy snow falls, frost penetration may be limited so few plants die. It might be feasible to remove the snow in this situation (e.g., by blowing it toward the centre of the lake) but it would result in increased cost of the program.

Because plants, like most organisms, require oxygen in order to survive, they cannot grow in anoxic areas. For this reason, plant growth in Kathlyn Lake is restricted to areas above the five meter contour (probably the three meter contour). By drawing down until those vegetated areas were exposed, all plants might be eradicated (depending on their sensitivity to drying and frost).

The combination of winter drawdown with spring and fall flushing is ecologically preferable since it would be effective in the short-term and would be correcting some of the underlying causes of the present eutrophic condition

Engineering studies of costs, hydraulic and hydrologic factors would be necessary before the true feasibility of such a program would be necessary to determine the best drawdown time, flushing schedule, amount of drawdown and other lake operating procedures. Such engineering investigations are not within the scope of this report.

5.1.5. Dredging

It is possible to remove the majority of offending weeds from Kathlyn Lake by dredging. It is probable, however, that the costs of such a program would be excessive. Costs would include dredging and reconstruction of numerous domestic water intakes. Water users would be inconvenienced for the duration of the project by interuption of service. The ultimate disposal of the sediments and also the changed contour of the lake would be factors of concern in such a program. If drawdown and flushing is rejected, this alternative may warrant further consideration, though this would not control algae.

5.1.6. Biological Control

Biological control is perhaps the ideal way of controlling the weed population in Kathlyn Lake. This could involve the use of either indigenous or exotic organisms. The details of biological control are beyond the scope of this report and interested individuals can find excellent material on this subject in most libraries.

Before a biological control program could be recommended, much more extensive and intensive research would have to be carried out. Biological control methods are usually relatively slow (and can be ecologically disastrous if not carefully researched and controlled).

Because the authors believe that the citizens of Smithers and the surrounding area want a relatively rapid solution to the problem of excessive weed growth in Kathlyn Lake, biological control is not recommended at this time.

5.1.7. Factors in Decision Making

No matter which method is chosen to overcome the problem of weed growth in Kathlyn Lake, some other factors which must be considerable are:

1) The effects of any diversions or drawdown on existing water licences.
2) The effect of diversions on stream erosion.
3) The effect of construction phase disruptions.
4) The effect of the downstream transportation of nutrients.
5) The effect of diversions, drawdown and construction phase disruptions on the local and regional fishery.

The solution to the problem should not entail the complete removal or death of all offending weed populations. Some desirable or advantageous aspects of the weeds are (Mulligan, 1969):

1) They produce oxygen as a by-product of photosynthesis.
2) They shade and cool the sediments of the littoral zone.
3) They provide habitats for sessile benthic organisms.
4) They provide surfaces for the attachment of bacteria, periphyton and aquatic insects.
5) They serve as food, nest-building material and sites for egg attachment.

6) They protect small fish from predation.

7) They anchor the soil in place by means of their root system.

In addition, Mulligan (1969) states,"Although Potamogeton pectinatus is the most noxious weed in irrigation and drainage ditches, where it retards water movement (Timmins, 1966), it is the most important duck food plant in the United States (Martin and Uhler, 1939)."

Thus the ultimate solution to the presence of excessive weed growth in Kathlyn Lake will require very careful consideration by all concerned citizens.

REFERENCES CITED

Allen, Harold L. 1971. Phytoplankton photosynthesis, micronutrient interactions, and inorganic carbon availability in a soft-water Vermont Lake. Pp. 63-83. In G.E. Likens (ed.). Nutrients and eutrophication. Special Symposia, Volume I. American Society of Limnology and Oceanography, Inc., Lawrence, Kansas. 328 pp.

Beard, Thomas D. 1973. Overwinter drawdown. Impact on the aquatic vegetation in Murphy Flowage, Wisconsin. Technical Bulletin No. 61, Dept. of Natural Resources, Madison, Wis. 14 pp.

Campbell, N.J. (Chairman). 1969. Report to the International Joint Commission on the pollution of Lake Erie, Lake Ontario, and the international section of the St. Lawrence River. Volume I. International Lake Erie Water Pollution Board and International Lake Ontario-St. Lawrence River Water Pollution Board. 3 Volumes.

Deevey, Edward S., Jr. 1971. Biogeochemistry of lakes: major substances. Pp. 14-20. In G.E. Likens (ed.). Nutrients and eutrophication. Special Symposia, Volume I. American Society of Limnology and Oceanography, Inc., Lawrence, Kansas. 328 pp.

Gerloff, G.C. 1969. Evaluating nutrient supplies for the growth of aquatic plants in natural waters. Pp. 537-555. In Eutrophication: causes, consequences, correctives. National Academy of Sciences, Washington, D.C. 661 pp.

Hem, John D. 1970. Study and interpretation of the chemical characteristics of natural waters. Second edition. U.S. Dept. of the Interior. Geological Survey Water-Supply Paper 1473. 363 pp.

Hutchinson, G. Evelyn. 1959. A treatise on limnology. Volume I. Geography, phsics, and chemistry. John Wiley and Sons, New York. 2 Volumes.

Jaworski, Norbert A., Donald W. Sear, Jr., and Orterio Villa, Jr. 1971. Nutrient management in the Potamac Estuary. pp. 246-273. In G.E. Likens (ed.). Nutrients and eutrophication. Special Symposia, Volume I. American Society of Limnology and Oceanography, Inc., Lawrence, Kansas. 328 pp.

Livingston, D.A. 1963. Chemical composition of rivers and lakes. In Data of geochemistry (6th ed.). U.S. Dept. of the Interior. Geological Survey Prof. Paper 440-G, G1-G64.

McCarren, E.F. 1972. Water quality of streams in the Neshaminy Creek Basin, Pennsylvania. U.S. Dept. of the Interior. Geological Survey Water-Supply Paper 1999-0.

Maloney, Thomas E., William E. Miller, and Tamotsu Shiroyama. 1971. Algal response to nutrient additions in natural waters. I. Laboratory assays. Pp. 134-156. In G.E. Likens (ed.). Nutrients and eutrophication. Special Symposia, Volume I. American Society of Limnology and Oceanography, Inc., Lawrence, Kansas. 328 pp.

REFERENCES CITED (cont'd)

Martin, A.C. and F.M. Uhler. 1939. Food of game ducks in the United States and Canada. U.S. Dept. of Agriculture. Technical Bulletin 634: 1-157.

Miller, A. 1962. Water and man's health. Agency for International Development, Office of Human Resources and Social Development, Washington, D.C. 92 pp.

Mulligan, Hugh F. 1969. Management of aquatic vascular plants and algae. Pp. 464-482. In Eutrophication: causes, consequences, correctives. National Academy of Sciences, Washington, D.C. 661 pp.

Oglesby, R.T. 1969. Effects of controlled nutrient dilution on the eutrophication of a lake. Pp. 483-493. In Eutrophication: causes, consequences, correctives. National Academy of Sciences, Washington, D.C. 661 pp.

Powers, C.F., D.W. Schults, K.W. Maleug, Robert M. Brice, and Marcus D. Schuldt. 1971. Algal responses to nutrient additions in natural waters. II. Field experiments. Pp. 141-156. In G.E. Likens (ed.). Nutrients and eutrophication. Special Symposia, Volume I. American Society of Limnology and Oceanography, Inc., Lawrence, Kansas. 328 pp.

Strumm, Werner, and James J. Morgan. 1970. Aquatic chemistry. An introduction emphasizing chemical equilibria in natural waters. Wiley-Interscience, New York. 583 pp.

Warren, Charles E. 1971. Biology and water pollution control. W.B. Saunders Co., Philadelphia. 484 pp.

TABLE I

SPECIES DISTRIBUTION IN KATHLYN LAKE

Station Number (see Figure 14)

Plants	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Brasenia sp.						X																			
Ceratophyllum demersum		X						X	X			X													
Ceratophyllum sp.													X												
Chara sp.																									X
Equisetum sp.																	X	X			X				
Isoetes sp.																X									
Juncus sp.																X									
Lilaea sp.																X									
Nitella sp.	X											X													
Nuphar sp.			X	X		X		X	X	X			X	X	X		X	X	X	X	X	X	X	X	
Potamogeton berchtoldii			X						X			X													
Potamogeton gramineus	X													X											
Potamogeton natans		X			X	X	X	X			X														
Potamogeton nodosus		X						X				X		X		X									
Potamogeton pectinatus			X		X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X			
Potamogeton sp.								X					X	X	X	X	X	X	X	X		X	X	X	
Potamogeton zosteriformis											X														
Ranunculus aquatilis	X	X						X	X			X		X		X									
Ranunculus sp.			X		X	X	X			X	X		X		X		X	X			X	X			
Sagittaria latifolia								X																	
Sagittaria sp.												X													
Sparganium sp.												X							X						
Typha sp.								X																	

TABLE II

Comparison of Water Chemistry, Kathlyn Lake and Nearby Streams

Variables	KATHLYN LAKE - 13.VIII.73 Sampling Depths					Kathlyn Cr.	Simpson Cr.	Glacier Cr.	"Club" Cr.
	0.0 m	2.5 m	5.0 m	7.5 m	8.0 m	14.VIII.73	14.VIII.73	14.VIII.73	13.VIII.73
Phenolphthalein Alkalinity ($CaCO_3$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity: Total ($CaCO_3$)	15.8	15.4	21.3	23.9	23.9	17.8	8.3	4.9	8.0
Calcium: Unfiltered (Ca)	4.9	4.9	5.7	6.4	6.5	5.0	3.0	2.4	2.9
Calcium: Dissolved (Ca)	4.9	4.9	5.5	6.2	6.3	5.0	3.0	1.7	2.8
Carbon: Total Organic (C)	6.	6.	9.	9.	11.	8.	1.	<1.	2.
Carbon: Total Inorganic (C)	2.	2.	6.	8.	8.	3.	1.	<1.	1.
Hardness: Total ($CaCO_3$)	16.6	16.6	18.6	20.9	21.3	17.2	9.01	5.07	8.84
Total Soluble Phosphorus	0.006	0.010	0.012	0.020	0.030	0.008	0.004	0.009	0.005
Magnesium: Dissolved (Mg)	1.05	1.05	1.18	1.32	1.35	1.15	0.37	0.20	0.45
Nitrogen: Ammonia (N)	<0.01	<0.01	0.01	0.24	0.25	0.03	0.03	0.03	<0.01
Nitrogen: Dissolved Nitrate + Nitrite (N)	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	0.04	0.05
Nitrogen: Organic (N)	0.24	0.27	0.39	0.32	0.28	0.28	<0.01	<0.01	0.06
Nitrogen: Total (N)	0.24	0.27	0.40	0.56	0.53	0.31	0.03	0.04	0.11
pH (units)	7.6	7.4	6.6	6.6	6.6	7.3	6.9	6.4	6.8
Phosphorus: Dissolved Ortho Phosphate (P)	<0.003	<0.003	0.006	0.014	0.023	<0.003	<0.003	0.005	0.003
Phosphorus: Total (P)	0.009	0.011	0.035	0.051	0.071	0.014	0.005	168.0*	0.10
Specific Conductance (umhos/cm)	44.	44.	51.	58.	60.	45.	25.	18.	25.
Turbidity (units)	0.8	1.0	4.3	11.0	16.0	1.7	0.7	160.*	8.0
Chloride: Dissolved (Cl)						1.0	<0.5	<0.5	
Magnesium: Unfiltered (Mg)						1.13	0.44	0.41	
Potassium: Dissolved (K)						0.5	0.1	0.3	
Residue: Total (105°C)						42.	2.	222.	
Residue: Nonfilterable (105°C)						1.2	1.6	217.	
Residue: Fixed Nonfilterable (550°C)						<1.	1.2	214.	
Residue: Volatile Nonfilterable						<1.	<1.	2.2	
Silica: Reactive (SiO_2)						4.1	2.9	1.6	
Sodium: Dissolved (Na)						1.6	0.4	0.6	
Sulphate: Dissolved (SO_4)						5.0	5.0	5.5	
Temperature: (°C)	19.1	18.6	12.1	9.8	9.6	15.8	6.0	5.0	11.0
Dissolved O_2 (ppm)	8.8	8.6	<1.0						

*Suspect Data

TABLE III

Chemical-Physical Properties of Waldo Lake
(extremely low productivity)
on Dates of ^{14}C Experiments at 20 m Depth

Measurement	June 23	July 24	August 19	September 22
NH_3-N (mg/litre)	<0.01	<0.01	<0.01	0.01
NO_2-N (mg/litre)	<0.01	<0.01	<0.01	<0.01
NO_3-N (mg/litre)	<0.01	<0.01		<0.01
Kjeldahl-N (mg/litre)	0.2	<0.1	0.4	
Total phosphate (as P) (mg/litre)	0.002	<0.01		0.003
Ortho phosphate (as P) (mg/litre)	0.002	0.003	0.006	<0.002
Total organic carbon (mg/litre)	3.0	<1.0	2.0	<1.0
Total inorganic carbon (mg/litre)	0.5	0.5	0.5	0.5
pH	5.7	5.8	5.7	6.0
Total alkalinity (mg/litre)	2.5			6.0
Total hardness (mg/litre)	3.0		1.0	
Total iron (mg/litre)			<0.04	
Dissolved oxygen (mg/litre)	10.9	10.8	10.6	9.3
Temperature (°C)	6.5	7.6	8.8	9.4
Submarine photometer: Percent of surface illumination				
Neutral filter	24.	27.	22.	21.5
Green filter		24.	22.	23.
Secchi disc (m)	24.	29.	29.	22.
Chlorophyll a (mg/m^3)	0.12	0.04	0.07	0.35

From: Powers *et al.* (1971)

TABLE IV

Chemical-Physical Properties of Triangle Lake
(moderately productive)
on Dates of ^{14}C Experiments at 4 m Depth

Measurement	July 7	August 5	September 2
NH_3-N (mg/litre)	0.01	<0.01	0.01
NO_2-H (mg/litre)	<0.01	<0.01	<0.01
NO_3-N (mg/litre)	<0.01	<0.01	<0.01
Kjeldahl-N (mg/litre)	0.3	0.4	0.4
Total phosphate (as P) (mg/litre)	0.017		0.009
Ortho phosphate (as P) (mg/litre)	0.007	<0.002	0.003
Total organic carbon (mg/litre)	<1.	<1.	
Total inorganic carbon (mg/litre)	5.0	4.4	2.8
pH	7.3	7.4	6.8
Total alkalinity (mg/litre)	17.	16.	15.
Total hardness (mg/litre)		14.	13.
Total iron (mg/litre)			<0.05
Dissolved oxygen (mg/litre)		9.6	8.4
Temperature (°C)	19.0	21.7	20.5
Submarine photometer: Percent of surface illumination			
Neutral filter	11.2	22.4	11.0
Green filter		13.7	15.6
Secchi disc (m)	2.2	3.5	2.5
Chlorophyll a (mg/m^3)	4.7	3.6	3.5

From: Powers et al. (1971)

TABLE V

Chemical-Physical Properties of Cline's Pond
(highly eutrophic)
on Dates of ^{14}C Experiments at 0.5 m Depth

Measurement	July 14	July 29	August 11	September 10
NH_3-N (mg/litre)	0.03	0.04	<0.01	<0.01
NO_2-N (mg/litre)	<0.01	<0.01	<0.01	<0.01
NO_3-N (mg/litre)	<0.01	<0.01	<0.01	<0.01
Kjeldahl-N (mg/litre)		1.4	1.1	1.1
Total phosphate (as P) (mg/litre)	0.16	0.04	0.006	
Ortho phosphate (As P) (mg/litre)	<0.01	0.007	0.009	0.273
Total organic carbon (mg/litre)	7.	5.	7.	5.
Total inorganic carbon (mg/litre)	18.	13.	11.	14.
pH	10.9	7.7	8.8	7.8
Total alkalinity (mg/litre)	61.0	46.8	41.3	56.0
Total hardness (mg/litre)	39.	36.		43.
Total iron (mg/litre)	0.50	0.60		3.3
Dissolved oxygen (mg/litre)	13.6	7.6	8.6	2.8
Temperature (°C)	21.0	22.0	23.0	19.5
Submarine photometer: Percent of surface illumination				
Neutral filter	9.0	40.9	26.7	20.8
Green filter		38.5		15.7
Secchi disc (m)	0.4	1.1	1.4	1.2
Chlorophyll a (mg/m^3)	21.1	13.9	8.3	13.2

From: Powers *et al*. (1971)

TABLE VI

Total Nitrogen and Phosphorus Contents of Samples of Higher Aquatic Plants Collected at Intervals During Growing Season from Lake Mendota, 1964 (%)

Plant Species	Dates Sampled							
	June 29		July 22		August 18		September 14	
	N	P	N	P	N	P	N	P
Ceratophyllum demersum	4.43	0.75	2.11	0.51	2.17	0.56	3.41	0.71
Heteranthera dubia	3.79	0.55	3.24	0.69	2.32	0.51	2.67	0.58
Myriophyllum spp.	2.72	0.41	2.42	0.35	2.63	0.35	2.77	0.41
Potamogeton richardsonii	-	-	3.73	0.45	3.24	0.32	2.59	0.23
Potamogeton zosteriformis	3.65	0.42	3.70	0.35	3.65	0.59	3.37	0.44
Vallisneria americana	3.85	0.42	2.88	0.42	2.34	0.43	1.98	0.37

From: Gerloff (1969)

TABLE VII

Total Organic Carbon and Total Inorganic Carbon Concentrations in Selected Lakes in British Columbia

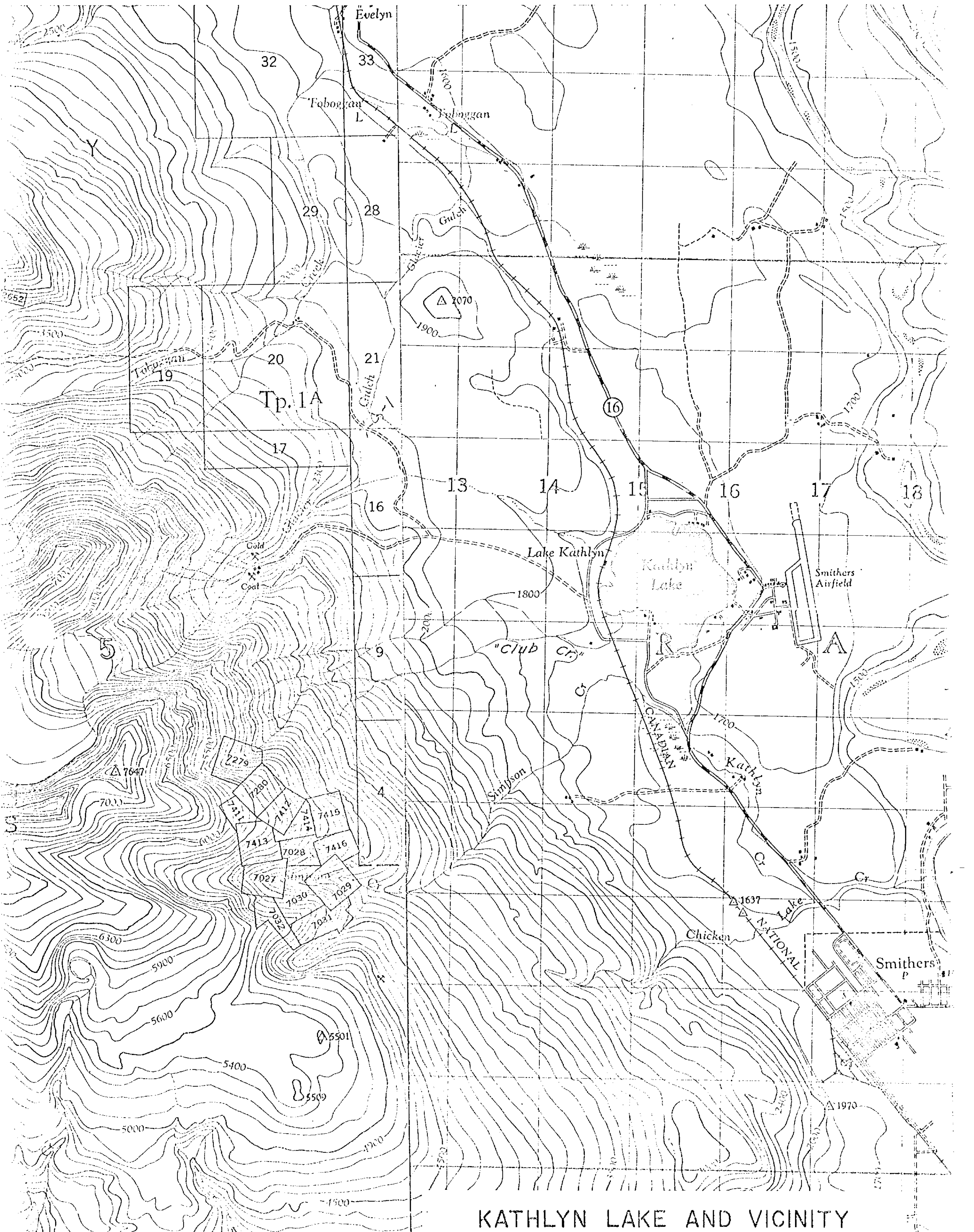
	Total Organic Carbon				Total Inorganic Carbon			
	Number of Samples	Range Low	Range High	Average	Number of Samples	Range Low	Range High	Average
Kalamalka Lake	30	5	11	7.5	30	28	56	34
Langford Lake	27	3	12	6.4	20	9	15	10.9
Wood Lake	28	7	20	11.7	28	22	41	30.4
Okanagan Lake	35	5	19	8.9	35	13	30	23.6
Kathlyn Lake	5	6	11	8.5	5	2	8	5

TABLE VIII

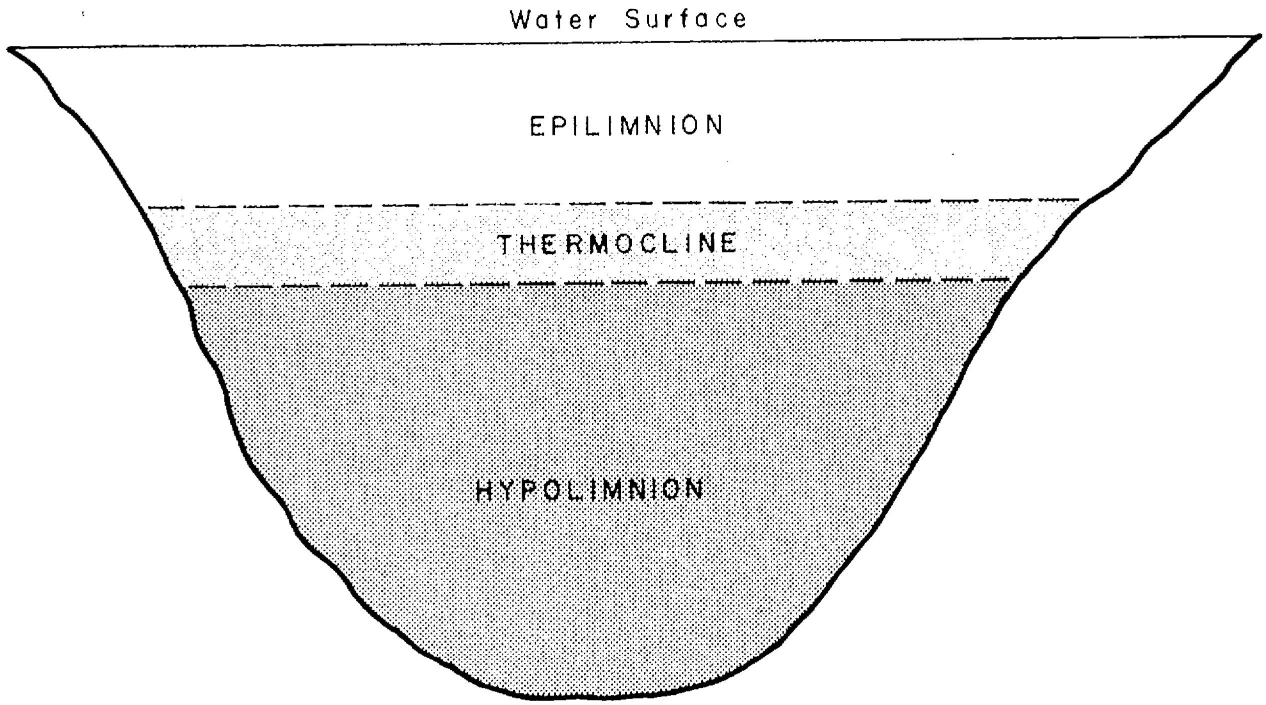
Plankton Algae Species Recorded in Kathlyn Lake on August 13, 1973

Numbers in Columns are Number of Specimens per Millilitre

Species (Grouped by Class)	Sampling Depths 0.0 m	2.5 m	5.0 m	7.5 m	8.0 m
CHLOROPHYCEAE					
Cosmarium sp.			40		
Crucigenia tetrapedia			40	40	40
Oocystis cf. *lacustris*					60
Scenedesmus arcuatus			140		
Schroederia setigera		20	10	20	
EUGLENOPHYCEAE					
Trachelomonas sp.	40	10	40	200	20
BACILLARIOPHYCEAE					
Nitzschia sp.	20				
Tabellaria fenestrata	80		80	40	
CHRYSOPHYCEAE					
Mallomonas sp.	40	60			
CRYPTOPHYCEAE					
Cryptomonas ovata	40	40	120	40	10
Rhodomonas minuta	580	520	280	40	30
CYANOPHYCEAE					
Anabaena sp.	20		170		
TOTAL SPECIMENS/ml	820	650	920	380	160



KATHLYN LAKE AND VICINITY



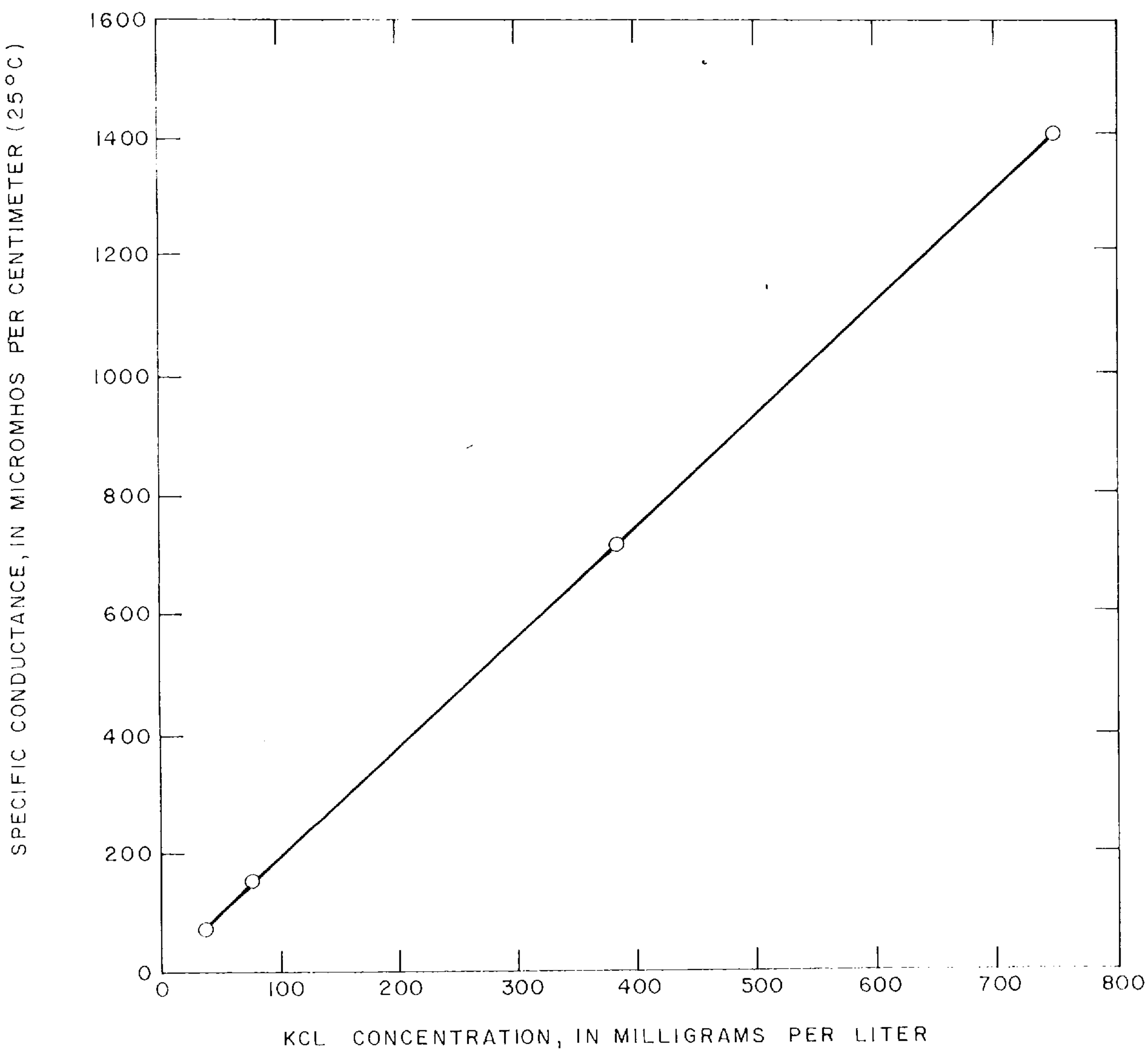
EPILMNION - the warm (lighter) upper layer of water.

THERMOCLINE – the transition layer of rapid temperature change between the upper warm water layer and the deep cold water.

HYPOLIMNION - the deep cold (heavier) water zone below the thermocline.

SECTION OF TYPICAL LAKE DURING SUMMER, SHOWING THE 3 ZONES RESULTING FROM THERMAL STRATIFICATION

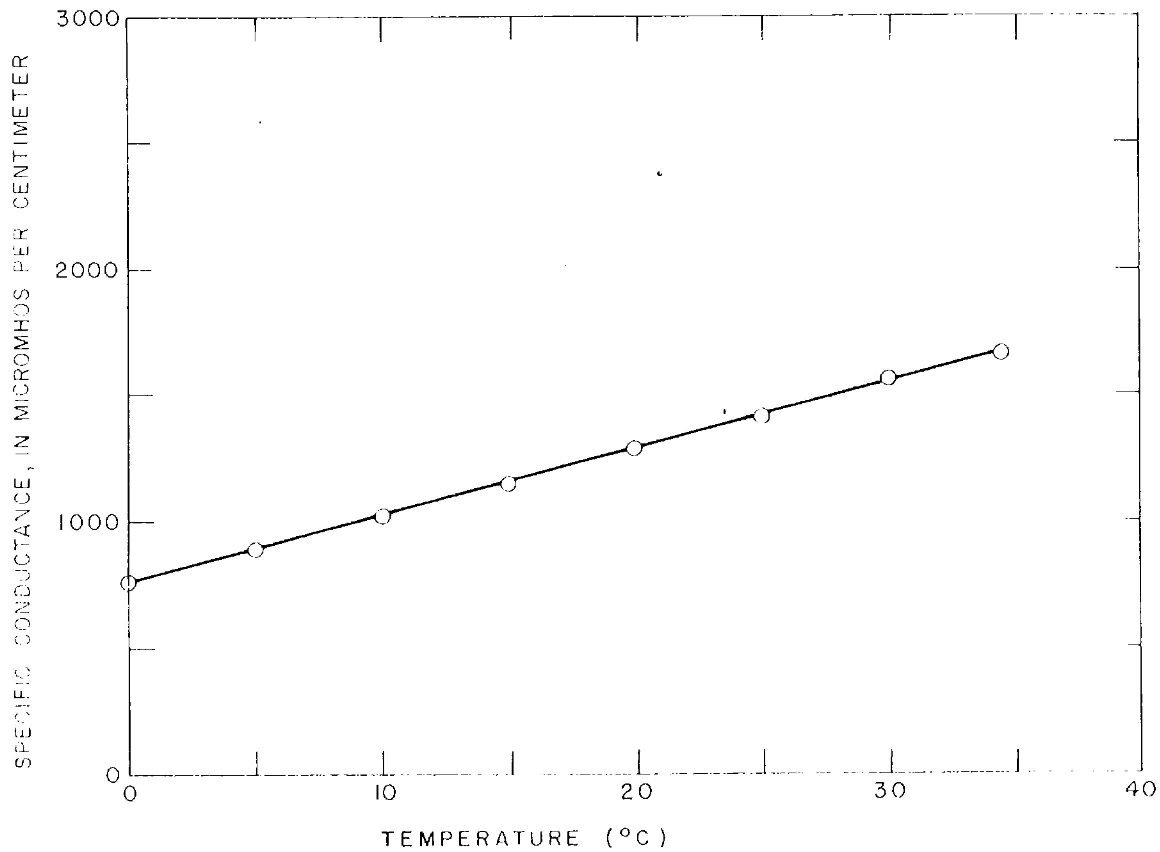
Figure 3



NOTE From Hem (1970), p. 97.

SPECIFIC CONDUCTANCE OF
POTASSIUM CHLORIDE SOLUTIONS

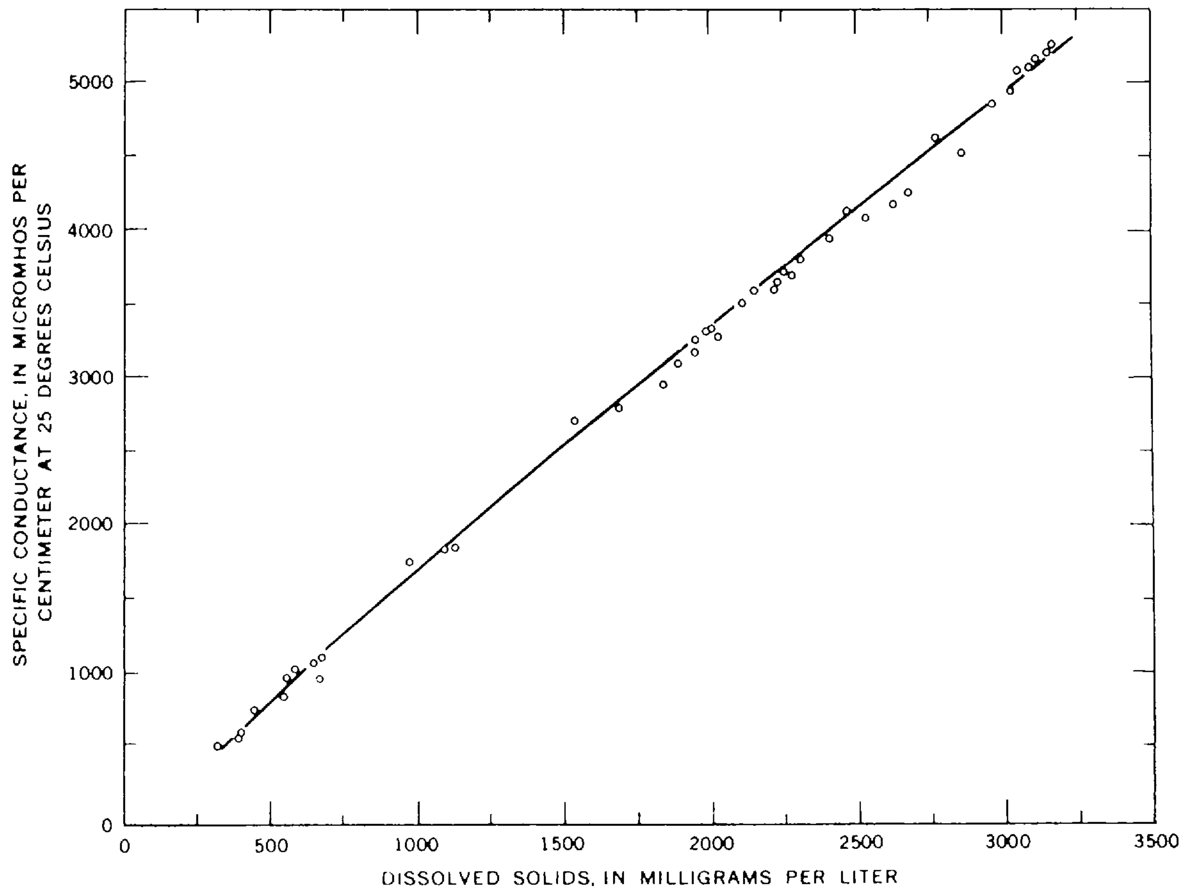
Figure 4



NOTE: From Hem (1970), p. 98.

TEMPERATURE EFFECTS ON SPECIFIC CONDUCTANCE
OF 0.01 M. POTASSIUM CHLORIDE SOLUTION

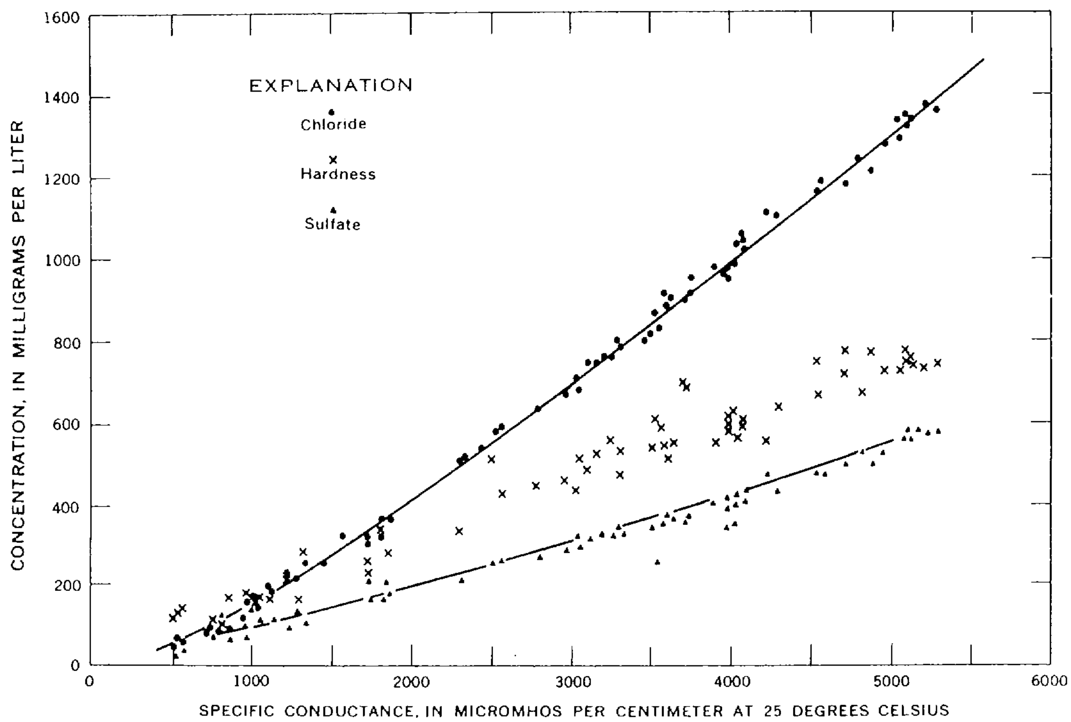
Figure 5



NOTE: From Hem (1970), p. 100.

AN EXAMPLE OF
SPECIFIC CONDUCTANCE VS DISSOLVED SOLIDS

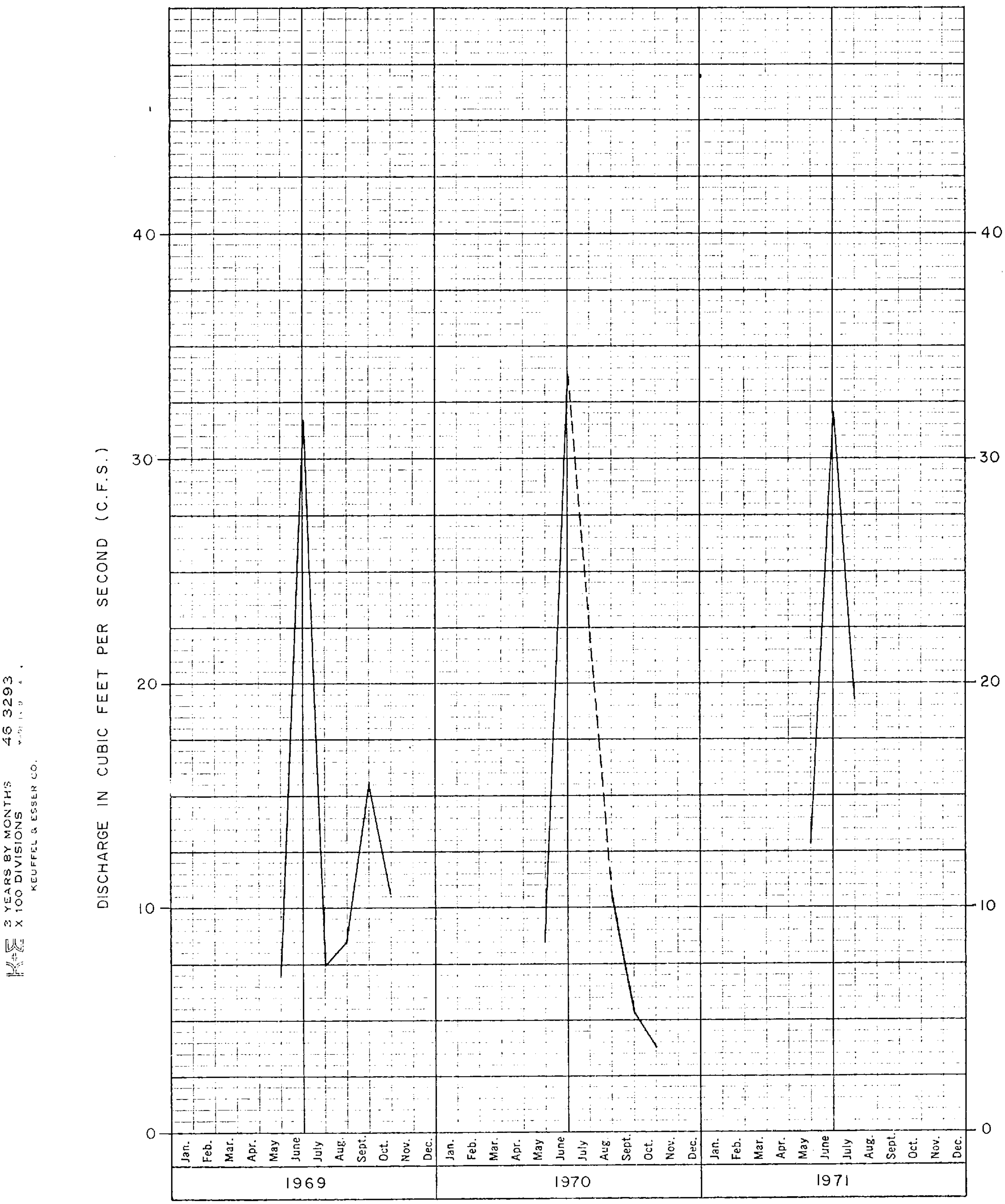
Figure 6



NOTE: From Hem (1970), p. 101.

AN EXAMPLE OF SPECIFIC CONDUCTANCE VS CHLORIDE, HARDNESS AND SULFATE

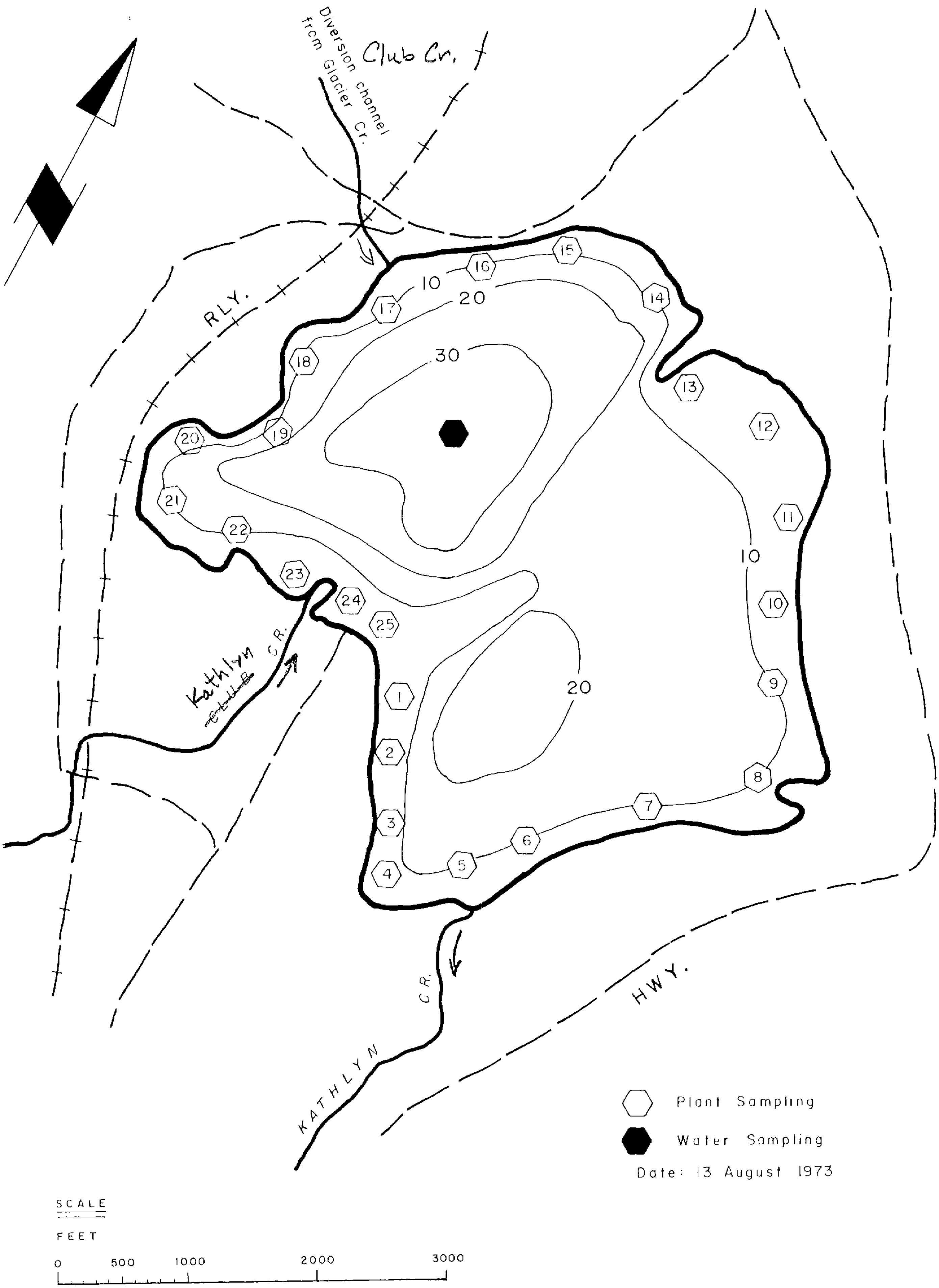
Figure 7



MONTHLY DISCHARGE, SIMPSON CR. AT MOUTH

STATION Nº 8EE 12

Figure 12



SAMPLING STATIONS, KATHLYN LAKE

Figure 14

APPENDIX I

Chemical and Physical Data from the Northwest Basin (K_2) of Kathlyn Lake Collected after August, 1973

Variables	13.V.74 1.0 m	13.V.74 8.0 m	22.VII.74 1.0 m	22.VII.74 4.0 m	22.VII.74 6.0 m	22.VII.74 8.0 m
Alkalinity: Total ($CaCO_3$)	18.3	18.1	15.0	14.5	16.5	20.0
Calcium: Dissolved (Ca)	5.6	5.7	4.8	4.6	5.2	5.8
Carbon: Total Organic (C)	12.	11.	7.	6.	7.	7.
Carbon: Total Inorganic (C)	4.	5.	2.	2.	4.	7.
Total Soluble Phosphorus	0.009	0.011	0.006	0.005	0.006	0.013
Magnesium: Dissolved (Mg)	1.49	1.47	1.17	1.12	1.15	1.27
Nitrogen: Dissolved Nitrate + Nitrite (N)	0.05	0.08	<0.02	<0.02	<0.02	0.02
Nitrogen: Total Kjeldahl (N)	0.41	0.39	0.11	0.28	0.31	0.53
Nitrogen: Total (N)	0.46	0.47	0.11	0.28	0.31	0.55
pH (units)	7.2	7.0	7.4	7.0	6.7	6.6
Phosphorus: Dissolved Ortho Phosphate (P)	<.003	0.003	<.003	<.003	<.003	0.007
Phosphorus: Total (P)	0.022	0.026	0.010	0.015	0.017	0.026
Specific Conductance (umhos/cm)	52.	51.	45.	43.	48.	56.
Turbidity (units)	2.8	3.3	1.2	1.8	3.8	8.7
Cadmium: Unfiltered (Cd)			<.0005	<.0005	<.0005	<.0005
Copper: Unfiltered (Cu)			0.003	0.002	0.003	0.003
Iron: Unfiltered (Fe)			0.2	0.3	0.5	0.5
Lead: Unfiltered (Pb)			<.001	<.001	<.001	<.001
Mercury: Unfiltered (Hg) (ug/l)			<0.05	<0.05	<0.05	<0.05
Nickel: Unfiltered (Ni)			<0.01	<0.01	<0.01	<0.01
Zinc: Unfiltered (Zn)			<.005	<.005	<.005	<.005
Temperature (°C)	7.3	6.2	17.3	14.0	10.0	9.8
Oxygen: Dissolved (mg/l)	10.1	9.3	9.5	8.5	1.1	<0.8
Conductivity (Field)	65.	60.	52.	50.	55.	61.