

CHEMISTRY OF LAKE SUPERIOR

by

**R. R. Weiler
Basin Investigation & Modeling
Applied Research**

PREFACE

This report was written as a draft for chapter 5.3 of volume III of the IJC report on the Upper Great Lakes which is to be published in the spring of 1977. As a consequence, the report contains references to other chapters in the report. Rather than rewriting the draft again to eliminate these references, the author decided to publish it as it was and to add extra material at the end as appendices.

CONTENTS

Preface	i
The Chemistry of Lake Superior	1
Introduction	2
Sampling and analytical methods	3
Major ions and conductivity	6
Trace elements	9
Nutrients	11
Oxygen and pH	14
Toxic substances	14
Discussion	15
Baseline values for epilimnion chemistry of Lake Superior	22
General Summary	22
References	23
List of Tables	25
Tables	26
Figure Captions	40
Figures	41
Addendum	57
Appendices	59
Introduction	60
Appendix A: concentrations in 1973 by cruise and lake segment	62
Appendix B: concentrations for zone 13 in 1973	89
Appendix C: concentrations for 1968-1971 in zones I and VIII	92

THE CHEMISTRY OF LAKE SUPERIOR

INTRODUCTION

The chemistry of Lake Superior is determined by the geology of the drainage basin, by the climate, by man-made inputs and by biological processes in the lake.

Most of Lake Superior lies in the Precambrian rock of the Canadian Shield. These rocks were laid down in extensive seas of either salty or fresh water, but have been metamorphosed into slates, quartzites, phyllites, gneisses and other types, depending on their composition and degree of metamorphosis. Large areas of the Shield contain granite and other igneous rocks. Lapping the Shield are Paleozoic sedimentary rocks, mainly limestones, dolomites, shales and sandstones, which have been consolidated but otherwise not greatly altered. These rocks wedge out on the flanks of the Shield.

Except for sections of the Shield, the bedrock is overlain by unconsolidated Pleistocene sediments derived from glacial and related action. Along the southern shore of the lake, the surficial sediments are a mixture of clay, sand and some carbonates and in the western tip, mostly clay.

Rivers and springs located in areas of igneous and metamorphic rocks will be rather dilute (total dissolved solids of the order of 4 to 10 mM/l) and contain large amounts of silica (0.1 to 2 mM/l). Depending on the source, the predominant cations are either sodium and potassium, or magnesium and calcium. The predominant anion is bicarbonate, derived mostly from the air. Waters from shales and sandstones are more concentrated, contain less silica and are dominated by sodium and potassium, and sulphate or bicarbonate. Calcium and magnesium, and bicarbonate are the main ions derived from limestone and dolomites, and the amount of silica is very small (around 0.2 mM/l).

* The material in the introduction is based on the following references: Hough (1958); Chandler (1964); Upchurch (1972); Hem (1970); and the additional reference "Great Lakes Water Use" map, 1st edition and published by the then Department of Fisheries and Forestry (Canada).

The lake is located between the source regions of contrasting polar and tropical air masses. As a result, the winters tend to be cold and snowy and the summers hot and humid. The precipitation is spread out rather evenly over the year and amounts to 75 to 100 cm/year. Therefore, erosional rates are not high especially since most of the rock is quite resistant to weathering and the natural inputs from the weathering of rocks will be spread out evenly over the year. The drainage area of Lake Superior is not large -- around $125,000 \text{ km}^2$ -- and is only 1 1/2 times the surface area of the lake itself. The wet and dry fallout directly on the lake, therefore, must contribute considerably to the input of some materials. On the other hand, since precipitation is less concentrated in other materials than the rivers, the input from the latter will be considerably diluted by the precipitation on the lake.

Finally, the region around Lake Superior is thinly populated with most of the drainage area having a population density of less than 10 per square kilometre. Only in the western tip of the lake and around Thunder Bay do the population densities approach $40/\text{km}^2$, with the Duluth region having around $400/\text{km}^2$. These are also the two main industrial regions.

The predominant form of land use is forest and wildland. Farming occurs in the two regions mentioned above and spottily along the southern shore.

Compared to the other Great Lakes, the impact of man on Lake Superior is as yet relatively small and localized and the chemistry is dominated by natural inputs.

Sampling and Analytical Methods

This discussion of the chemistry of Lake Superior is based chiefly on information gathered by Canada Centre for Inland Waters during 1973, although earlier CCIW results as well as other available data have been used.

Over two hundred stations were sampled on six cruises in 1973. The numbers and dates of these cruises, as well as of earlier CCIW cruises, are listed in Table 1. The results were analysed on the basis of fifteen zones into which the lake was divided (Figure 1a). The results of earlier years are discussed on the basis of only the eight zones shown in Figure 1b.

Although almost every station was sampled for nutrients and oxygen on every cruise, only around thirty stations were sampled for the trace metals and the major ions. Consequently, some zones were not sampled at all or not sampled on every cruise or are represented by a single station. Table 2 lists the zones sampled for a particular parameter as well as the number of stations in that zone.

Averages for each zone and for the whole lake were calculated as follows. For all parameters, a simple arithmetic average for the first ten metres -- to approximate the epilimnion -- and for the layer 10 metres to the bottom (hypolimnion) was calculated. For the nutrients and oxygen, an area and volume-weighted average was calculated for the whole water column.

The methods of sampling, sample treatment and the analytical procedures used by the Water Quality Branch (WQB) Laboratory (Ontario Region) are described by Philbert and Traversy (1973). The samples for soluble nutrients, total alkalinity, major ions and trace metals were filtered through .45 μ pore size Sartorius cellulose acetate filters.

A brief discussion of the probable magnitude of the errors for the parameters follows. There are three types of errors: analytical, sampling and inter-laboratory.

The analytical errors for the WQB Laboratory methods are given in Philbert and Traversy (1973), but some values have been revised since (F. Philbert, WQB, personal communication). Strachan (1973) has discussed sampling errors for some parameters. Inter-laboratory comparisons for

major cations and anions are discussed by McGirr and Wales (1973, 1975) and McGirr (1974). The analytical and other errors are listed in Tables 3a, 3b and 3c.

Based on the results given in the above publications, it seems that the analytical and interlaboratory standard deviations are roughly a constant percentage of the mean, whereas the sampling error is a constant value independent of the size of the mean. The ratio of the sampling error to the analytical error varies from around 1.5 to over 20, depending on the parameter, with the most common value being around 4 to 5. If the sampling error is not known, it may be estimated by multiplying the analytical error by five.

Although the analytical variation for trace metals ranged from 2 to 15% (measured as a relative error of the mean), the WQB Laboratory experience is that, near the detection limit, the variation is of the order of 100%. The occasional very high values in trace element concentration -- 10 to 100 times the mean -- can probably be ascribed to contamination at some stage in the processing of the sample. Such obviously erroneous values have been rejected from further analysis. Samples only slightly contaminated, however, may not have been identified. The values quoted for the trace metals are, therefore, more likely to be too high than to be too low.

The results from different laboratories for replicate samples can easily differ by a factor of 2 (McGirr and Wales, 1973) and "systematic biases commonly are present in data sets that arise from chemical determinations carried out in several laboratories" (Robertson, Elder and Davies, 1974). These may be caused by the use of different analytical methods or by the faulty application of the same method.

It is, therefore, very difficult to establish long-term trends from analyses obtained by different laboratories. Similarly, it will be very

difficult to determine the actual concentrations of chemical species, especially trace metals and nutrients, in Lake Superior since the year-to-year changes are so small and many species are at or below the detection limit of the analytical method.

Major Ions and Conductivity

The lakewide averages of major ion concentration as measured by CCIW in the years 1968 - 1973 are shown on Figure 2. Except where indicated by the error bars, one standard deviation is delimited by the size of the symbol.

No significant differences could be found among the zonal averages or between the epilimnion and hypolimnion values, by either the t-test or the Mann-Whitney rank-test using the zonal averages. The only exception is chloride in zone 7 which is significantly higher by about 0.1 to 0.3 mg/l than the concentration in zone 13. Progressively lower average concentrations are found in zones 8 and 9*.

No major ion shows a seasonal cycle with the possible exception of alkalinity. The apparent drop during the summer months is not, however, consistent from year to year. The charge balance of the anions and cations can be used to check on the reality of the drop. The concentration in Table 4 gives an exact balance. The sum of the negative charges is about 1.5% higher than the sum of the positive charges if the alkalinity for the May, 1973 cruise (42.9 mg/l) is substituted. The use of the August value (41.3 mg/l) makes the negative charges about 1.8% too low. Therefore, it is likely that the May value is high and the August value low although, considering the error limits shown in Table 4, they cannot be dismissed completely.

* As an indication of the difficulties in determining accurately the concentration at low levels of even so common an ion as chloride, it should be noted that for the last 1973 cruise the average concentrations in all of the zones are 0.5 - 0.6 mg/l higher than the averages for all of the previous cruises in that year. Another example is the sulphate value for the April, 1970 cruise which is more than one mg/l lower than all the other results.

In the light of the above discussion, the average values in Table 4 for the major ions, based on the CCIW results from 1968 to 1973, are believed to be accurate to within the limits shown. In the same table are given the values Callender (1973) has chosen, based on a review of a different data base. The agreement is quite good.

The long-term variations in the chemistry of Lake Superior are shown on Figure 3. The data are from unpublished CCIW results for 1968 - 1973; Beeton (1965); Callender (1973); Ayers (1962); Parker et al (1969); and Chandler (1964). Many of these, especially Beeton, also quote earlier values.

Calcium, magnesium, chloride and sulphate have remained unchanged since 1885 within the errors of measurement. The sodium and potassium are unchanged since about 1940. The earlier higher values are likely caused by difference in analytical methods (Beeton, 1965). The decline in total dissolved solids is likely not real since it is a difficult parameter to measure with great precision. McGirr (1974) quotes an inter-laboratory standard deviation of 12.8 at a concentration of 75 mg/l.

A major problem exists with the alkalinity values. The pre-1965 levels are around 46 mg/l; the more recent ones cluster around 42. If there has been an actual decrease, then there should also be a decrease in the total amount of cations to preserve charge neutrality. Since such a decrease is not apparent from the data, the earlier higher levels must be in error.

The conductivity reflects the total amount of ions in the lake. Since, as has been shown above, the composition of the lake is essentially unchanged over the period of a year as far as the major ions are concerned, and since the conductivity is corrected to 25°C, then there should be no seasonal changes as shown by the 1973 data. The 1968 - 1971 results confirm this.

The average value for the conductivity for 1968 - 1971 is around 97 μS at 25°C. The 1973 average is around 92. Kramer (1964) has shown that the ionic strength (μ), defined as $1/2 \sum c_i z_i^2$, where c_i is the concentration and z_i the charge on ion i , and conductivity (k) at 18°C are related by the equation

$$\mu = -8.695 \times 10^{-5} + 1.835 \times 10^{-5} k$$

The value for μ is 14.07×10^{-4} and the corresponding k is 81.4. The k at 25°C is then 95.7 μS , in good agreement with the 1968 - 1971 average.

The measurement in February, 1976 of the conductivities of some samples taken between July and November, 1973 and stored since, gave values between 94 and 98 μS . These are from 5 to 14 μS higher than the values for the matched samples measured in 1973. This result lends further credence to the belief that the 1973 conductivities are erroneous.

Adams (1974) quotes a value of 94 μS at 25°C for the eastern half of the lake in 1968 and 96 for the western half in 1969. Callender (1973) quotes an FWPCA value of 97.4 for 1968, but expresses some doubt about its validity. Schelske and Roth (1973) give a value of 95 ± 4.8 for open lake stations in the eastern end and 93 ± 3 for Whitefish Bay for a cruise in July, 1970. On the other hand, data collected by the Reserve Mining Company during the period from June to October, 1972 in the western end of the lake (zones 5 to 8) average around 90.5 ± 2 . This discrepancy in the measured values of 5 to 7 μS cannot be definitely resolved, but from the available information, the most likely value for the lake average is 97 μS .

In summary, therefore, (a) the major ion chemistry has not changed since 1885; (b) the lake is almost homogeneous, both vertically and horizontally with respect to these ions; and (c) at such low levels, quite large analytical and sampling errors can occur with even commonly analysed for ions. Areas close to sources of these ions, such as the Duluth area and other onshore regions are, of course, more variable, but even here

the differences are barely detectable statistically. A complete listing of values and their variances by lake segment may be found in Weiler (1976).

Trace Elements

The values in Table 5 are the averages for the whole lake. The distribution histograms for the same elements are shown on Fig. 4a. In drawing the histograms, values falling exactly on a class boundary are included in the next highest class.

The agreement between the various years (Table 5) is generally within a factor of 2 or 3 which is very good for low levels of trace elements. There are a few exceptions. The higher values that Callender (1973) gives for iron are for total iron, whereas the WQB analyses are for filtered samples. There is no ready explanation for the considerably higher WQB zinc results. It is also suspicious that there is an apparent year-to-year increase and that their zinc values after 1974 in the other Great Lakes are in the range of a few $\mu\text{g/l}$. The average of 1.8 $\mu\text{g/l}$ given by Callender should, for the present, be accepted as the most probable value.

Many of the averages in Table 5 are at or below the nominal detection limit. This situation arose from the decision of the WQB Laboratory to revise its limits after 1973.

Because over 60% of the values for cobalt, lead, chromium and cadmium are below their respective detection limits, no further analysis of the data for these metals was done. The zinc data, also, were not analyzed further since there is considerable doubt about their quality.

Figure 4b gives an indication of the cruise-to-cruise variability of the lake averages. On it are shown also the standard deviations for each cruise, the yearly average for 1973 and the standard deviations calculated

from the cruise averages and the detection limits. There were no significant differences between hypolimnion and epilimnion averages. Single factor analysis of variance tests were done using the zonal averages to see whether the variations between cruises for iron, copper, manganese, and nickel were statistically significant. The testing had to be restricted to the first four cruises since no samples were taken near Duluth (zone 7) for the last two. The variations were highly significant ($P = .001$) for Cu and Ni, but not for iron or manganese. If the value for cruise 305, which is nearly four times the yearly average, is excluded from the nickel analysis, the variation is no longer significant. Thus, only copper can be said to have a seasonal cycle with any degree of certainty. The cycle seems to follow the turbidity which also has minimum values in the July-August period. The trace metal data for the western Lake Superior close to Duluth (Callender, 1973) do not show a cycle similar to the CCIW data for 1973. If anything, the highest values are to be found at the end of August.

The spatial variation during 1973 of iron, copper, nickel and manganese was tested to see whether any of the zones close to land were significantly different from the mid-lake area. The cruise averages for other zones were compared with the averages for zone 13 using the Mann-Whitney rank-test with a two-tailed significance level of 0.05. The hypolimnion averages were used, since results for more cruises were available. Since the averages for the epi- and hypolimnion are, however, not significantly different, the conclusions should also apply to the epilimnion.

The zonal averages and the results of the test are in Table 6. Only in the case of two zones for iron and one zone for manganese are differences on a yearly basis between those zones and zone 13 statistically different. This does not mean that on any one particular cruise there are not significant differences in concentration. For example, in 1971, the iron in zone 1 (near Duluth) was higher ($P = .001$) than the iron in zone 8 (mid-lake) for cruises 301 (May 26 - June 2) and 305 (October 5 - 13). The same is true for copper for cruise 301 only.

It may, therefore, be concluded that there is evidence that the iron and manganese levels are higher than the mid-lake levels only for the area near Duluth. The other variations are not significant.

The conclusions Callender (1973) draws from his study of Lake Superior are the following; the waters in the Duluth area have significantly higher total iron and total manganese levels than other areas in western Lake Superior and there are no significant differences for copper, zinc, chromium, nickel, cadmium and lead. The present study supports these conclusions.

Nutrients

The following will be discussed under this heading: total phosphorus (TP), total dissolved phosphorus (TFP), dissolved reactive phosphorus (SRP), nitrate plus nitrite nitrogen (NO_3), ammonia nitrogen (NH_3) and dissolved reactive silica (SiO_2).

The average lake-wide concentrations* for 1973 calculated from the lake-wide averages for the six cruises are in Table 7. The t-test does not show any significant differences between the annual averages for the epilimnion and the whole water column for any of the nutrients.

In Figure 5 are plotted the lake-wide cruise averages as obtained by CCIW for the epilimnion and the whole water column for 1968 - 1973. All of the parameters show annual cycles in 1973. For silica and nitrate only do the epilimnion values differ from the whole column values, being lower near the surface. This difference is significant (t-test) on cruises 306, 310 and 312 for nitrate, but only on 310 for silica. One way analysis of variance using zonal cruise averages indicates that the annual cycles for the epilimnion are significant at the $P = .001$ level. When, however, the results for cruise 302 are excluded in the nitrate analysis, the variation is no longer significant. Compared with the

*The concentrations of the various phosphorus forms are in $\mu\text{gP/l}$; of nitrate and ammonia in $\mu\text{gN/l}$ and for silica in $\mu\text{gSiO}_2/\text{l}$.

1968 and 1971 values, the average for this cruise does seem to be rather high.

Table 7 also includes values taken from Callender (1973). Results going back in time are also summarized by him and by Dobson (1972). The trends for nitrate, total phosphorus and silica are shown in Figure 6 since for these parameters only are there at least 15 years of data available.

Only nitrate shows a clear-cut historical trend. If the earlier data are reliable, an increase of about $3.3 \mu\text{g/l}$ per year is indicated. The drop of silica values from more than 3.5 mg/l before 1958 to around 2.25 is most likely caused by changes in analytical techniques. The increase in the CCIW silica concentrations from 2.25 mg/l in 1968 - 1971 to around 2.4 in 1973 is ascribed to the change by the WQB laboratory from storage of analytical standards and samples in glass bottles to storage in Teflon flasks. Since this change eliminated the contamination of standards by the leaching of silica from the glass flasks, the higher 1973 results should be accepted (F. Philbert, personal communication, 1976).

The total phosphorus values are more scattered. The two early values are unexplained but can probably be dismissed as being too high. The pre-1969 data from CCIW should be treated with caution because of possible contamination by the Millipore filters then used. The results for 1970-1972 are between 2.5 and $4 \mu\text{g/l}$, but in 1973, the CCIW values were around 6.5. From Table 7, it is clear that for all three phosphorus fractions the 1973 values are about twice as high as the previous CCIW results. A new analytical method was adopted by the WQB Laboratory at the end of 1972. A comparison between the new and old methods showed no bias and, if anything, the newer method would be expected to give results that are lower than the older. The high values for the September cruise are attributed to analytical difficulties which were later resolved (F. Philbert, personal communication, 1976).

The ammonia values are too few and too variable to draw any conclusions about long-term trends.

On the basis of the above discussion, the present lake-wide concentrations for nutrients in Lake Superior averaged over a year are in $\mu\text{g/l}$: nitrate - 285; ammonia - 2-6; silica - 2400; total phosphorus - 3-6; total filtered phosphorus - 2-4.5; soluble reactive phosphorus - 0.9-1.6. Despite the large uncertainty in the absolute values, analyses for areal and seasonal trends are not affected as long as data from the same laboratory and analyses by the same method are used.

Areal variations in Lake Superior are not extensive. This conclusion was reached by comparing averages for the top ten metre layer of the fourteen other zones with that of zone 13. The t-test was used. Only those zones for which at least 50% of the cruises had differences that were significant at $P = .01$ or better were considered further. In the case of soluble reactive phosphate, there were no such zones.

The results of this analysis are shown on Table 8. Zone 7 is the only zone common to all of the parameters; zone 1 for all except silica. It is difficult to descry an overall pattern from this table, but the following observations can be made.

In the case of TP and TFP, zone 7 is always higher. Zone 1 is generally also higher. Both zones are higher in the case of ammonia. For nitrate, all of zones except 5 are depleted relative to zone 13, especially in spring and summer. Indeed, during cruise 306 (July 27 - Aug. 7), all of the zones, including 14, are lower than 13. Zone 5 is the only one that is almost always higher. In the case of silica, the pattern is more complex. Zones 2, 9 and 11 along the southern and eastern shores are depleted relative to 13, whereas 6, 7 and 15 are enriched, except for cruises 306 and 310 (Sept. 6 - 16).

Oxygen and pH

The yearly averages for 1973 for these parameters are given in Table 9 together with averages for other years taken from Callender (1973). The CCIW values for individual cruises during 1968 - 1973 are plotted on Figure 7.

The oxygen concentrations for all of the years are in good agreement. The lake remains essentially saturated with oxygen since the percent saturation for the whole lake drops below one hundred only in November. The average percent saturation for the whole colum is 101.5 ± 2.1 . However, areas of oxygen depletion do occur during August - September in Zone 1. Values as low as 82% of saturation were prevalent.

With pH, there is a definite divergence between the different years. Whereas before 1973 there is no seasonal variation, in 1973 there definitely is.

Toxic Substances

Water, seston and sediment samples were collected on a cruise during July 29 - August 6, 1974 in Lake Superior at stations shown on Figure 8. The water samples were collected at a depth of one metre, stored, refrigerated, extracted and analysed by gas chromatography (Strachan, 1975).

No traces of any of fifteen organophosphorus pesticides were found. The quantification limit ranged from .005 to .05 $\mu\text{g/l}$. It may be concluded that these "are either not being applied in quantity in the drainage area of these water bodies or are biodegrading at a rate sufficient to reduce them to levels below those of detection" (Strachan, 1975).

No organochlorine pesticides (quantification limit of .005 to .01 $\mu\text{g/l}$ for the 17 species examined) or polychlorinated biphenyls (PCBs quantification limit of .1 $\mu\text{g/l}$) were found. Detectable amounts of

lindane, which is the active component in benzene hexachloride, were found in every water sample examined.

DISCUSSION

It was mentioned in the introduction that the following factors determine the chemistry of Lake Superior: the geology of the drainage basin and the climate, which together determine the amount and nature of the chemical input into the lake and, hence, its basic chemistry; man-made inputs, and, finally, biological processes which determine the seasonal variations in the lake.

For a lake to be in equilibrium, the outputs must equal the inputs from all sources. The historical data presented in the section as major ions strongly suggest that, at least for these components, this is the case for Lake Superior.

Budgets for total dissolved solids, chloride, dissolved silica, and total phosphorus and nitrogen have been presented in Chapter 3, section 3.10. Upchurch (1972) has calculated the inputs for dissolved solids, chloride, phosphorus, calcium and aqueous silica. The two sets are compared in Table 10. Upchurch has not estimated the municipal and industrial inputs going directly into the lake. Wastewater discharges upstream from the mouths of tributaries are included in the tributary inputs for both sets of calculation.

It was pointed out in Chapter 5.1.3 that "the concentration of any material in the lake will increase if the amount discharged annually via the St. Marys River is less than 0.56% of the total amount in the lake. As the lake volume is $11.92 \times 10^{12} \text{ m}^3$, the discharge limit of non-degradation is $66,750 \text{ C metric tons/yr.}$, where C is the lake mean concentration in ppm". This figure has also been included in table 10 as an equilibrium discharge.

The inputs calculated in Chapter 3 are higher than those of Upchurch (1972). The discrepancy is largest for chloride. The theoretical and actual outputs from the lake are in close agreement suggesting the concentration in the lakes is either not increasing or is increasing very slowly. The positive residual in the budgets suggests that the latter is the case.

Part of this discrepancy is caused by the difficulties in calculating budgets (see discussion below). The other part is explained by biological activity. Large portions of the dissolved nitrogen, phosphorus and silica are sedimented out together with organic carbon and, hence, removed from the water column. It is to be expected, therefore, that their inputs should exceed their outputs.

If the all of 313 Gg of silica were retained in the water column, then the concentration should increase by about 0.025 mg/l/year (app. 1%/year). Such an increase should be detectable over a period of 5 years. No conclusions about an actual increase can be drawn from the available data.*

The amount of total phosphorus retained is 2.95 Gg. This would amount to a yearly increase of 0.25 $\mu\text{g/l}$. The available data do not allow any conclusions to be drawn about actual changes in concentration.

For nitrogen, the amount retained (73.4 Gg) should give rise to a yearly increase of about 6 $\mu\text{g/l}$. The apparent increase in nitrate is about 3 $\mu\text{g/l}$, suggesting that about 50% of the incoming nitrogen is sedimented out.

There are no known sinks for total dissolved solids or for chloride. It could be argued that the residual of the total solids is precipitated out as a carbonate. However, as has been shown by Weiler and Chawla (1969),

* The apparent increase between 1971 and 1973 in the CCIW data is about 0.2 mg/l; the theoretical one should be about 0.05. As discussed in the earlier section on nutrients, the measured increase can be explained by analytical difficulties.

Lake Superior is undersaturated with respect to both calcite and dolomite. The residual is, therefore, most likely due to the difficulties inherent in budget calculations. As an example of this, the total dissolved solids budget for Lake Huron (Vol. II, Chap. 3) shows a considerable excess of outputs over inputs.

The chloride inputs as calculated in Chapter 3 are three times those of Upchurch and the atmospheric inputs are 6 times larger. It is possible to compare different aspects of the loadings in detail.

First of all, the total yearly discharges of water by the tributaries are quite comparable. The water budget in Chapter 5.1 gives about 48 Tl; Upchurch calculates 45 and, from the data used in the Chapter 3.1 calculations, it is possible to obtain a figure of 47. However, when the discharges, mean chloride concentrations and loadings from individual tributaries are compared, two to five-fold differences are common. As the flow differences are usually within a factor of two, the main problem seems to lie in the chloride determinations.

An earlier paper by Eriksson (1955) gives discharge rates of chloride by rivers in the eastern half of the United States. The discharge for the Lake Superior watershed varies between 3.5 and 10 kg/ha/yr with an average of around 7. Based on a drainage area of $125,000 \text{ km}^2$, discharge at 7 kg/ha/yr amounts to 87 Gg/yr which is not far from that calculated by Upchurch.

A curious feature is the rather small percentage, based on the figures of Junge and Werby (1958), of the total chloride loading by tributaries that is contributed by precipitation. On the assumption that rainfall over the lake and over the drainage area are equal and that there are no sinks for chloride on land, then the amount reaching the lake via the tributaries is equal to the amount falling directly on the lake multiplied by the ratio of the drainage area to the lake surface. The amount discharged then would be 10.5 - 12 Gg/year which would equal, to between 6 and 12% of the calculated river loadings in Table 10.

Hence, most of the chloride in the rivers is derived from other sources. Eriksson (1955) suggests several other sources, including rock weathering, agricultural fertilizers and the capture of aerosols by vegetation. The aerosol particles are later washed off by rains and end up in the streams. Finally, there are the man-made inputs from municipalities, industry and road salting.

A greater discrepancy is found between the amounts contributed by precipitation directly on the lake. The budget in Chapter 3.1 uses atmospheric loading estimates from the study by Acres for the Canada Centre for Inland Waters (1975). The chloride loadings are given in Figure A8.7* of that report. Calculating backwards and using the precipitation amounts in Chapter 5.1, the mean concentration in rain water turns out to be close to 0.9 mg/l. Junge and Werby (1958), on the other hand, give concentration of around 0.12 to 0.14 mg/l for the same region resulting in a loading of 6.9 to 8.0 Gg/yr. Upchurch used the same information in calculating his atmospheric loading.

Some of this difference can be explained by the circumstances that only the precipitation was collected in the Junge and Werby study, whereas the dry fallout was also included in the CCIW study. The Junge and Werby figures should be increased by a factor of 1.25 (Junge and Gustafson, 1957) to 3 (Erikson, 1960) to allow for the dry fallout. If the higher factor is accepted, the concentration in precipitation found by Junge and Werby should be increased to around 0.4 mg/l which agrees with the 0.45 mg/l found by Pearson and Fisher (1971) for their "rural inland stations" in New York state. Shiomi and Kuntz (1973) found around 1 mg/l for stations on land around Lake Ontario, but they feel that their samples were probably contaminated by salt used on roads. Since the stations around Lake Superior were also on land, then the true concentrations in that area should be less than one mg/l.

This is confirmed by some samples collected in 1975 on a buoy in Lake Huron off the Bruce Peninsula. If the grossly contaminated samples

* The loadings should be in $\text{ng}/\text{cm}^2/\text{day}$, not in $\mu\text{g}/\text{cm}^2/\text{day}$ as shown on the figure.

are disregarded (concentrations $>2.5 \text{ mg/l}$), then the average is 0.5 mg/l and around 60% of the samples have concentrations less than 0.3 mg/l (K. Kuntz, 1976, private communication).

There is no reason to believe that the nephelometric method used by Junge and Werby and claimed to be accurate to $\pm 10\%$ and the colorimetric mercuric thiocyanate method (Philbert and Traversy, 1973) give rise to systematic differences.

If the concentration in the precipitation is taken as 0.4 mg/l , then the percent contributed by precipitation to river discharge should be increased to between 18 and 36% (see above) and the atmospheric loading calculated by Upchurch should be around 27 Gg/year (Table 10).

As a final point, if the Chapter 3.1 loadings are assumed to be correct, then the amount retained in the lake is 235 Gg/yr, or the equivalent of 0.02 mg/l/yr . An increase of this magnitude should be detectable, at least over a period of 5 years, but the available data suggest that chloride has remained constant or is increasing at a much lower rate. Therefore, the loadings calculated by Upchurch are more reasonable, especially as there are no known sinks for chloride.

Kramer (1964) has developed an equilibrium model for the chemistry of the Great Lakes. The calculated concentrations for Lake Superior are higher than the actual ones. He points out, however, that the input from the tributaries, which contain "saturated" water, is diluted by precipitation which contains only small quantities of dissolved matter. The calculated concentrations, therefore, should be corrected by the factor land drainage/(land drainage + direct precipitation). Using the figures from Chapter 5.1, the dilution factor is 0.45. The modified concentrations are compared with the actual ones in Table 11. The good agreement suggests that the major ion chemistry in the lake is governed basically by mineral-water equilibria.

The major ions in Lake Superior do not show extensive areal variations. However, zones 7 and 15 are generally different in composition. This is most obvious in the case of chloride which decreased from an average concentration of 1.41 mg/l to 1.22 in zone 8 and 1.28 in zone 9. In zone 15, the average concentration is 1.24. This distribution agrees with what can be expected from the known sources of chloride and the generally counter-clockwise circulation in the lake.

The evidence for temporal changes caused by variations in the flows of tributaries is rather weak. As the major run-off period is in April and May, the highest concentrations in near-shore zones should be found on the May cruise. In zones 7 and 9, the chloride is about 0.1 - 0.2 mg/l higher for the first cruise, but such an effect is not noticeable in zone 15.

Nutrients are affected not only by physical factors, but also by biological uptake and release. The elevated levels of total phosphorus and silica in zone 7 and generally in the near-shore zone in the western end of the lake are, no doubt, linked to man-made and riverine inputs.

The same conclusion has been reached by Callender (1973) on the basis of a different data base. His information also shows that the greatest effect is noted near the southern shore within 30 km of Duluth.

If the maximum summertime depletion in the epilimnion of silica, total phosphorus and total filtered phosphorus (fig. 9) in the fifteen zones are plotted as functions of total annual production in the zones (N.H. F. Watson, CCIW, personal communication, 1975), an approximately direct linear relationship is evident. This relationship is not so apparent for soluble reactive phosphorus and, in the case of nitrate, it is probably non-existent, although an inverse relationship can be imagined.

On the other hand, the annual production is linearly dependent on the average silica and total phosphorus concentrations (fig. 10), but evidently, independent of the nitrate concentration. Thus, the nutrients and the phytoplankton in the lake form parts of an interdependent unit.

The phytoplankton biomass in almost all zones reaches a maximum in the months of August to September, although peaks as late as October are also observed (N.H.F. Watson, CCIW, personal communication, 1973). The exception is zone 7 where June is the highest month. Nitrate and silica have minimum values in the same months or soon after. Ammonia reaches maxima at the same times. Phosphorus has high values in spring and declines to steady values by July in 1973, but a similar decline is not apparent in data from previous years. Both the maxima and minima are rather broad, so that it is difficult to determine the exact times when they occur, but it is clear that the maximum depletions occur at the same time as the maxima in the biomass. A similar relationship between chlorophyll α and depletion of nutrients is evident from the data in Watson, Nicholson and Culp (1975).

The drop in the oxygen concentration in the epilimnion is chiefly a physical effect caused by the increasing temperature which decreases the oxygen solubility. Since the lake cannot degas as rapidly as the temperature increases, the oxygen concentration remains above the saturation concentration.

A slight increase of the pH in the epilimnion might be expected since phytoplankton removes CO_2 and, hence, increases the pH. The maximum also coincides with the production maximum in September.

Baseline Values for Epilimnion Chemistry of Lake Superior

Figures 12 and 13 summarize the available information and present the concentrations of the total phosphorus, nitrate, silica, chloride, specific conductance, and mean vertical extinction believed to be representative of each of the segments of the epilimnion of Lake Superior. The mean, maximum, and minimum based on the cruise averages and number of cruises considered are included. Each cruise average is based on several station samples. All data presented in these figures are subjected to the restrictions and qualifications as discussed in this chapter but are believed to represent the best estimate of the baseline conditions of Lake Superior in 1973.

General Summary

- (1) The waters of Lake Superior are very homogeneous both vertically and horizontally.
- (2) The only region where the water chemistry differs consistently from that of the mid-lake region is the western end near Duluth and Superior.
- (3) No seasonal cycles can be clearly demonstrated to exist for the major ions or most of the trace metals, with the possible exception of copper. Of the nutrients, only nitrate and silica can be shown to have seasonal cycles.
- (4) The concentration of major ions has remained constant since the beginning of the century. The quality and scarcity of data for the trace metals do not allow deductions to be made. The same is true of the nutrient data, except for nitrate which does show a steady increase of about 3 $\mu\text{g/l}$ per year.
- (5) At no time of the year does Lake Superior become seriously de-oxygenated since the minimum average saturation level reached is about 95 - 98%.

REFERENCES

- Adams, C. E. 1972. Variations in the physico-chemical properties of Lake Superior. Proc. 15th Conf. Great Lakes Res. 221 - 236.
- Ayers, J. C. 1962. Great Lakes waters, their circulation and physical and chemical characteristics. In "Great Lakes Basin" (H. J. Pincus, ed.). AAAS Publication #71, p 71 - 89.
- Beeton, A. M. 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. Oceanogr. 10: 240 - 254.
- Callender, E. 1973. Chemistry of Lake Superior. Unpublished manuscript. U. of Michigan, Ann Arbor, Michigan.
- Canada Centre for Inland Waters (1975). Atmospheric loading to the Upper Great Lakes. Vol. 3: Appendixes.
- Chandler, D. C. 1964. The St. Lawrence Great Lakes. Verh. Internat. Verein. Limnol. 15: 59 - 75.
- Dobson, H. F. 1972. Nutrients in Lake Superior. Unpublished manuscript. CCIW, 68 pp.
- Eriksson, E. 1955. Airborne salts and the chemical composition of river waters. Tellus 7: 243 - 260.
- Eriksson, E. 1960. The yearly circulation of chloride and sulfur in nature; meteorological, geochemical and pedological implications. Part II. Tellus 11: 63 - 109.
- Hem, J. D. 1970. Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water-Supply Paper 1473; 2nd ed.; xiv + 363 p.
- Hough, J. L. 1958. Geology of the Great Lakes. U. of Illinois Press xvii + 312 p.
- Junge, C. E. and P. E. Gustafson. 1957. On the distribution of sea salt over the United States and its removal by precipitation. Tellus 9: 164 - 173.
- Junge, C. E. and R. T. Werby. 1958. The concentration of chloride, sodium, potassium, calcium, and sulfate in rain water over the United States. J. Meteor. 15: 417 - 425.
- Kramer, J. R. 1964. Theoretical model for the chemical composition of fresh water with application to the Great Lakes. Proc. 7th Conf. Great Lakes Res. Publ. #11, Great Lakes Res. Div., Univ. of Michigan, p. 147 - 160.

- McGirr, D. J. 1974. Interlaboratory quality control study no. 6. Specific conductance, pH, colour and residue. Inland Waters Directorate Report Series No. 28. 6 pp.
- McGirr, D. J. and R. W. Wales. 1973. Interlaboratory quality control study No. 7. Major cations and anions. Inland Waters Directorate Report Series No. 30. 15 pp.
- McGirr, D. J. and R. W. Wales. 1975. Interlaboratory quality control study No. 9. Copper, cadmium, aluminum, strontium and mercury. Inland Waters Directorate Report Series No. 34. 13 pp.
- Parkos, W. G., T. A. Olson and T. O. Odlaug. 1969. Water quality studies on the Great Lakes based on carbon fourteen measurements on primary productivity. WRRC, Univ. of Minnesota, Bulletin #17. 121 pp.
- Pearson, F. J. and D. W. Fisher. 1971. Chemical composition of atmospheric precipitation on the northeastern United States. U.S. Geological Survey Water Supply Paper 1535-P. 23 p.
- Philbert, F. J. and W. J. Traversy. 1973. Methods of sample treatment and analysis of Great Lakes water and precipitation samples. Proc. 16th Conf. Great Lakes Res.: 294 - 308.
- Robertson, A., F. C. Elder and T. T. Davies. 1974. IFYGL chemical inter-comparisons: Proc. 17th Conf. Great Lakes Res. 682 - 696.
- Schelske, C. L. and J. C. Roth. 1973. Limnological survey of Lakes Michigan, Superior, Huron and Erie. Great Lakes Research Division, University of Michigan, Publication No. 17. vii + 108 p.
- Shiomni, M. T. and K. W. Kuntz. 1973. Great Lakes precipitation chemistry: part 1. Lake Ontario basin. Proc. 16th Conf. Great Lakes Res.: 581 - 602.
- Strachan, W. J. 1973. A statistical examination of Great Lakes chemical monitor data at the Canada Centre for Inland Waters. Proc. 16th Conf. Great Lakes Res.: 949 - 957.
- Strachan, W. J. 1975. Report on toxic materials, cruises 74-22-208/303/509. Unpublished report, ULRG - Project B28. 16 pp.
- Upchurch, S. B. 1972. Natural weathering and chemical loads in the Great Lakes. Proc. 15th Conf. Great Lakes Res.: 401 - 415.
- Wales, R. W. and D. J. McGirr. 1973. Interlaboratory quality control study No. 5. Chromium, iron, molybdenum and vanadium. Inland Waters Directorate Report Series No. 26. 6 pp.

Watson, N. H. F., H. F. Nicholson and L. R. Culp, 1975. Chlorophyll a
and primary production in Lake Superior, May to November, 1973.
Fisheries and Marine Service (Environment Canada) Technical Report
No. 525, 28 pp.

Weiler, R. R., 1976. Chemistry of Lake Superior. Unpublished Report.
Canada Centre for Inland Waters, 101 pp.

Weiler, R. R. and U. K. Chawla, 1969. Dissolved mineral quality of Great
Lakes waters. Proc. 12th Conf. Great Lakes Res.: 801 - 818.

LIST OF TABLES

- Table 1** Cruise dates and numbers for CCIW cruises during 1968 - 1973.
- Table 2** Zones sampled on a particular cruise and number of stations per zone for parameters sampled by CCIW.
- Table 3** Precision of analyses by WQB Laboratory, Burlington. Sampling and interlaboratory errors.
- Table 4** Average lake-wide concentration of major ions and conductivity in Lake Superior for 1973.
- Table 5** Average lake-wide concentrations of trace elements in Lake Superior for 1970 - 1973.
- Table 6** Annual averages of certain trace metals in selected zones in Lake Superior in 1973.
- Table 7** Annual averages of nutrients in whole water column and in epilimnion for Lake Superior in 1973.
- Table 8** Epilimnion concentration anomalies of nutrients for selected zones in Lake Superior in 1973.
- Table 9** Annual averages of pH and oxygen in Lake Superior for 1973.
- Table 10** Material balances in Lake Superior.
- Table 11** Comparison between observed major ion concentrations in Lake Superior and those calculated using the equilibrium model of Kramer (1964).

TABLE 1

<u>Year</u>	<u>Cruise Number</u>	<u>Date</u>
1968	301	Aug. 18 - 28
1969	302	Nov. 15 - 23
1970	301	April 15 - 23
	302	Oct. 28 - Nov. 6
1971	301	May 26 - June 2
	303	June 30 - July 7
	305	Oct. 5 - 13
1973	302	May 12 - 22
	305	June 15 - 27
	306	July 27 - Aug. 7
	310	Sept. 6 - 16
	312	Oct. 14 - 25
	313	Nov. 14 - 28

TABLE 2A
Zones Sampled During 1973 Cruises

Parameters	May 12-22	June 15-27	July 27-Aug. 7	Sept. 6-16	Oct. 14-25	Nov. 14-28
Major Ions						
SO ₄ , Na, K		2 - 7, 9			3 - 6	2 - 7, 9
Mg, Ca		11 - 15			11 - 15	11 - 15
Alkalinity	1. - 15	3 - 6	1 - 15	none	1 - 15	none
Chloride		12 - 14				
	1 - 15	3 - 6, 9	1, 11, 13	1 - 15	1 - 15	2 - 6, 9
		12, 14				11 - 15
Conductivity	4 - 6	3 - 6	1, 3 - 6		3 - 6	
	11 - 14	12 - 14	12 - 14		12 - 14	
Trace Metals						
Cu, Zn, Co, Pb		2 - 7, 9			3 - 6, 9	2 - 6, 9
Cd, Cr, Ni		11 - 15			11 - 15	11 - 15
Mn	2 - 7, 9	3 - 7, 9	2 - 7, 9	2 - 7, 9	3 - 6, 9	2 - 6, 9
	11 - 15	12 - 15	11 - 15	11 - 15	11 - 15	11 - 15
Fe	2 - 7		2 - 7, 9		3 - 6, 9	2 - 6, 9
	11 - 15		11 - 15		11 - 15	11 - 15
Hg	3 - 7, 9			none		
	11 - 15					
Nutrients						
SiO ₂ , NO ₃ , TP						
TFP, SRP, NH ₃						
pH	3 - 6				3 - 6	
	11 - 14				12 - 14	
Oxygen					1 - 15	

.../Continued

TABLE 2B

Stations Sampled per Zone⁽¹⁾

<u>Parameters</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>Total</u>
Major Ions																
Ca, Mg, Na, K, SO ₄	-	1	3	1	2	2	1	-	1	-	4	1	9	3	1	29
Alkalinity	5	7	7	7	6	6	6	7	6	8	14	4	20	11	3	117
Chloride	8	8	11	9	6	6	7	10	8	7	19	5	22	12	3	141
Conductivity	-	-	1	1	2	2	-	-	-	-	4	1	9	3	-	19
Trace Metals																
all	-	1	3	1	2	2	1	-	1	-	4	1	9	3	1	29
Nutrients																
all	6	7	8	8	6	5	4	4	5	8	10	4	20	11	3	109
	8	8	12	9	6	6	7	10	8	8	19	5	23	12	3	144
Oxygen																
	same as for nutrients															
pH	-	-	1	1	2	2	-	-	-	-	1	1	9	3	-	20

⁽¹⁾ The number given represents the maximum number of stations per zone for a particular parameter. The total number may vary by 4 to 5 from cruise to cruise. In the case of nutrients and oxygen, the variation is larger and so the maximum and minimum numbers are given.

TABLE 3A

Major ions and conductivity. Standard deviation in mg/l and $\mu\text{S}/\text{cm}$

<u>Type of error</u>	<u>Parameter</u>	<u>Alk.</u>	<u>Cl</u>	<u>SO₄</u>	<u>Ca</u>	<u>Mg</u>	<u>Na</u>	<u>K</u>	<u>Cond.</u>
Analytical ¹⁾		.3	.04	.05	.05	.1	.1	.04	1.0
Sampling ²⁾		.7 ± .3	.2 ± .1	-	-	-	-	-	-
Interlaboratory ³⁾		1-3	.4	-	2.2	.2	.5	.1	14.5

¹⁾ Philbert and Traversy, 1973 ²⁾ Strachan, 1973 ³⁾ McGirr and Wales, 1973; McGirr, 1973

TABLE 3B

Trace metals. Detection limits and standard deviations in $\mu\text{g}/\text{l}$

<u>Parameter</u>	<u>Detection limits</u>	<u>Analytical Error</u> ¹⁾	<u>Interlaboratory error</u> ²⁾
Li	.5	.1/1.7 ³⁾	-
Cu	.5	.1/.9	1.6/5
Sr	.2	1.4/180	3.7/40
Zn	.1	.2/7.9	-
Cd	.2	.04/.3	.8/5
Hg	.05	-	.01/.1
Pb	1.0	.1/.9	-
V	1.0	.0/.1	-
Cr	.2	.05/.7	-
Mo	.2	.13/1.5	.2/.9
Mn	.2	.04/.28	-
Fe	.5	.1/5.6	1.7/6.5
Co	.5	.08/4.2	-
Ni	1.0	.3/2.1	-

¹⁾ O. El-Kei, CCIW, personal communication. ²⁾ Wales & McGirr, 1973

³⁾ The first number is the standard deviation; the second the concentration at which this deviation was found.

TABLE 3A

Major ions and conductivity. Standard deviation in mg/l and $\mu\text{s}/\text{cm}$

<u>Type of error</u>	<u>Parameter</u>	<u>Alk.</u>	<u>Cl</u>	<u>So₄</u>	<u>Ca</u>	<u>Mg</u>	<u>Na</u>	<u>K</u>	<u>Cond.</u>
Analytical ¹⁾		.3	.04	.05	.05	.1	.1	.04	1.0
Sampling ²⁾		.7 ± .3	.2 ± .1	-	-	-	-	-	-
Interlaboratory ³⁾	1-3	.4	-	2.2	.2	.5	.1	14.5	

¹⁾ Philbert and Traversy, 1973 ²⁾ Strachan, 1973 ³⁾ McGirr and Wales, 1973; McGirr, 1974

TABLE 3B

Trace metals. Detection limits and standard deviations in $\mu\text{g}/\text{l}$

<u>Parameter</u>	<u>Detection limits¹⁾</u>	<u>Analytical Error¹⁾</u>	<u>Interlaboratory error²⁾</u>
Li	.5	.1/1.7 ³⁾	-
Cu	.5	.1/.9	1.6/5
Sr	.2	1.4/180	3.7/40
Zn	.1	.2/7.9	-
Cd	.2	.04/.3	.8/5
Hg	.05	-	.01/.1
Pb	1.0	.1/.9	-
V	1.0	.0/.1	-
Cr	.2	.05/.7	-
Mo	.2	.13/1.5	.2/.9
Mn	.2	.04/.28	-
Fe	.5	.1/5.6	1.7/6.5
Co	.5	.08/4.2	-
Ni	1.0	.3/2.1	-

¹⁾ O. El-Kei, CCIW, personal communication. ²⁾ Wales & McGirr, 1973

³⁾ The first number is the standard deviation; the second the concentration at which this deviation was found.

TABLE 3C

Nutrients. All values in $\mu\text{g/l}$

<u>Parameter</u>	<u>Units</u>	<u>Working Range</u>	<u>Detection Limit</u> ¹⁾	<u>Analytical</u> ¹⁾	<u>Sampling</u> ²⁾
Total phosphorus ³⁾	$\mu\text{g P/l}$	.5-50	.5	.7	-
Total soluble phosphorus	$\mu\text{g P/l}$	.5-50	.5	.7	-
Soluble reactive phosphorus	$\mu\text{g P/l}$	.2-50	.2	.2	.7 \pm .3
Nitrate ³⁾	$\mu\text{g N/l}$	5-500	5	4	12 \pm 5
Ammonia ⁵⁾	$\mu\text{g N/l}$	1-50	1	.8	3 \pm 1
Soluble reactive Silica	$\mu\text{g SiO}_2/\text{l}$	25-3000	10	8	70 \pm 31

¹⁾ F.J. Philbert (WQB, Burlington), personal communication. The analytical error represents the between-runs standard deviation.

²⁾ Strachan, 1973. The numbers represent the overall mean standard deviation -95% confidence limit.

³⁾ Method changed at beginning of 1973. No evidence of bias between methods.

⁴⁾ Method changed at beginning of 1973. No evidence of bias. Data obtained on 1967-1969 should be treated with caution because of probable contamination by Millipore filters.

⁵⁾ Method changed at end of 1972. Data from 1967-1972 about 18% less than data after 1972.

TABLE 3D

Oxygen and pH

<u>Parameter</u>	<u>Analytical error</u> ¹⁾	<u>Interlaboratory error</u> ²⁾	<u>Sampling error</u> ³⁾
Oxygen (mg/l)	.01	-	.19 \pm .13
pH	.01	.3 - .5	.04 \pm .02

¹⁾ Philbert and Traversy, 1973. ²⁾ McGirr, 1974. ³⁾ Strachan, 1973

TABLE 4

<u>Parameter</u>	<u>Average Concentration (mg/l)</u>	
	<u>CCIW</u>	<u>Callender</u>
Alkalinity	42.0 [1.0] ²⁾	43.3
Sulphate	3.2 [.5]	3.2
Chloride	1.2 [.1]	1.36
Calcium	13.0 [.2]	12.7
Magnesium	2.8 [.2]	2.7
Sodium	1.2 [.1]	1.2
Potassium	0.5 [.05]	0.5
Conductivity (HS)	97 [5]	78.7 - 95

1) Callender, 1973.

2) The second number represents the estimate of the limits between which the average lies.

TABLE 5

Parameter	Average for whole lake ($\mu\text{g/l}$)			Median ($\mu\text{g/l}$) ¹⁾	Mode ($\mu\text{g/l}$) ²⁾	Callender ($\mu\text{g/l}$) ¹⁾	Detection Limit	Percent less than d. 1.
	1970 ³⁾	1971	1973	1973	1973	1973		
Li	0.8[.1] ⁴⁾							
Cu	3[2]	7.8[6.9]	2.3[1.7](682)	2.0		2.0 - 2.5	0.5	5.7
Sr	29[8]					<u>1.4</u> -3.8		
Zn	5[2]	12.9[9.6]	14.0[11.2](659)	11.0				
Cd ₅₎	<1	0.4[.3]	0.1[.2](694)	0.0		<u>1.8</u> -<300 <0.1; 0.25-<2	1.0	0.3
Hg	<1		0.1[.01](118)	0.1		b.d-<0.5	0.2	72.0
Pb	2[2]	1.4[0.7]	0.8[.9](684)	0.6		<u>1.6</u> ; 1.0-8	0.05	6.8
V	<1	0[.1]					1.0	63.2
Cr	<1	0.3[.5]	0.1[.1](700)	0.1	0	<1		
Mo	<1	0.2[.1]	0.2[.1]				0.2	63.0
Mn		0.3[.2]	0.4[.4](575)	0.3	0.2 - 0.4	<u>0.7</u> -<3		
Fe	7[5]	0.3[8.2]	2.1[2.2](617)	1.5	1	<u>11</u> ; 10 - 14	0.2	17.7
Co ₆₎	1[1]	0.5[0.4]	0.2[.3](700)	0.1	0	0.5	0.5	3.1
Ni	<1	1.0	1.6[1.8](670)	1.0	0	<u>2.4</u> ; 1.3-3.9	0.5	74.3
							1.0	46.0

1) From Callender, 1973. The average value accepted by Callender is underlined; the other figure indicates the range he has found in the literature.
2) From histograms, Figure 4a.

3) In 1970, the values were quoted to the nearest $\mu\text{g/l}$.

4) The numbers represent - average [standard deviation] (sample population).

5) Cruise 302 only; b.d - below detection limit.

6) Cruise 305 is excluded from the average.

TABLE 6

<u>Parameter</u>	<u>Average concentration in zone ($\mu\text{g/l}$)</u>								
	<u>13</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7¹⁾</u>	<u>9</u>	<u>11</u>	<u>14</u>	<u>15</u>
Cu	2.3	3.0	2.3	2.0	2.7	3.2	2.6	2.3	2.3
Mn	.29	.32	.25	.63 ^{*2)}	.37	.48	.42	.26	.44
Fe	1.9	2.5	1.8	3.0	6.8*	2.6	3.1	1.1	4.4*
Ni	1.5	1.5	2.1	1.7	3.3	1.9	1.2	2.2	1.5

1) For zone 7, only the first four cruises are compared with the first four of zone 13.

2) Indicates that the average concentration for that zone differs from the average concentration in zone 13 at least at the $P = .05$ level.

TABLE 7

<u>Parameter</u>	<u>Concentration ($\mu\text{g/l}$)</u>	<u>Callender¹⁾</u>
	<u>Whole column</u>	<u>Epilimnion</u>
Total phosphorus	5.4 [1.3] ²⁾	6.3 [1.4] 3.1
Total soluble phosphorus	4.0 [1.1]	4.5 [1.4] -
Soluble reactive phosphorus	1.5 [.5]	1.6 [.9] .9
Nitrate	295 [14]	278 [25] 272
Ammonia	5.3 [1.7]	5.8 [1.9] 2 (?)
Silica ³⁾	2.44[.01]	2.38[.06] 2.22

¹⁾The numbers are the best values accepted by Callender.

²⁾The number in brackets represents the average deviation for the 6 cruises.

³⁾Concentration in mg/l.

TABLE 8

<u>Parameter</u>	<u>Zone</u>	<u>Anomaly</u> ¹⁾ by Cruise and Concentrations in Zone 13					
		May 12-22	June 15-27	Jul 27	Sept 6-16	Oct 14-25	Nov 14-28
Concentration in zone 13		318	290	27.4	252	270	287
Nitrate ($\mu\text{g/l}$)	1	-2	-16 ^{*2}	-18	2	-17 [*]	-16 [*]
	5	1*	2*	-19*	12	15	8
	7	-18*	-33*	-29*	-9	2	3
	9	-20	-22*	-14*	-13	-6*	-5*
	11	-2	-15	-24	-8	-15	-10
Concentration in zone 13		2.6	3.8	4.2	6.9	7.6	3.6
Ammonia ($\mu\text{g/l}$)	1	2.2*	2.0*	16.7*	4.1*	0	5.7*
	7	5.7	7.0	3.7	1.4	8.8*	6.8
Concentration in zone 13		6.4	5.2	4.4	6.2	5.4	4.6
Total phosphorus ($\mu\text{g/l}$)	1	-2.8*	4.4	1.9	N.D. ³	-.6	3.1*
	7	9.1*	3.9*	2.7*	1.7	7.1*	11.1*
Concentration in zone 13		5.2	4.0	2.9	5.1	3.3	3.5
Total filtered phosphorus ($\mu\text{g/l}$)	1	-2.3*	4.0*	1.1	N.D.	-.6	1.9*
	7	5.9*	.7*	1.4*	.4	2.3*	3.2*
Concentration in zone 13		2.43	2.44	2.41	2.33	2.37	2.41
Silica (mg/l)	3	.01*	.01*	-.11*	0	-.10	-.07*
	6	.04*	.04*	-.02*	.08*	.03*	.05*
	7	.13*	.07	-.11*	-.06	.52*	.28
	9	.18	-.04	-.10*	-.08	-.09*	-.04*
	11	0	-.03*	-.15*	-.10	-.08*	-.05*
	15	.06	.05	.10	0	.07	.10

¹⁾ Anomaly = Concentration in zone 1 - Concentration in zone 13.

²⁾ Anomaly is significant at P = .01 or better

³⁾ No data available

TABLE 9

<u>Parameter</u>	<u>Yearly Average</u>		
	<u>Epilimnion</u>	<u>Whole Column</u>	<u>Callender</u>
Oxygen (mg/l)	12.06 [1.13] ¹	12.94 [53]	
pH	8.02 [.19]	7.91 [11]	7.4 - 7.8

1) The second number represents one standard deviation

TABLE 10
Amount in Gg/year

	Total Dissolved Solids	Chloride	Silica (as SiO ₂)	Total Phosphorus (as P)	Total Nitrogen (as N)
	A ¹⁾	B ¹⁾	A	B	A
<u>Inputs</u>					
Municipal +)	273	32.6	10.2	0.23	1.1
Industrial)					
Tributary	6000	4200	212.3	280	36.6
Atmospheric	120	300	55.0	0	56.0
Other	<u>213</u>	<u>—</u>	<u>12.1</u>	<u>14.4</u>	<u>1.6</u>
Total	6606	4500	312.0	462.5	95.3
<u>Outputs</u>					
St. Marys R.	4020	76.7	150	0.40	21.9
Residual	2580	235.3	312.5	3.74	73.4
Equilibrium ²⁾	4209 ⁴⁾	75.4	156	0.43	18.1
<u>Output</u>					

- 1) A - Chapter 3.1 estimates. B - estimates by Upchurch (1972).
- 2) Calculated from $66.75 \times C(\text{mg/L})$ Chap. 5.1.3) where C was taken as the average concentration in zone 1.
- 3) Converted from PO₄ to P by multiplying with 0.33.
- 4) The concentration was calculated by multiplying the conductivity by 0.65. The average conductivity in zone 1 was taken as 97 μS .

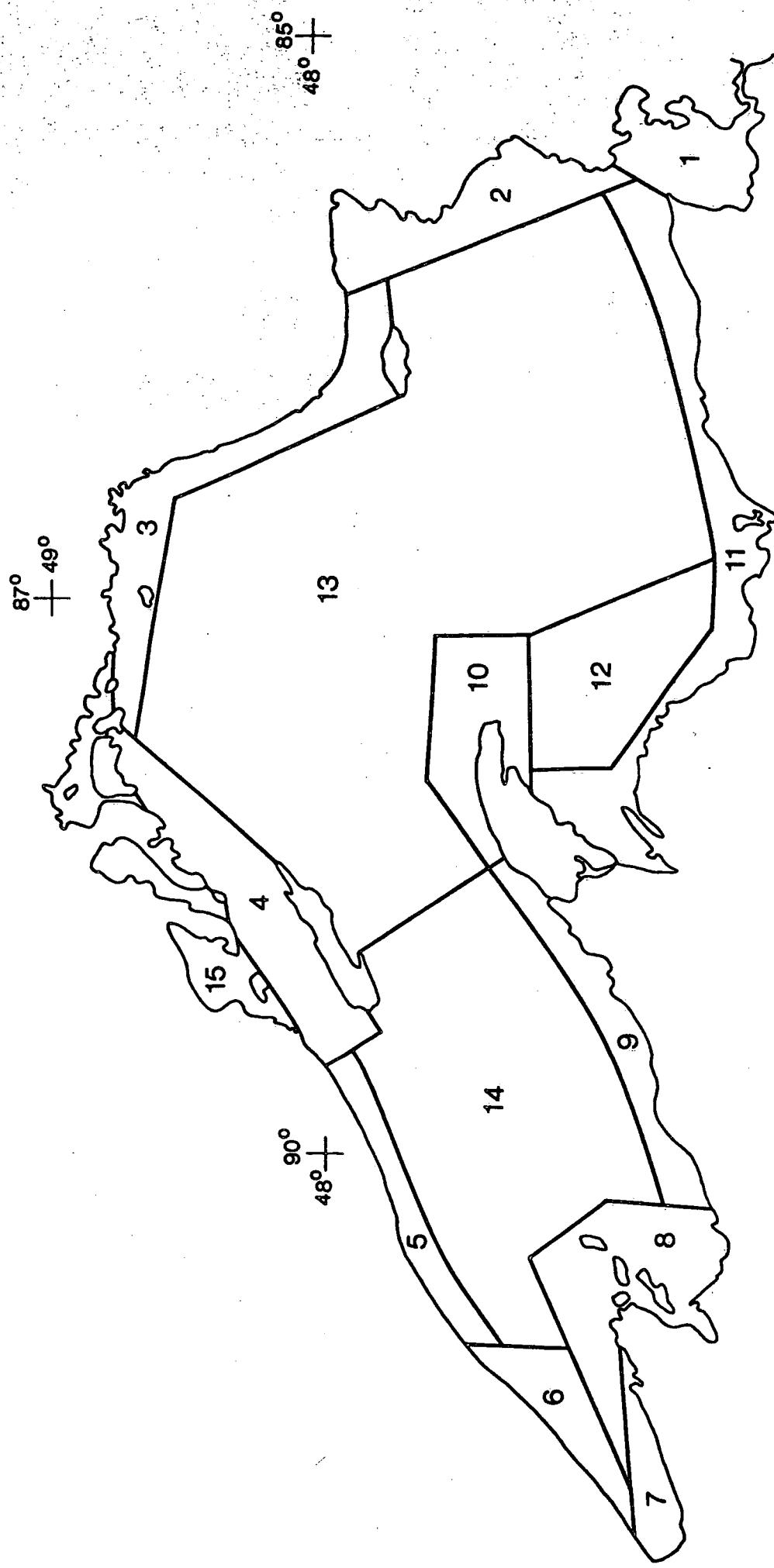
TABLE 11

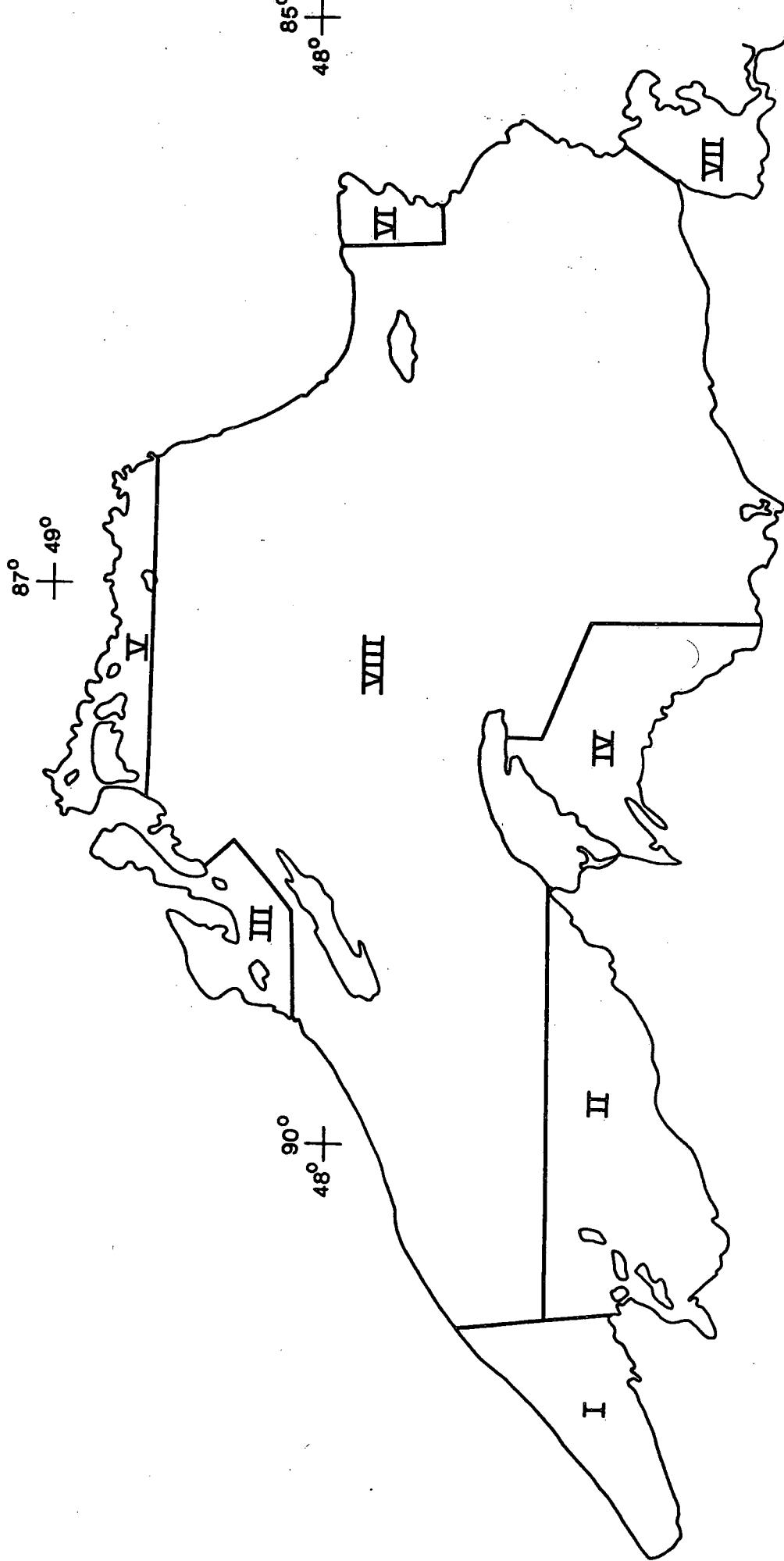
Concentration (mg/l)

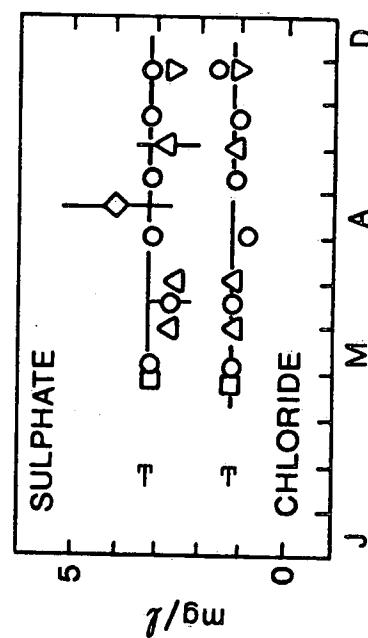
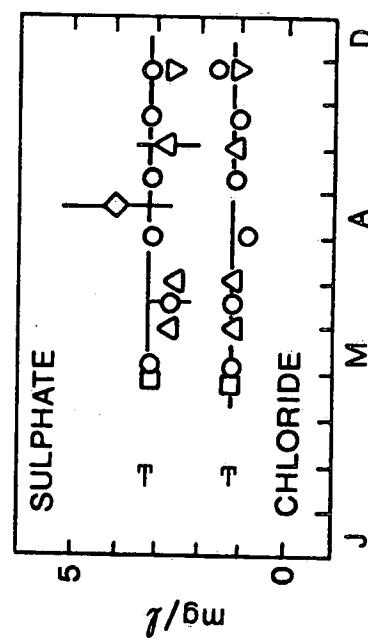
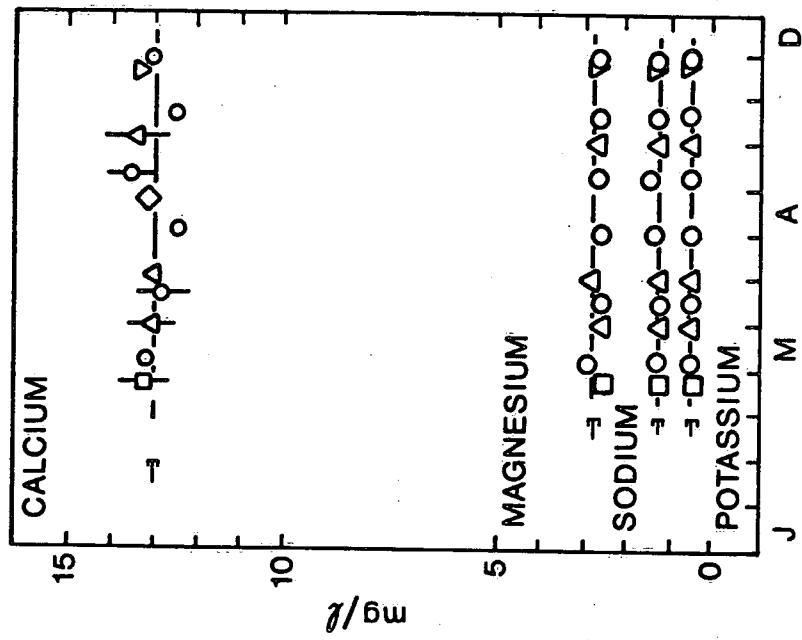
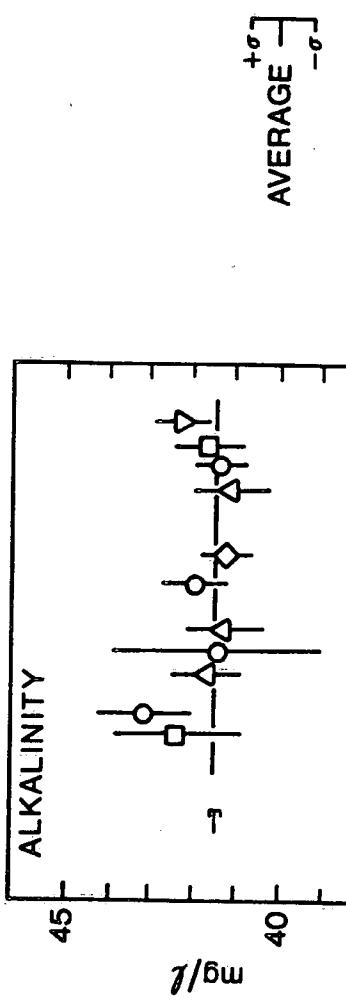
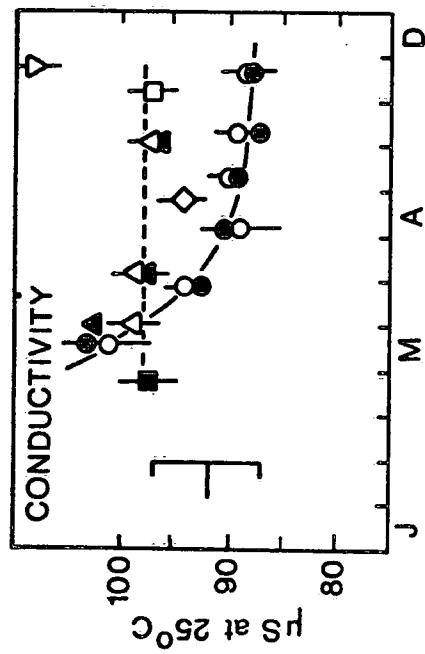
	<u>Alk.</u>	<u>Ca</u>	<u>Mg</u>	<u>Na</u>	<u>K</u>	<u>SiO₂</u>
Kramer's Model	46	9.5	3.1	5	0.7	2.5
Actual	42	13.0	2.8	1.2	0.5	2.4

FIGURE CAPTIONS

- Figure 1a** Division of Lake Superior into zones for 1973.
- 1b** Division of Lake Superior into zones for 1968 - 1971.
- Figure 2** Concentrations of major ions and conductivity in Lake Superior during 1968 - 1973. Error bars represent one standard deviation.
- Figure 3** Historical trends for major ions and total dissolved solids in Lake Superior for the period 1885 - 1973.
- Figure 4a** Histograms of trace metal concentrations in 1973.
- 4b** Trace metal concentrations in epilimnion and hypolimnion of Lake Superior for 1970 - 1973. Error bars represent one standard deviation. Solid symbols are for epilimnion; open for hypolimnion.
- Figure 5** Nutrient concentrations in epilimnion and whole water column in Lake Superior for 1968 - 1973. Error bars represent one standard deviation. Solid symbols are for epilimnion; open for whole water column.
- Figure 6** Historical trends for total phosphorus, silica and nitrate for the period 1905 - 1973. Solid symbols represent CCIW data; open other data.
- Figure 7** Oxygen and pH in Lake Superior, 1968 - 1973. Error bars represent one standard deviation. Solid symbols are for epilimnion; open for whole water column.
- Figure 8** Stations for toxic substances sampling in Lake Superior in 1974.
- Figure 9** Maximum summertime depletion (concentration in spring less minimum concentration in summer) in epilimnion of Lake Superior for silica, total phosphorus, total dissolved phosphorus, dissolved reactive phosphorus and nitrate as a function of total annual production.
- Figure 10** Annual production as a function of average silica, total phosphorus and nitrate in epilimnion of Lake Superior.
- Figure 11** Mean epilimnion concentrations of selected nutrients by zone in Lake Superior in 1973. Concentrations are in $\mu\text{g/l}$. N is the number of cruises.
- Figure 12** Mean epilimnion concentrations of chloride (mg/l), specific conductivity (μS) and mean vertical extinction coefficient ($\text{MVEC} \times 10$; λ -400 to 500 nm) in Lake Superior in 1973.



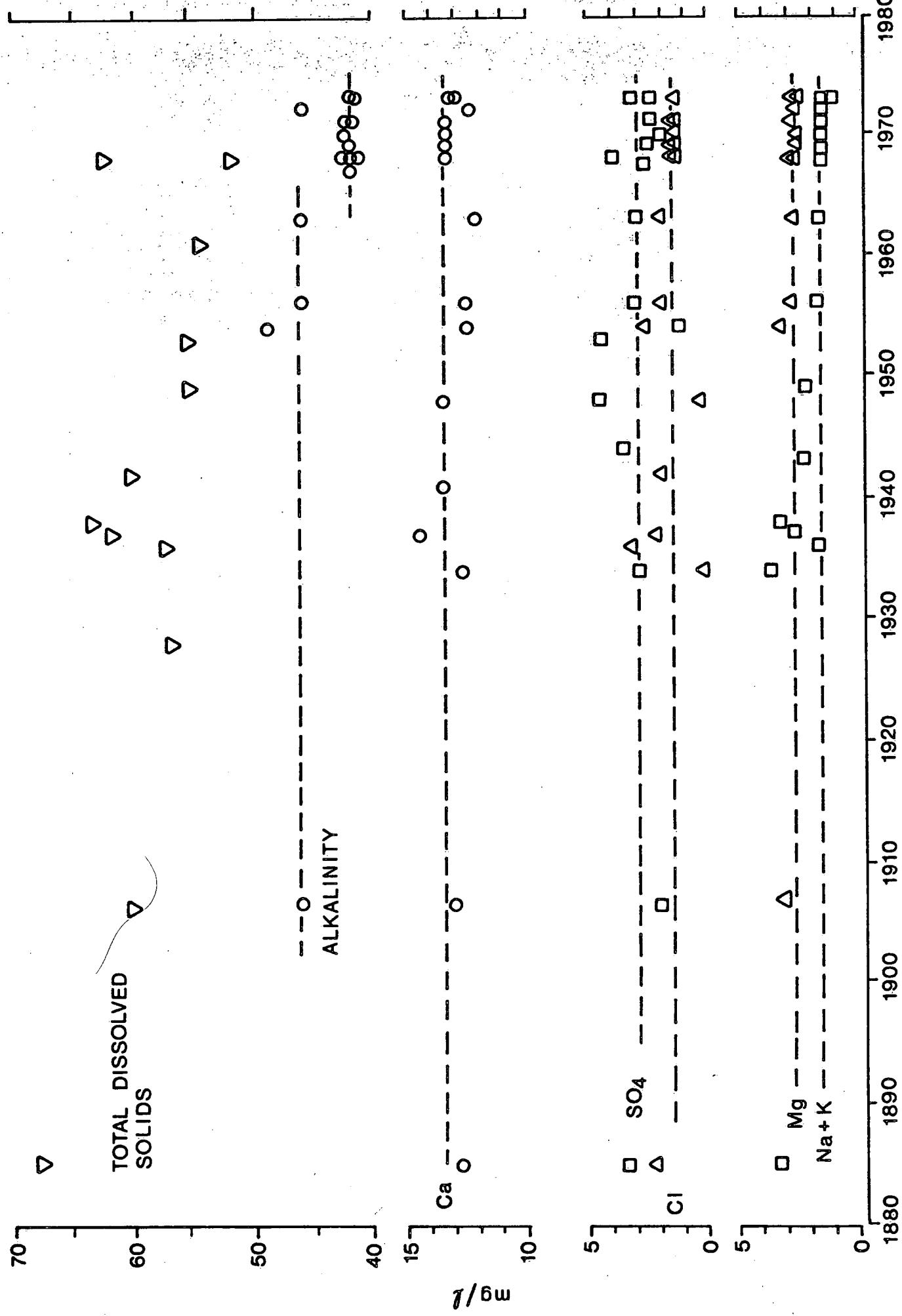


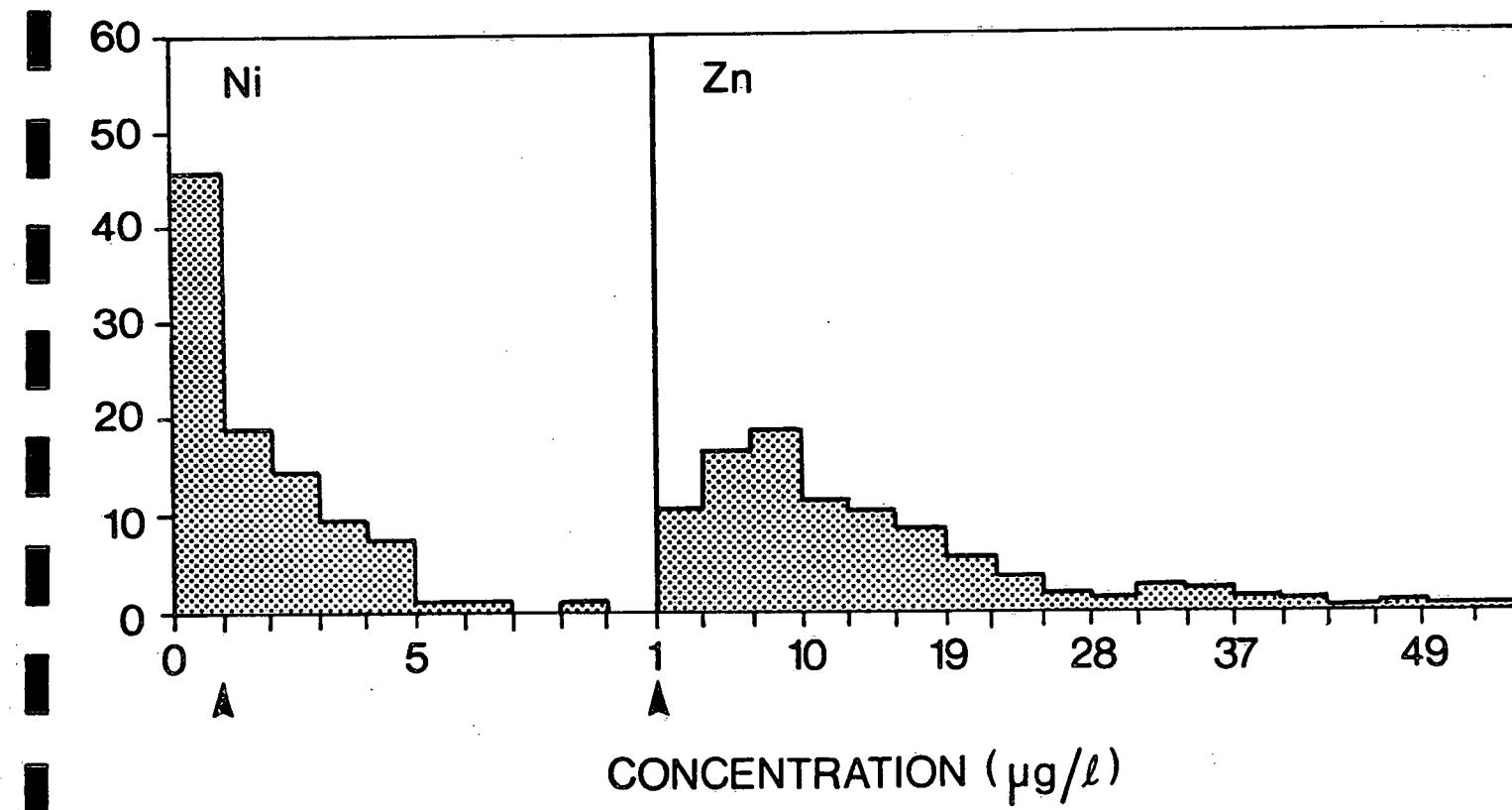
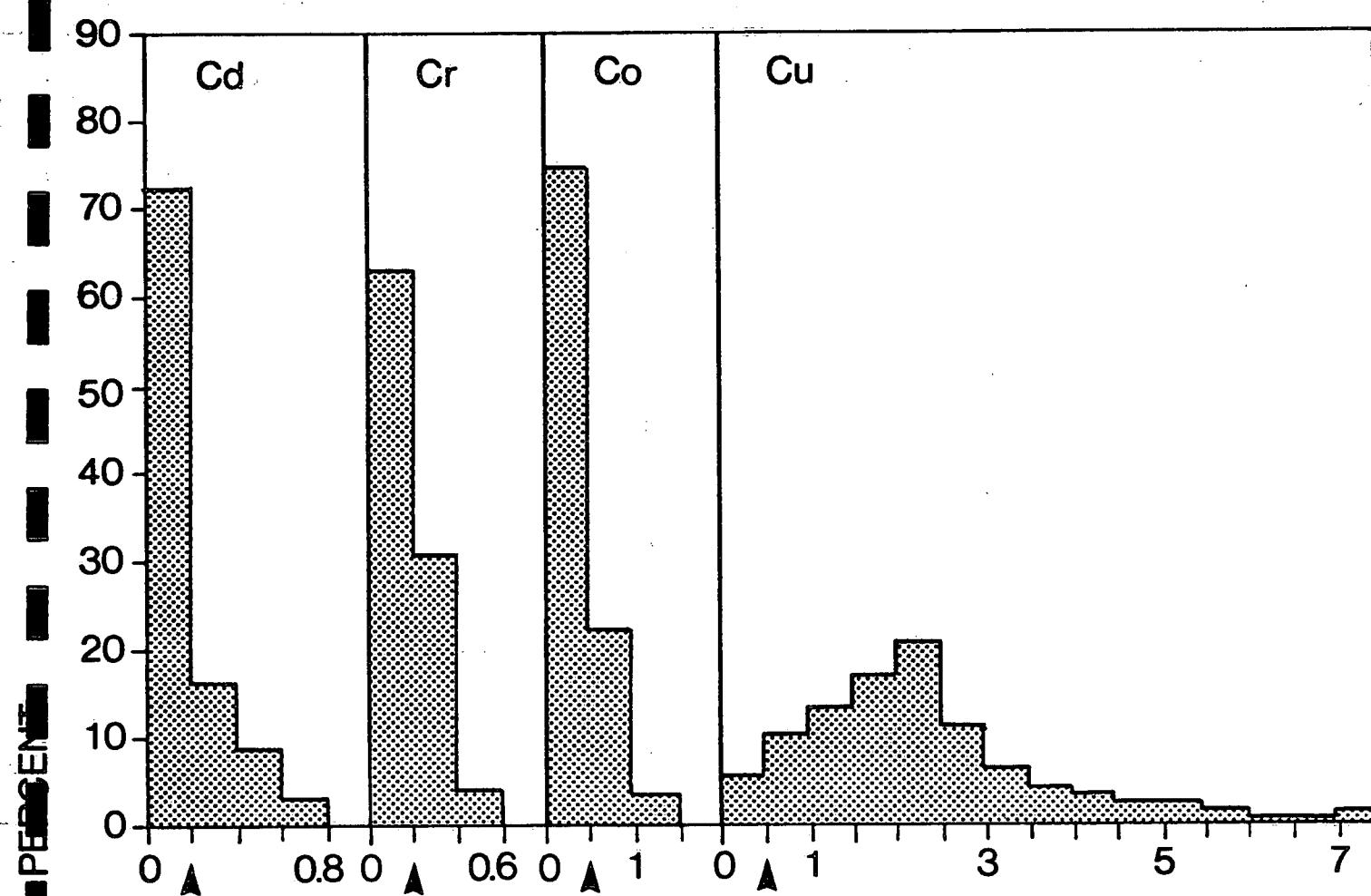


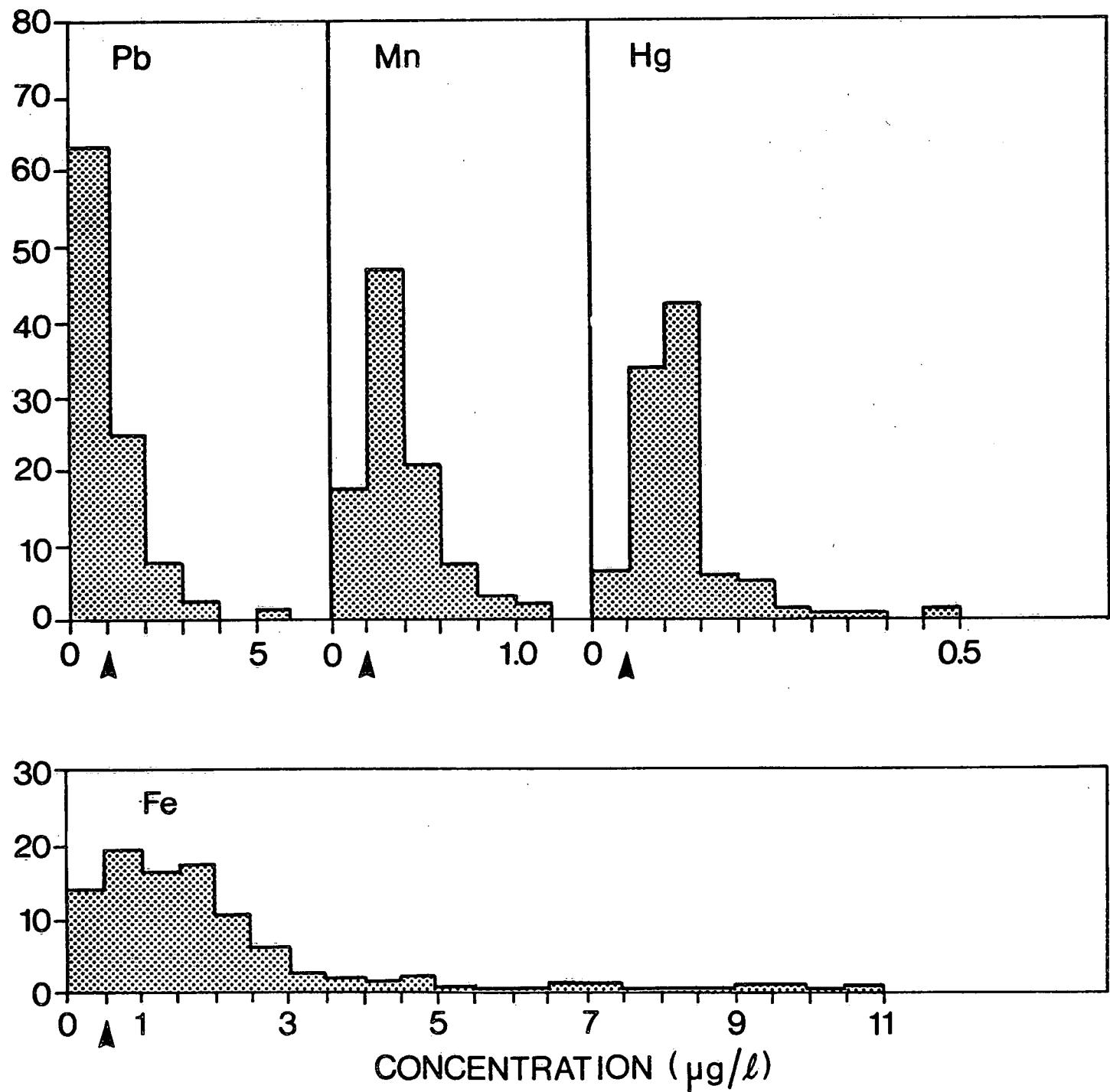
AVERAGE $\left[\begin{matrix} +\sigma \\ -\sigma \end{matrix} \right]$

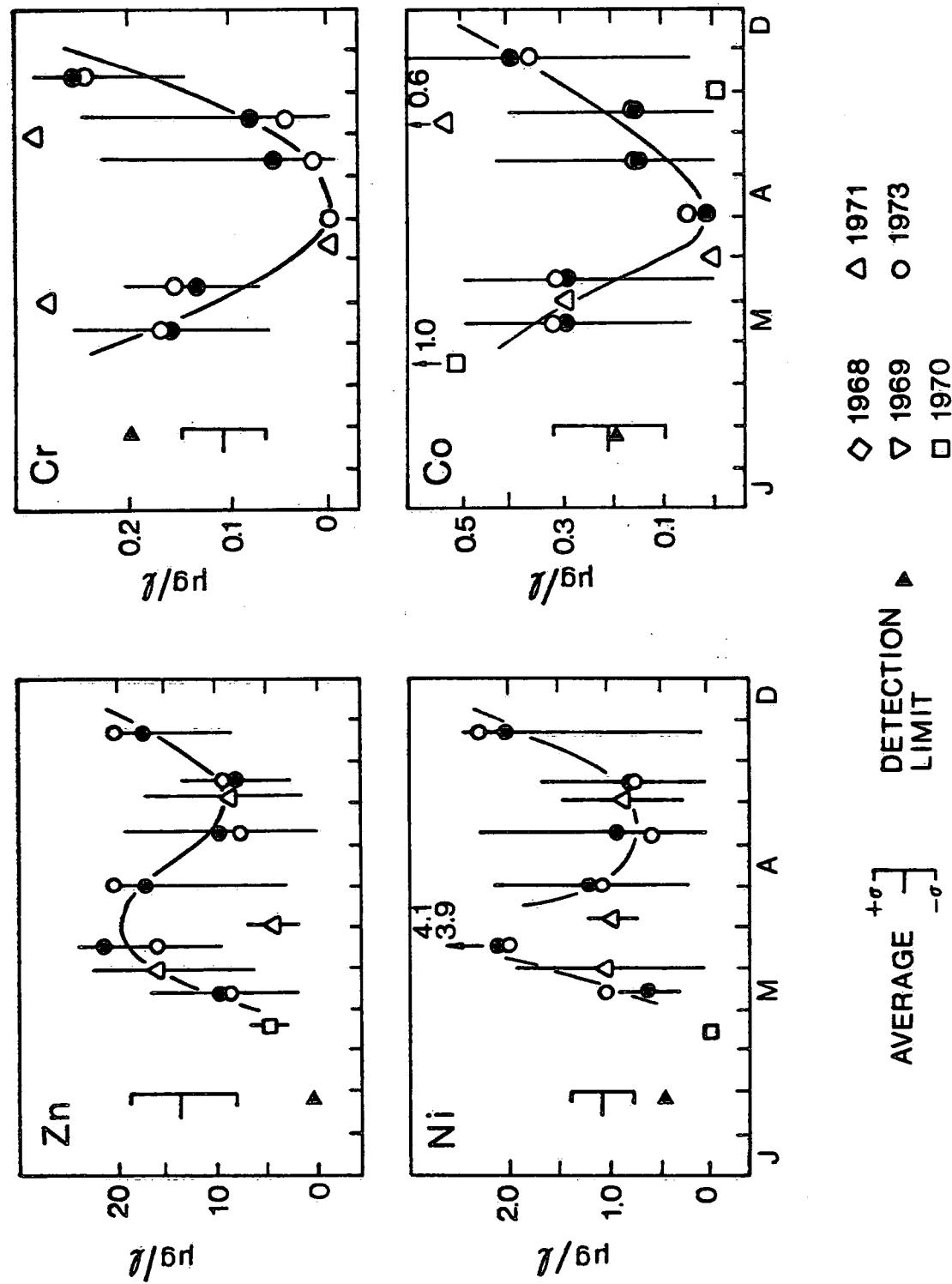
MAGNESIUM
SODIUM
POTASSIUM

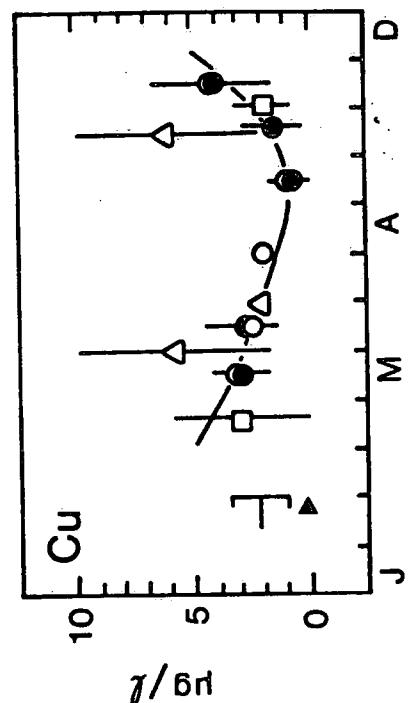
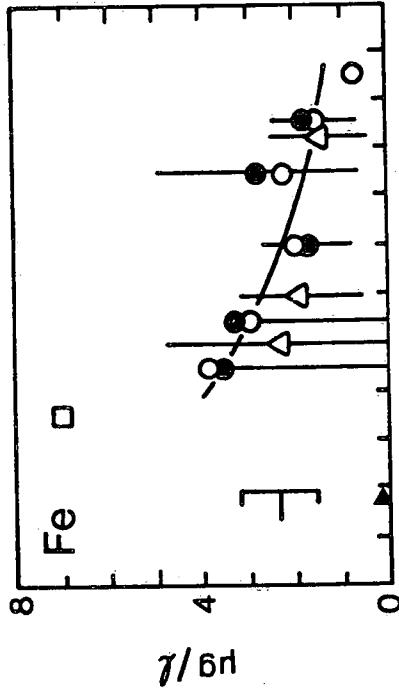
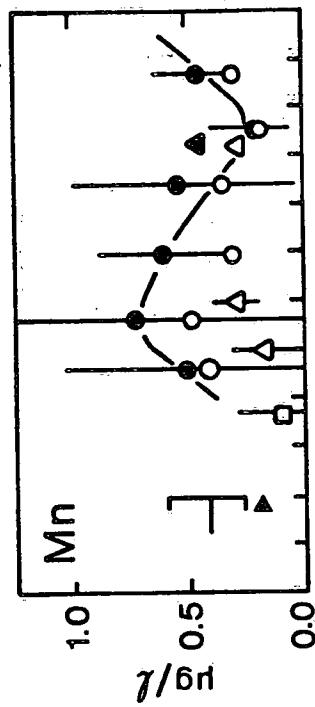
J M A D





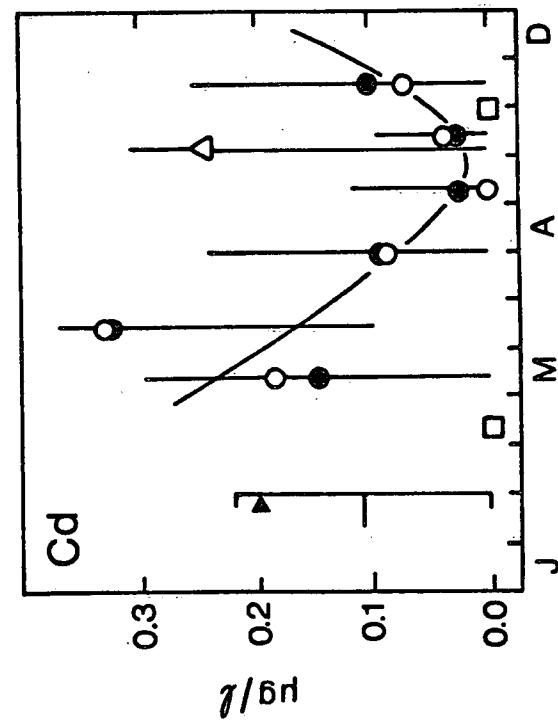
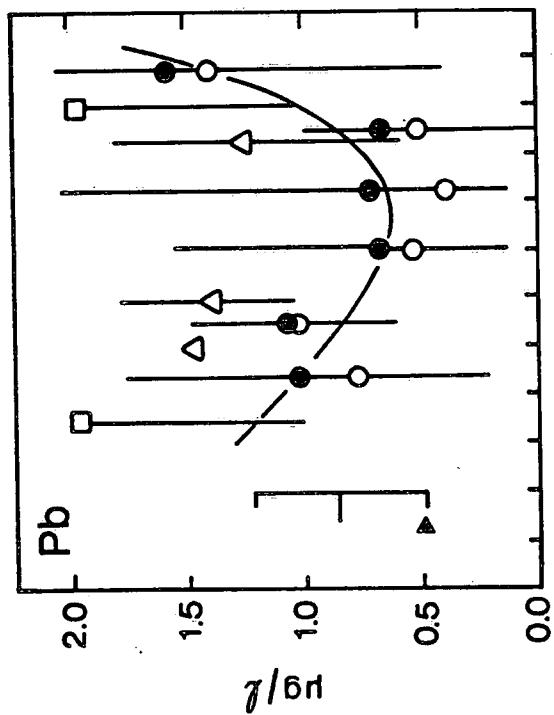


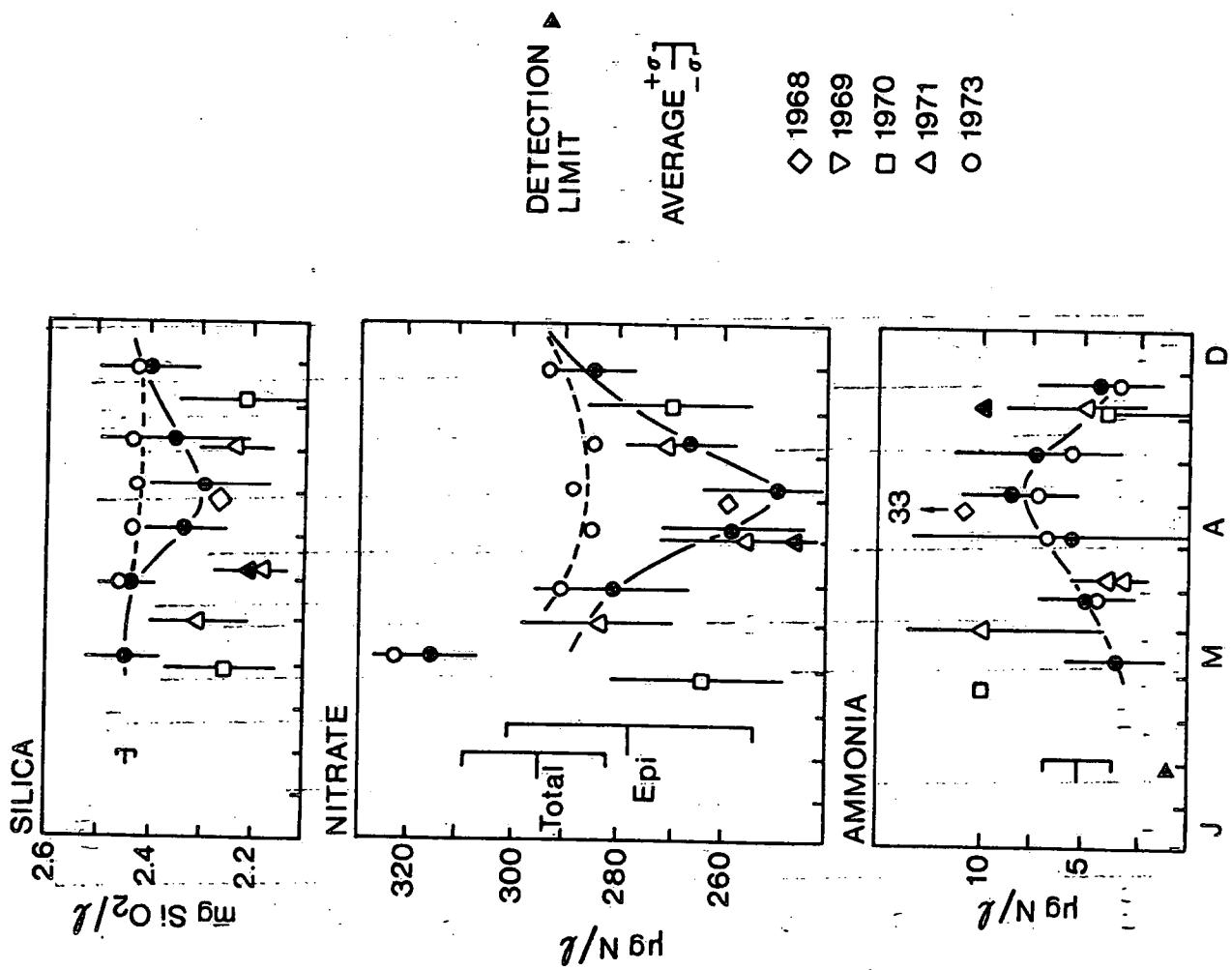
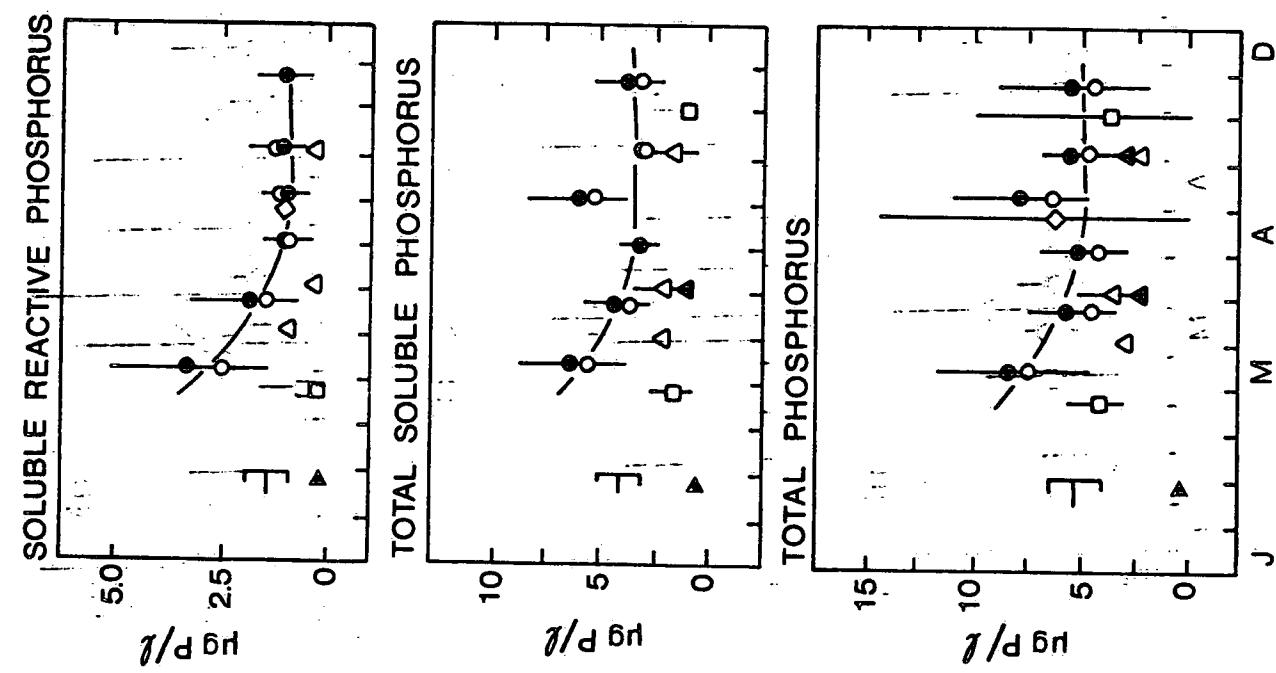


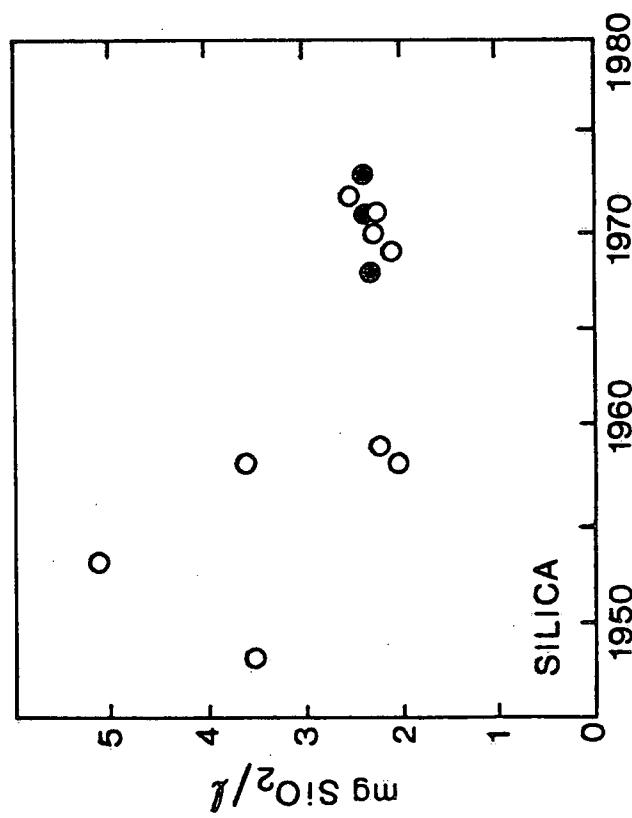
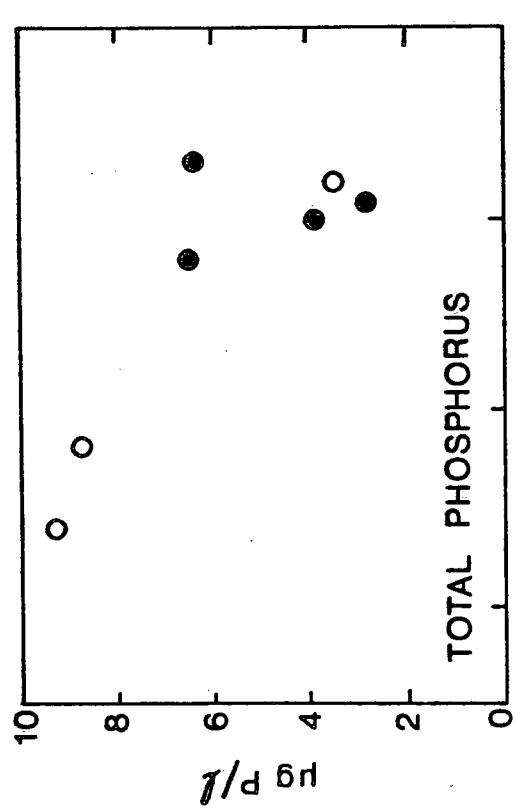
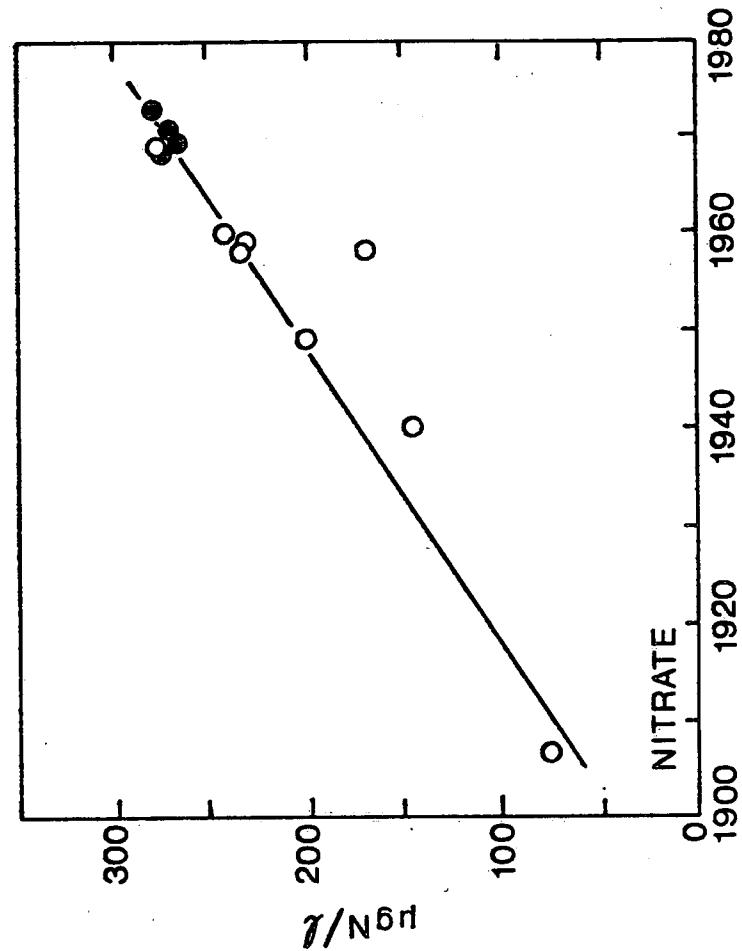


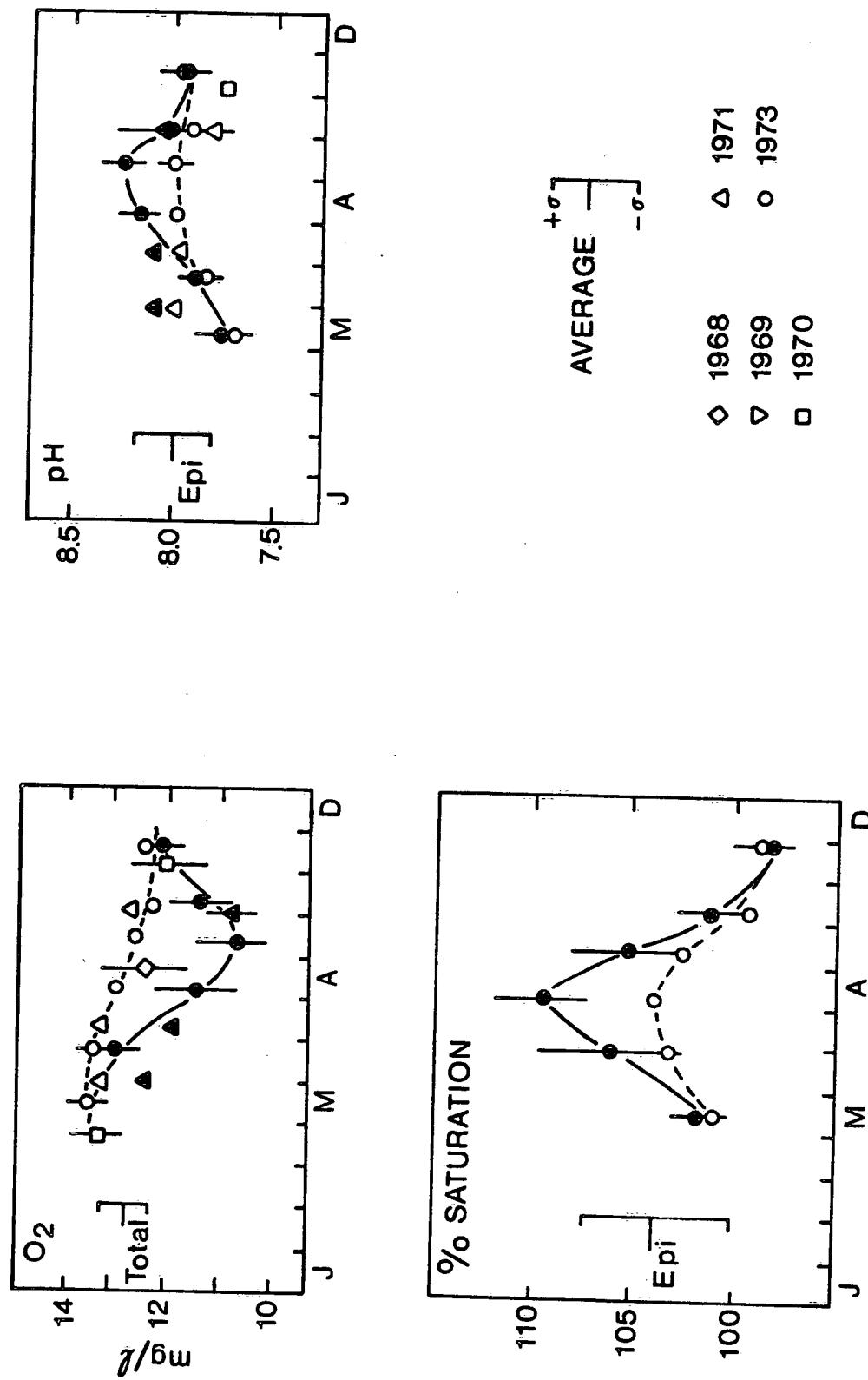
DETECTION
LIMIT
AVERAGE
 $\pm \sigma$

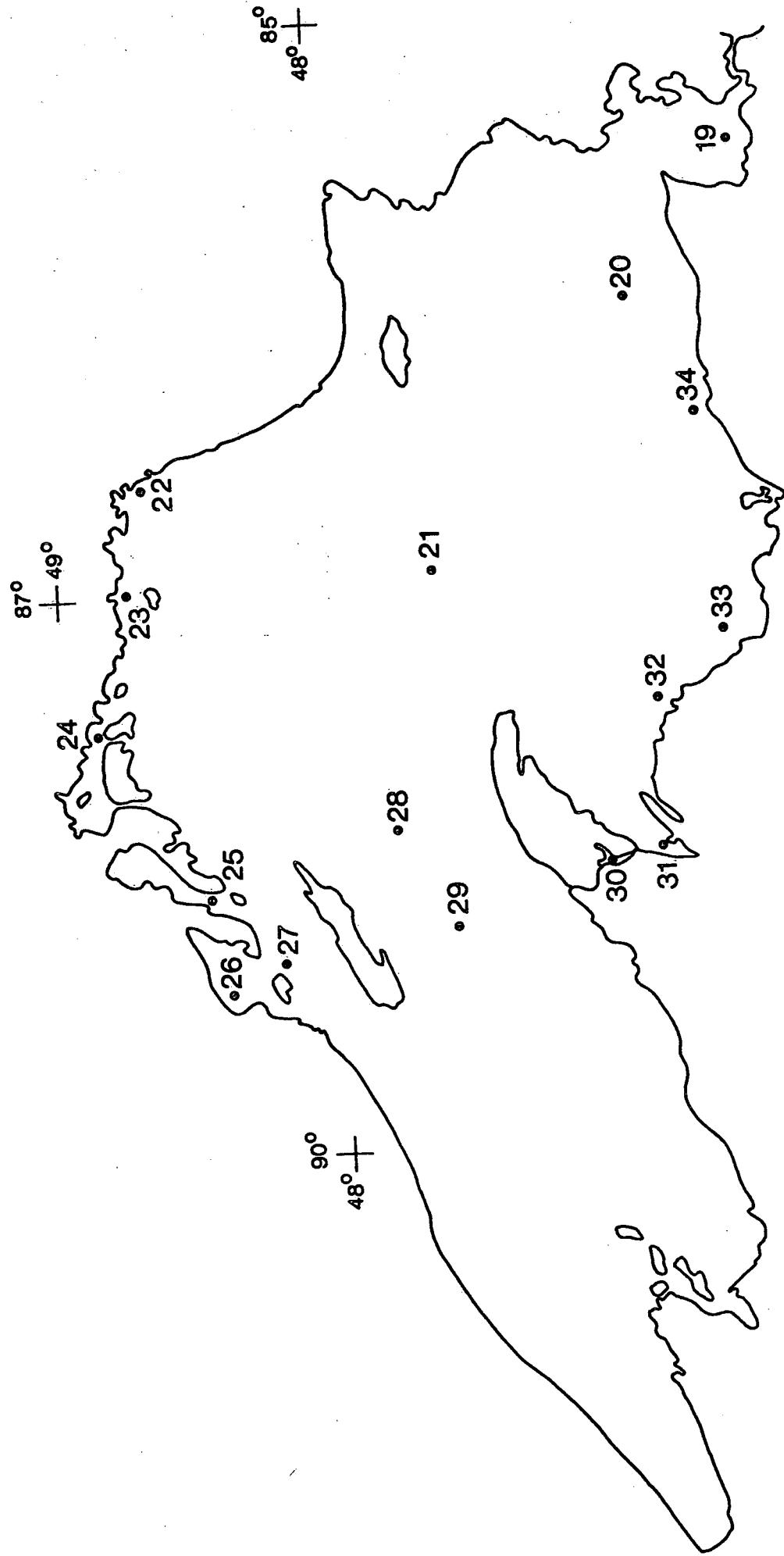
◇ 1968
□ 1969
▽ 1970
△ 1971
○ 1973

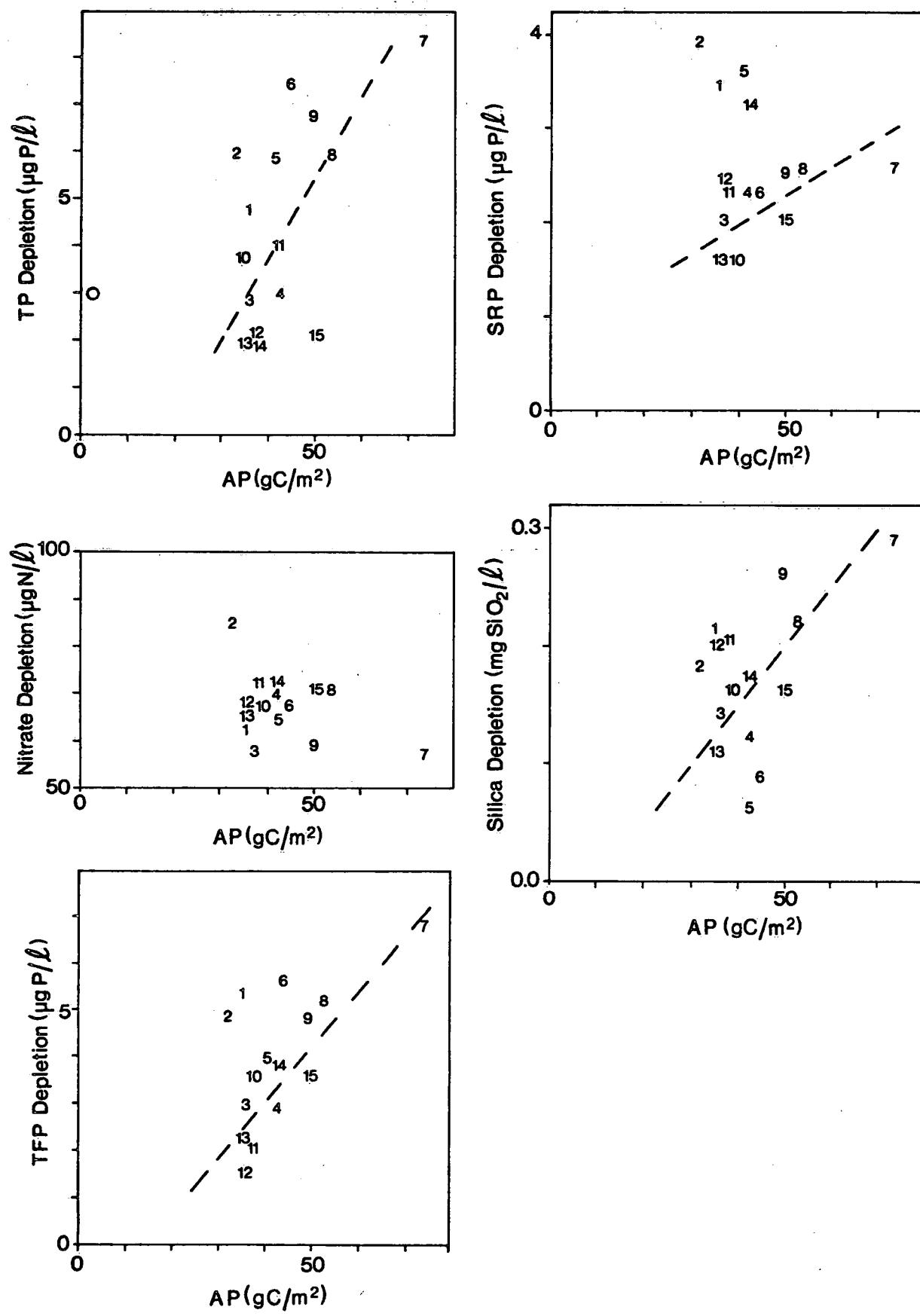


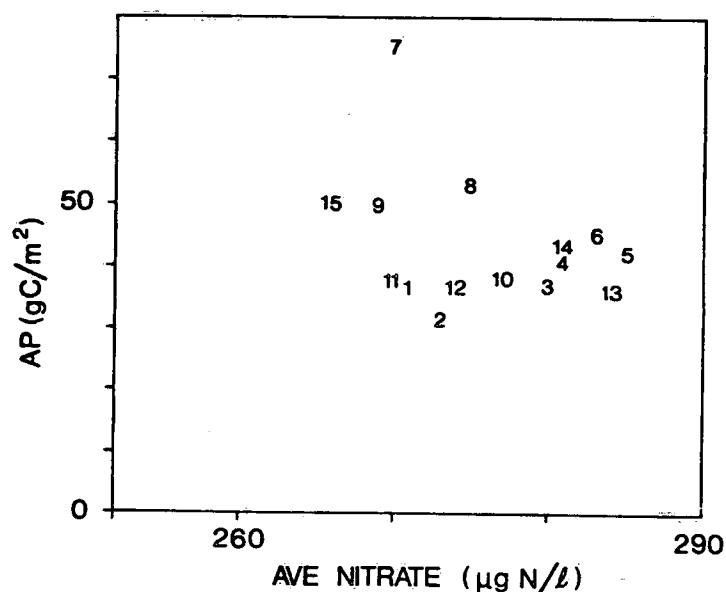
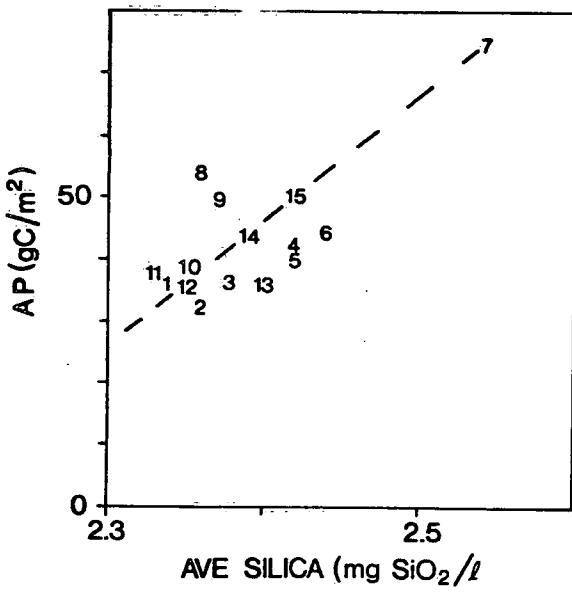
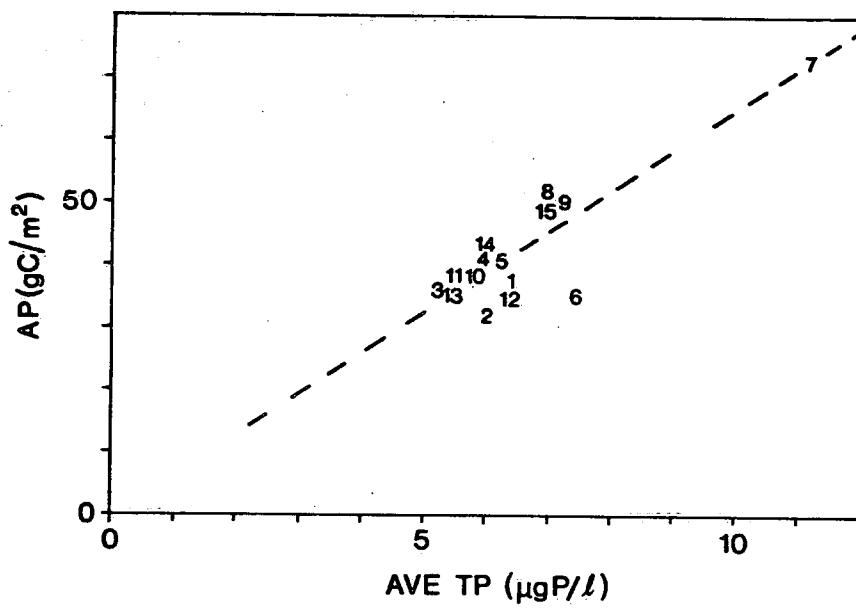


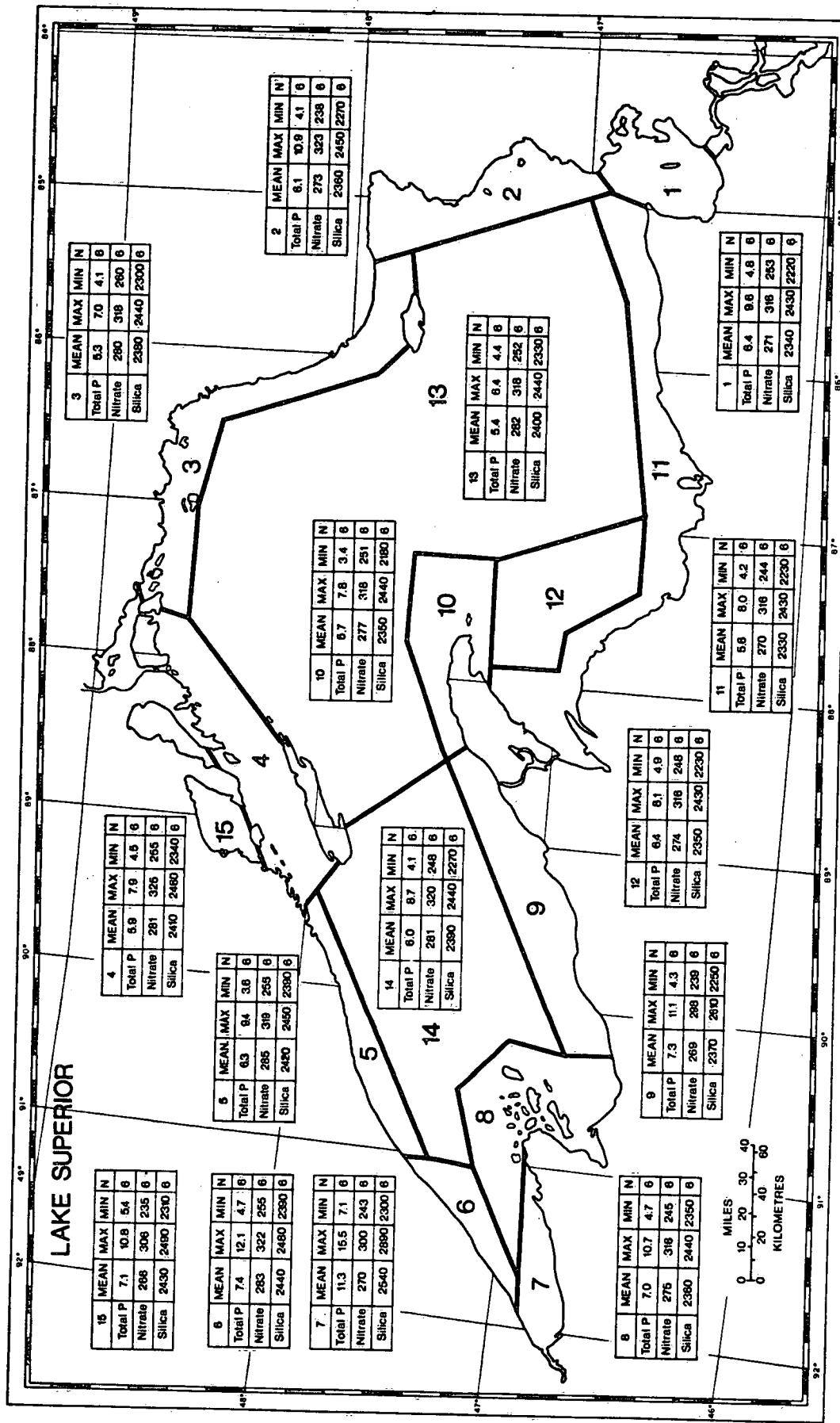


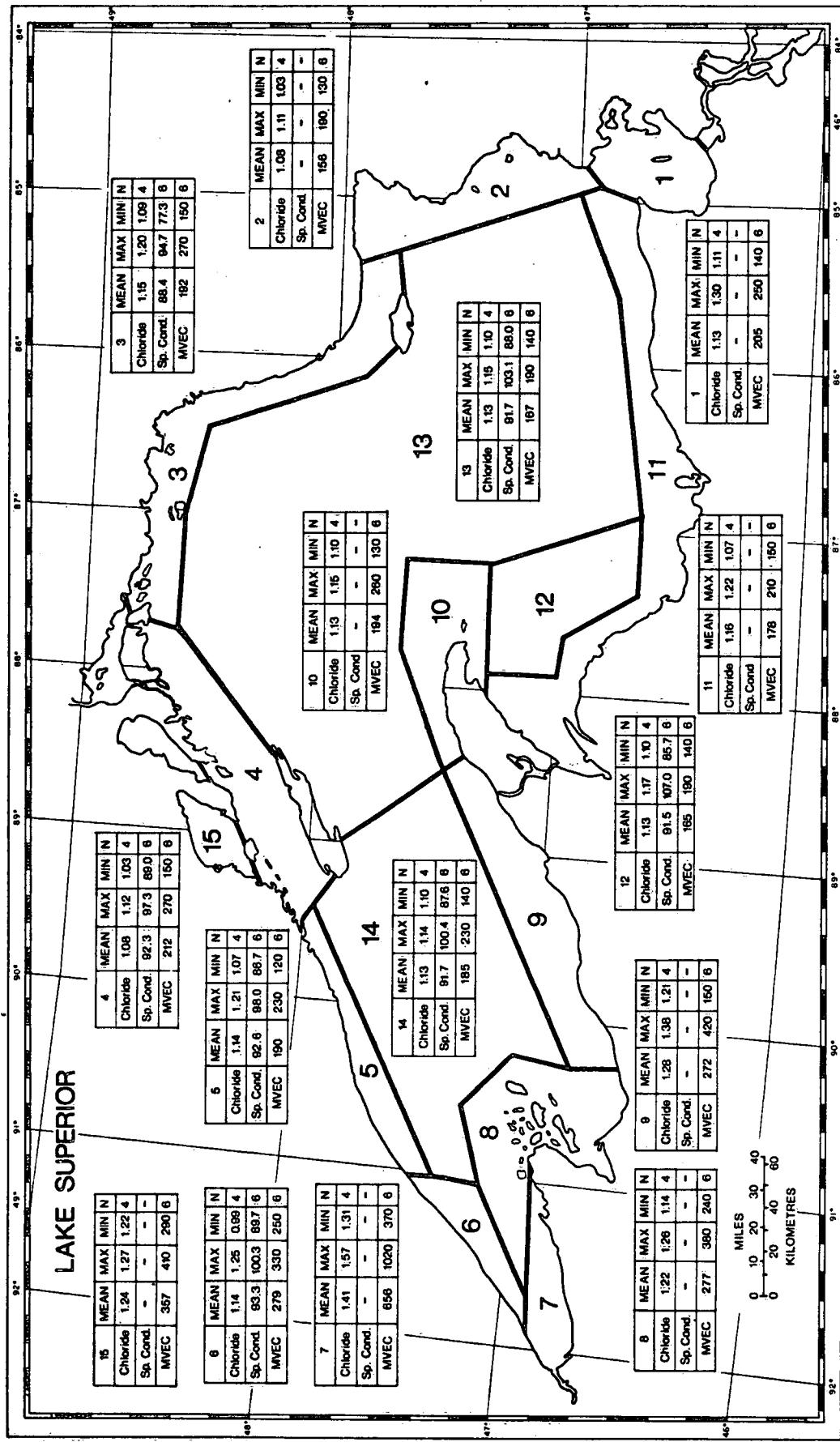












ADDENDUM

The problem of the precision and accuracy of the observations has been discussed in the section "Sampling and Analytical Methods" as well as in other sections of the report.

Recent discussions (September, 1976) with the WQB laboratory at CCIW have resulted in the following conclusions based in part on measurements made on a June, 1976 cruise in Lake Superior.

- the 1973 measurements of conductivity are clearly wrong and should be disregarded, although no clear cut reasons as to the cause could be found at this late date. The correct value is around 97 μS at 25°C .
- the 1973 total and total filtered phosphorus values are about 1.5 to 2 $\mu\text{g}/\text{l}$ too high, and the results for the September cruise should be disregarded altogether. A possible reason for the high values is the difficulties the laboratory had that year with a new auto-analyzer system.
- all silica data prior to 1973 are about 10% too low. The cause for this is the storage of intermediate standards in glass bottles from which silica was leached.

APPENDICES

INTRODUCTION

The tables presented in the main text are extracts from much more extensive tables. To enable the interested reader to supplement the discussion in the main text, these extended tables have been appended.

There are 3 appendices. Appendix A presents all of the 1973 data by cruise and by lake segment (Figure 1a). For each parameter, epilimnion (top 10 m) and hypolimnion (10 m to bottom) arithmetic averages have been calculated. In addition, volume weighted averages for the whole water column have also been obtained for the nutrients. The arrangement in each cell of the tables is as follows:

epilimnion - average (standard deviation) sample size
hypolimnion - average (standard deviation) sample size
volume-weighted average

The arithmetic averages were calculated as follows. For each station, all the readings within the epilimnion were averaged. Similarly for the hypolimnion. Then the averages for each station within a lake segment were averaged to obtain the average value for the segment. The sample size, in consequence, is determined by the number of stations within each segment.

Briefly, the method for calculating the weighted averages is the following. Concentrations for every station at specified fixed depths were interpolated from the observations. The lake was divided into 4 km by 4 km squares, the number of squares decreasing with depth because of the shape of the lake basin. At the specified

depths, each square was assigned a concentration corresponding to that of the nearest station. This procedure is equivalent to a linear interpolation. For each zone that the lake was divided into, the concentrations were then integrated vertically to obtain the volume weighted average.

Appendix B consists of two tables of arithmetic averages (epilimnion and hypolimnion) for zone 13 for all the cruises in 1973. In these tables, all of the conductivity measurements and the phosphorus measurements for the September cruise have been omitted since they are almost certainly wrong.

Appendix C consists of tables of data for 1968 to 1971 for zones I and VIII (Figure 1b). The cruise dates are given in Table 1. The numbers in the table represent: average (standard deviation) sample size. Prior to 1971, averages for the whole column were calculated. In 1971, separate averages for the epilimnion and the hypolimnion were calculated. In the tables, the top row for each cruise in 1971 is the epilimnion value and the bottom, the hypolimnion. The sample size represents the number of analytical determinations per zone, not, as in 1973, the number of stations per zone.

Appendix A: Concentrations in 1973 by cruise and lake segment

<u>Year</u>	<u>Cruise Number</u>	<u>Date</u>
1968	301	Aug. 18 - 28
1969	302	Nov. 15 - 23
1970	301	April 15 - 23
	302	Oct. 28 - Nov. 6
1971	301	May 26 - June 2
	303	June 30 - July 7
	305	Oct. 5 - 13
1973	302	May 12 - 22
	305	June 15 - 27
	306	July 27 - Aug. 7
	310	Sept. 6 - 16
	312	Oct. 14 - 25
	313	Nov. 14 - 28

CALCIUM (mg Ca/l)

CRUISE ZONE	302	305	306	310	312	313
1						
2	13.20 12.95	12.30 12.65	12.00 12.25	13.40 13.00		12.90 12.70
3	13.40(0.10) 3 13.44(0.07) 3	13.03(0.58) 3 13.15(0.44) 3	12.33(0.29) 3 12.67(0.03) 3	13.53(0.12) 3 13.63(0.32) 3	12.40(0.10) 3 12.49(0.08) 3	12.90(0.17) 3 12.90(0.10) 3
4	13.10 12.88	12.90 12.75	12.50 12.40	13.60 13.55	12.50 12.60	13.00 13.10
5	13.10(0.14) 2 13.05(0.07) 2	12.70(0.28) 2 12.86(0.16) 2	12.05(0.07) 2 12.35(0.18) 2	13.70(0.42) 2 13.90(0.07) 2	12.40(0.14) 2 12.55(0.04) 2	12.90(0.14) 2 12.95(0.11) 2
6	12.90(0.0) 2 12.94(0.09) 2	12.65(0.21) 2 12.73(0.04) 2	12.30(0.0) 2 12.28(0.0) 2	13.90(0.42) 2 14.05(0.28) 2	12.45(0.21) 2 12.48(0.04) 2	13.15(0.07) 2 13.13(0.11) 2
7	13.10 13.05	12.90 14.00	12.10 12.40	15.40 14.20		
8						
9	12.80 13.10	12.90 12.60	12.60 12.30	14.00 14.00		13.30 13.00
10						
11	13.10(0.14) 4 13.12(0.09) 4	13.08(0.46) 4 12.74(0.28) 4	12.40(0.22) 4 12.38(0.17) 4	12.73(0.31) 3 13.58(0.47) 3	12.50(0.27) 3 12.50(0.0) 3	12.98(0.26) 4 13.00(0.16) 4
12	12.90 13.03	12.80 12.73	12.10 12.55	13.60 13.55	12.40 12.78	13.00 12.98
13	13.27(0.24) 9 13.18(0.15) 9	12.57(0.68) 9 12.76(0.25) 9	12.47(0.11) 9 12.55(0.15) 9	13.33(0.42) 9 13.43(0.25) 9	12.54(0.07) 8 12.53(0.15) 8	12.93(0.17) 9 12.84(0.05) 9
14	13.30(0.44) 3 13.00(0.04) 3	12.67(0.40) 3 12.75(0.07) 3	12.13(0.12) 3 12.23(0.19) 3	13.20(1.04) 3 14.00(0.26) 3	12.37(0.23) 3 12.45(0.04) 3	13.13(0.06) 3 13.04(0.06) 3
15	13.00 13.00	12.80 13.00	12.60 12.50	13.80 14.70	12.70 12.45	13.60 13.20
WHOLE LAKE	13.17(0.24) 29 13.12(0.17) 29	12.75(0.49) 29 12.84(0.33) 29	12.34(0.21) 29 12.44(0.18) 29	13.48(0.63) 28 13.69(0.41) 28	12.48(0.15) 24 12.52(0.11) 24	13.01(0.21) 28 12.95(0.14) 28

MAGNESIUM (mg Mg/l)

CRUISE ZONE	302	305	306	310	312	313
1						
2	2.80 2.80	2.50 2.65	2.50 2.60	2.50 2.60		2.60 2.60
3	2.90 (0.0) 3 2.90 (0.0) 3	2.60 (0.0) 3 2.62 (0.04) 3	2.57 (0.06) 3 2.64 (0.03) 3	2.60 (0.0) 3 2.58 (0.03) 3	2.60 (0.0) 3 2.61 (0.02) 3	2.60 (0.0) 3 2.56 (0.05) 3
4	2.90 2.88	2.70 2.63	2.70 2.63	2.60 2.63	2.60 2.63	2.50 2.55
5	2.85 (0.07) 2 2.85 (0.04) 2	2.60 (0.0) 2 2.66 (0.05) 2	2.60 (0.0) 2 2.63 (0.04) 2	2.75 (0.07) 2 2.69 (0.02) 2	2.60 (0.0) 2 2.61 (0.02) 2	2.55 (0.07) 2 2.55 (0.0) 2
6	2.90 (0.0) 2 2.91 (0.02) 2	2.60 (0.0) 2 2.64 (0.02) 2	2.60 (0.0) 2 2.61 (0.02) 2	2.65 (0.07) 2 2.70 (0.0) 2	2.65 (0.07) 2 2.66 (0.02) 2	2.70 (0.0) 2 2.68 (0.0) 2
7	3.00 2.95	2.60 2.50	2.60 2.65	2.80 2.85		
8						
9	2.90 2.90	2.60 2.60	2.60 2.60	2.70 2.70		2.60 2.60
10						
11	2.83 (0.05) 4 2.82 (0.03) 4	2.65 (0.06) 4 2.64 (0.05) 4	2.63 (0.05) 4 2.61 (0.03) 4	2.53 (0.06) 3 2.53 (0.06) 3	2.70 (0.0) 3 2.70 (0.0) 3	2.68 (0.05) 4 2.63 (0.05) 4
12	2.80 2.83	2.60 2.65	2.60 2.70	2.60 2.53	2.70 2.70	2.60 2.60
13	2.86 (0.05) 9 2.84 (0.05) 9	2.63 (0.05) 9 2.62 (0.02) 9	2.60 (0.05) 9 2.63 (0.03) 9	2.56 (0.05) 9 2.58 (0.03) 9	2.65 (0.05) 8 2.65 (0.04) 8	2.60 (0.05) 9 2.57 (0.05) 9
14	2.90 (0.0) 3 2.90 (0.0) 3	2.67 (0.06) 3 2.63 (0.05) 3	2.53 (0.06) 3 2.57 (0.04) 3	2.67 (0.12) 3 2.66 (0.06) 3	2.60 (0.0) 3 2.61 (0.01) 3	2.60 (0.0) 3 2.58 (0.03) 3
15	3.00 2.80	2.60 2.70	2.80 2.60	2.70 2.65	2.70 2.65	2.70 2.70
WHOLE LAKE	2.87 (0.06) 29 2.86 (0.05) 29	2.62 (0.05) 29 2.63 (0.04) 29	2.60 (0.07) 29 2.62 (0.04) 29	2.61 (0.09) 28 2.62 (0.08) 28	2.64 (0.05) 24 2.65 (0.04) 24	2.61 (0.06) 28 2.59 (0.05) 28

SODIUM (mg Na/l)

CRUISE ZONE \	302	305	306	310	312	313
1						
2	1.30 1.20	1.10 1.10	1.20 1.30	1.30 1.35		1.30 1.30
3	1.20 (0.0) 3 1.20 (0.0) 3	1.23 (0.06) 3 1.20 (0.0) 3	1.33 (0.06) 3 1.30 (0.0) 3	1.43 (0.06) 3 1.39 (0.04) 3	1.30 (0.0) 3 1.30 (0.0) 3	1.33 (0.06) 3 1.33 (0.06) 3
4	1.20 1.20	1.20 1.20	1.30 1.33	1.40 1.45	1.30 1.30	1.30 1.33
5	1.20 (0.0) 2 1.21 (0.02) 2	1.20 (0.0) 2 1.25 (0.07) 2	1.30 (0.0) 2 1.30 (0.0) 2	1.50 (0.0) 2 1.51 (0.05) 2	1.30 (0.0) 2 1.30 (0.0) 2	1.30 (0.0) 2 1.31 (0.02) 2
6	1.20 (0.0) 2 1.20 (0.0) 2	1.20 (0.0) 2 1.20 (0.04) 2	1.30 (0.0) 2 1.30 (0.0) 2	1.45 (0.07) 2 1.55 (0.18) 2	1.30 (0.0) 2 1.29 (0.02) 2	1.30 (0.0) 2 1.31 (0.02) 2
7	1.30 1.30	1.20 1.10	1.40 1.35	1.40 1.40		
8						
9	1.20 1.40	1.10 1.10	1.30 1.30	1.50 1.40		1.30 1.30
10						
11	1.22 (0.05) 4 1.21 (0.02) 4	1.20 (0.08) 4 1.21 (0.03) 4	1.32 (0.05) 4 1.30 (0.0) 4	1.40 (0.10) 3 1.35 (0.05) 3	1.27 (0.06) 3 1.27 (0.06) 3	1.30 (0.0) 4 1.33 (0.05) 4
12	1.30 1.20	1.20 1.18	1.30 1.30	1.40 1.40	1.30 1.30	1.30 1.30
13	1.28 (0.13) 9 1.23 (0.03) 9	1.19 (0.03) 9 1.20 (0.03) 9	1.27 (0.05) 9 1.29 (0.03) 9	1.37 (0.07) 9 1.38 (0.05) 9	1.24 (0.05) 8 1.26 (0.05) 8	1.30 (0.0) 9 1.30 (0.01) 9
14	1.23 (0.06) 3 1.21 (0.01) 3	1.20 (0.0) 3 1.19 (0.03) 3	1.30 (0.0) 3 1.30 (0.0) 3	1.43 (0.06) 3 1.44 (0.04) 3	1.30 (0.0) 3 1.30 (0.0) 3	1.33 (0.06) 3 1.30 (0.0) 3
15	1.40 1.20	1.20 1.20	1.50 1.35	1.50 1.50	1.30 1.30	1.40 1.40
WHOLE LAKE	1.25 (0.09) 29 1.22 (0.04) 29	1.19 (0.05) 29 1.19 (0.04) 29	1.30 (0.06) 29 1.30 (0.02) 29	1.41 (0.07) 28 1.41 (0.08) 28	1.27 (0.04) 24 1.28 (0.04) 24	1.31 (0.03) 28 1.31 (0.03) 28

POTASSIUM (mg K/l)

CRUISE ZONE	302	305	306	310	312	313
1						
2	0.50 0.50	0.40 0.40	0.50 0.50	0.50 0.30		0.50 0.50
3	0.47 (0.06) 3 0.49 (0.02) 3	0.43 (0.06) 3 0.41 (0.02) 3	0.50 (0.0) 3 0.50 (0.0) 3	0.43 (0.06) 3 0.41 (0.02) 3	0.50 (0.0) 3 0.50 (0.0) 3	0.50 (0.0) 3 0.50 (0.0) 3
4	0.50 0.50	0.40 0.43	0.50 0.53	0.40 0.45	0.50 0.50	0.50 0.50
5	0.50 (0.0) 2 0.50 (0.0) 2	0.40 (0.0) 2 0.44 (0.02) 2	0.50 (0.0) 2 0.53 (0.04) 2	0.40 (0.0) 2 0.44 (0.02) 2	0.50 (0.0) 2 0.50 (0.0) 2	0.50 (0.0) 2 0.50 (0.0) 2
6	0.50 (0.0) 2 0.50 (0.0) 2	0.45 (0.07) 2 0.46 (0.02) 2	0.50 (0.0) 2 0.50 (0.0) 2	0.40 (0.0) 2 0.39 (0.02) 2	0.50 (0.0) 2 0.50 (0.0) 2	0.50 (0.0) 2 0.50 (0.0) 2
7	0.50 0.50	0.50 0.40	0.50 0.55	0.6 0.45		
8						
9	0.50 0.50	0.50 0.40	0.50 0.50	0.50 0.30		0.50 0.50
10						
11	0.47 (0.05) 4 0.40 (0.05) 4	0.43 (0.05) 4 0.45 (0.04) 4	0.50 (0.0) 4 0.50 (0.0) 4	0.33 (0.06) 3 0.33 (0.03) 3	0.50 (0.0) 3 0.50 (0.0) 3	0.50 (0.0) 4 0.50 (0.0) 4
12	0.50 0.50	0.40 0.53	0.50 0.50	0.30 0.38	0.50 0.50	0.50 0.50
13	0.50 (0.0) 9 0.50 (0.01) 9	0.43 (0.05) 9 0.43 (0.03) 9	0.50 (0.0) 9 0.50 (0.01) 9	0.41 (0.14) 9 0.37 (0.05) 9	0.50 (0.0) 8 0.50 (0.0) 8	0.50 (0.0) 9 0.50 (0.0) 9
14	0.50 (0.0) 3 0.50 (0.0) 3	0.43 (0.06) 3 0.45 (0.03) 3	0.53 (0.06) 3 0.50 (0.0) 3	0.77 (0.38) 3 0.45 (0.03) 3	0.50 (0.0) 3 0.50 (0.0) 3	0.50 (0.0) 3 0.50 (0.0) 3
15	0.50 0.50	0.50 0.40	0.50 0.50	0.50 0.40	0.50 0.50	0.50 0.50
WHOLE LAKE	0.49(0.03)29 0.50(0.01)29	0.43 (0.05)29 0.43 (0.03)29	0.50 (0.02)29 0.51 (0.01)29	0.45 (0.18)28 0.39 (0.05)28	0.50 (0.0)24 0.50 (0.0)24	0.50 (0.0) 28 0.50 (0.0) 28

ALKALINITY (mg CaCO₃/l)

CRUISE ZONE	302	305	306	310	312	313
1	42.24(1.94) 5 42.50(2.02) 5		41.16(1.05) 8 41.37(1.51) 8		40.91(0.37) 6 40.04(2.55) 6	
2	42.23(1.38) 7 42.54(1.98) 7		40.45(0.58) 8 41.24(0.77) 8		41.46(0.29) 7 41.43(0.70) 7	
3	42.87(0.83) 7 43.41(1.19) 7	43.30 44.40	41.44(0.95) 11 42.11(0.60) 11		41.24(0.53) 8 41.53(0.62) 8	
4	43.74(0.68) 7 44.19(0.92) 7	42.63 43.16	42.50(1.03) 9 42.35(0.77) 9		41.15(0.52) 8 41.43(0.30) 8	
5	43.53(0.96) 6 43.46(1.28) 6	40.88(0.78) 2 41.31(1.31) 2	42.34(0.36) 6 42.63(0.45) 6		41.20(0.93) 6 41.61(0.65) 6	
6	44.05(0.59) 6 44.75(1.32) 6	41.75(1.86) 2 43.71(2.34) 2	41.74(0.25) 6 42.08(0.35) 6		40.56(0.95) 5 40.80(1.30) 5	
7	43.62(0.49) 6 44.03(0.64) 6		42.09(0.80) 7 42.31(0.88) 7		41.17(0.80) 4 41.14(0.84) 4	
8	43.87(1.97) 7 44.65(2.39) 7		42.26(0.42) 10 42.51(0.40) 10		41.58(0.29) 4 41.85(0.27) 4	
9	42.28(0.67) 6 43.64(1.37) 6		41.83(0.43) 8 42.06(0.54) 8		41.56(0.54) 5 41.58(0.98) 5	
10	41.21(1.15) 8 41.81(1.53) 8		41.88(0.93) 7 41.81(0.96) 7		41.33(0.59) 8 41.47(0.28) 8	
11	42.20(1.30) 14 42.63(1.33) 14		41.80(0.56) 19 42.12(0.73) 18		41.67(0.45) 10 41.64(0.45) 10	
12	42.88(0.99) 4 43.61(1.38) 4	39.13 39.50	41.79(0.29) 5 42.38(0.56) 5		41.70(0.37) 4 42.05(0.35) 4	
13	43.17(0.82) 20 43.95(1.29) 20	40.75(2.85) 9 41.00(3.40) 9	41.74(0.60) 22 41.97(0.80) 22		41.29(0.61) 20 41.53(0.66) 20	
14	42.71(1.67) 11 43.29(1.62) 11	41.79(1.58) 3 41.73(1.49) 3	42.15(0.42) 12 42.41(0.35) 12		41.32(0.46) 11 41.32(0.43) 11	
15	42.56(0.80) 3 42.93(0.97) 3		43.64(0.28) 3 43.10(0.30) 3		41.90(0.30) 3 41.65(0.48) 3	
WHOLE LAKE	42.85(1.34) 117 43.43(1.59) 117	41.18(2.22) 19 41.65(2.70) 19	41.84(0.83) 141 42.11(0.80) 140		41.32(0.60) 109 41.41(0.89) 109	

CHLORIDE (mg Cl/l)

CRUISE ZONE	302	305	306	310	312	313
1	1.11 (0.21) 5 1.14 (0.23) 5		0.82 (0.12) 4 0.80 (0.08) 4	1.30 (0.15) 7 1.28 (0.18) 7	1.11 (0.13) 6 1.08 (0.14) 6	1.60
2	1.03 (0.27) 7 0.97 (0.31) 7			1.11 (0.11) 8 1.18 (0.14) 8	1.11 (0.05) 7 1.11 (0.05) 7	1.70 (0.17) 3 1.60
3	1.18 (0.10) 7 1.16 (0.11) 7	1.20 1.27		1.14 (0.08) 11 1.13 (0.10) 11	1.09 (0.07) 8 1.09 (0.07) 8	1.60 1.57 (0.12) 3
4	1.07 (0.06) 7 1.11 (0.09) 7	1.03 1.18		1.12 (0.09) 9 1.07 (0.07) 9	1.08 (0.07) 8 1.08 (0.04) 8	1.55 (0.21) ? 1.60
5	1.18 (0.10) 6 1.16 (0.13) 6	1.10 (0.09) 2 1.08 (0.06) 2		1.21 (0.13) 6 1.20 (0.10) 6	1.07 (0.10) 6 1.06 (0.11) 6	1.50 (0.0) 2 1.60 (0.0) 2
6	1.25 (0.07) 6 1.25 (0.09) 6	1.10 (0.0) 2 1.14 (0.04) 2		1.23 (0.07) 6 1.19 (0.09) 6	0.99 (0.09) 5 0.99 (0.07) 5	
7	1.57 (0.54) 6 1.55 (0.53) 6			1.31 (0.11) 7 1.26 (0.05) 7	1.34 (0.25) 4 1.28 (0.21) 4	
8	1.26 (0.14) 7 1.27 (0.12) 7			1.25 (0.12) 11 1.23 (0.10) 11	1.14 (0.07) 4 1.11 (0.06) 4	
9	1.38 (0.33) 6 1.36 (0.22) 6	1.30 1.10		1.22 (0.05) 7 1.16 (0.08) 7	1.21 (0.07) 5 1.27 (0.13) 5	1.50 1.70
10	1.10 (0.07) 8 1.08 (0.07) 8			1.15 (0.16) 6 1.13 (0.27) 6	1.15 (0.10) 8 1.14 (0.12) 8	
11	1.07 (0.16) 14 1.10 (0.14) 14		1.17 1.20	1.22 (0.13) 19 1.17 (0.09) 19	1.17 (0.12) 10 1.13 (0.10) 10	1.63 (0.05) 4 1.63 (0.10) 4
12	1.14 (0.16) 4 1.16 (0.16) 4	1.17 1.00		1.11 (0.04) 5 1.10 (0.05) 5	1.10 (0.07) 4 1.13 (0.05) 4	1.60 1.58
13	1.15 (0.12) 20 1.16 (0.15) 20	1.11 (0.06) 9 1.14 (0.10) 9	0.83* 0.95	1.15 (0.11) 23 1.13 (0.12) 23	1.10 (0.08) 20 1.09 (0.10) 20	1.62 (0.15) 9 1.59 (0.08) 9
14	1.13 (0.14) 11 1.13 (0.11) 11	1.10 (0.07) 3 1.09 (0.08) 3		1.14 (0.12) 12 1.16 (0.14) 12	1.14 (0.06) 11 1.13 (0.06) 11	1.57 (0.23) 3 1.54 (0.04) 3
15	1.22 (0.11) 3 1.25 (0.09) 3			1.24 (0.15) 3 1.19 (0.15) 3	1.27 (0.03) 3 1.22 (0.06) 3	1.70 1.90
WHOLE LAKE	1.17(0.22)117 1.17(0.22)117	1.12 (0.07)20 1.13 (0.09)20		1.19(0.12)140 1.17(0.12)140	1.13(0.11)109 1.11(0.11)109	1.61 (0.13)28 1.60 (0.10)28

SULPHATE (mg SO₄/L)

CRUISE ZONE	302	305	306	310	312	313
1						
2	3.15 3.10	3.10 3.00	3.20 4.10	3.10 3.30		3.00 3.00
3	3.01 (0.04) 3 2.97 (0.12) 3	3.00 (0.57) 3 2.87 (0.46) 3	3.03 (0.03) 3 3.13 (0.06) 3	3.08 (0.03) 3 3.20 (0.0) 3	3.13 (0.09) 3 3.07 (0.06) 3	3.07 (0.06) 3 3.13 (0.12) 3
4	2.98 2.90	2.75 2.70	2.93 3.00	2.80 3.20	3.23 3.10	3.08 3.10
5	2.91 (0.16) 2 2.95 (0.07) 2	2.80 (0.04) 2 2.80 (0.0) 2	2.80 (0.46) 2 2.90 (0.14) 2	3.13 (0.32) 2 3.05 (0.21) 2	3.15 (0.11) 2 3.30 (0.14) 2	3.04 (0.02) 2 3.05 (0.07) 2
6	3.16 (0.02) 2 3.10 (0.0) 2	2.91 (0.05) 2 2.80 (0.14) 2	2.91 (0.02) 2 2.95 (0.07) 2	2.75 (0.07) 2 2.80 (0.0) 2	3.11 (0.02) 2 3.10 (0.0) 2	3.11 (0.02) 2 3.10 (0.0) 2
7	4.05 2.70	2.65 3.40	3.05 3.10	2.60 2.90		
8						
9	3.20 3.80	2.70 2.80	3.00 3.00	3.40 3.40		3.10 3.10
10						
11	3.06 (0.13) 4 2.97 (0.15) 4	2.41 (0.12) 4 2.38 (0.10) 4	3.08 (0.07) 4 3.15 (0.17) 4	3.14 (0.05) 4 3.15 (0.06) 4	3.03 (0.06) 3 3.10 (0.10) 3	3.05 (0.06) 4 3.10 (0.08) 4
12	2.90 3.00	2.90 2.40	3.05 3.10	3.50 3.00	3.05 3.00	3.08 3.00
13	3.03 (0.11) 9 3.02 (0.12) 9	2.67 (0.46) 9 2.60 (0.29) 9	3.00 (0.10) 9 3.02 (0.13) 9	3.13 (0.26) 9 3.21 (0.32) 9	3.07 (0.06) 8 3.09 (0.04) 8	3.03 (0.07) 9 3.06 (0.13) 9
14	2.93 (0.03) 3 3.00 (0.10) 3	2.77 (0.04) 3 2.60 (0.10) 3	2.83 (0.09) 3 2.90	3.00 (0.22) 3 2.95 (0.07) 2	3.09 (0.04) 3 3.13 (0.06) 3	3.05 (0.05) 3 3.07 (0.06) 3
15	3.50 3.50	3.80 3.80	3.20 3.20	3.30 3.60	3.20 3.40	3.30 3.40
WHOLE LAKE	3.08 (0.23) 29 3.04 (0.21) 29	2.77 (0.40) 29 2.71 (0.36) 29	2.99 (0.15) 29 3.09 (0.24) 27	3.08 (0.24) 29 3.15 (0.25) 28	3.10 (0.07) 24 3.12 (0.10) 24	3.06 (0.07) 28 3.09 (0.11) 28

SPECIFIC CONDUCTIVITY (μS at 25°C)

CRUISE ZONE \	302	305	306	310	312	313
ZONE /						
1			93.3 96.0			
2						
3		94.7 95.0	92.3 97.7	89.7 89.7	88.0 90.0	77.3 79.7
4	97.3 98.4	95.0 95.0	91.7 92.8	90.7 91.4	90.0 91.4	89.0 88.6
5	98.0 (0.5) 2 100.3 (2.1) 2	95.0 94.8	95.7 (4.2) 2 93.7 (3.1) 2	90.3 89.6 (0.1) 2	90.0 (1.4) 2 90.6 (0.4) 2	86.7 (5.7) 2 89.1 (2.5) 2
6	100.3 100.0	93.7 (2.8) 2 95.7 (0.6) 2	94.5 (2.1) 2 91.7 (3.2) 2	91.7 91.7	89.8 (1.1) 2 88.4 (5.4) 2	89.7 (1.4) 2 89.0 (0.2) 2
7						
8						
9						
10						
11	91.3 91.0					
12	107.0 108.8	91.3 90.5	87.0 93.8	89.7 89.0	88.5 91.0	85.7 85.3
13	103.1 (10.6) 9 101.0 (4.0) 8	92.2 (2.4) 9 93.8 (1.4) 9	90.3 (3.8) 9 89.0 (4.1) 9	89.9 (1.6) 9 90.0 (1.7) 9	87.1 (2.8) 8 89.4 (1.0) 8	88.0 (2.3) 9 88.4 (2.6) 9
14	100.4 (4.2) 3 100.9 (2.5) 3	94.0 (1.7) 3 95.8 (1.5) 3	92.3 (1.3) 3 96.5 (4.6) 4	91.0 (1.9) 3 91.4 (0.9) 3	84.8 (5.9) 3 89.9 (1.3) 3	87.6 (4.0) 3 89.8 (0.4) 3
15						
WHOLE LAKE	101.2 (8.2) 18 100.6 (4.3) 17	93.0 (2.2) 18 94.4 (1.7) 18	91.7 (3.5) 20 92.3 (4.7) 21	90.2 (1.4) 17 90.3 (1.4) 18	87.6 (3.3) 18 89.7 (1.7) 18	87.4 (3.6) 19 88.2 (2.9) 19

p H

CRUISE ZONE \	302	305	306	310	312	313
ZONE /						
1						
2						
3	8.00 7.92	7.97 7.96	8.17 8.03	8.24 8.15	8.16 8.05	8.12 8.06
4	7.95 7.70	7.94 7.91	8.21 7.98	8.23 8.01	8.12 8.01	7.97 7.90
5	7.84(0.18)2 7.71(0.10)2	7.94(0.03)2 7.92(0.0)2	8.22(0.02)2 7.96(0.02)2	8.21(0.20)2 7.94(0.08)2	8.06(0.07)2 7.93(0.03)2	7.93(0.04)2 7.88(0.02)2
6	7.82(0.08)2 7.73(0.01)2	7.89(0.02)2 7.87(0.01)2	8.30(0.04)2 7.92(0.0)2	8.15(0.03)2 7.87(0.03)2	8.30(0.03)2 7.99(0.06)2	7.92(0.04)2 7.93(0.01)2
7						
8						
9						
10						
11	7.54 7.81					
12	7.69 7.70	7.91 7.75	8.27 8.00	8.27 8.09	8.14 8.07	8.12 8.01
13	7.74(0.10)9 7.70(0.08)9	7.85(0.12)9 7.83(0.07)9	8.12(0.07)9 7.98(0.04)10	8.26(0.1)9 8.06(0.07)9	7.87(0.28)8 7.83(0.18)8	7.97(0.17)9 8.01(0.09)9
14	7.67(0.05)3 7.66(0.03)3	7.85(0.02)3 7.88(0.02)3	8.29(0.04)3 8.02(0.06)3	8.35(0.06)3 8.00(0.02)3	8.12(0.44)3 7.93(0.02)3	7.93(0.11)3 7.95(0.04)3
15						
WHOLE LAKE	7.76(0.13)20 7.72(0.08)20	7.88(0.09)19 7.86(0.07)19	8.19(0.09)19 7.98(0.05)20	8.26(0.12)19 8.02(0.09)19	8.03(0.28)18 7.91(0.14)18	7.97(0.13)19 7.97(0.08)19

OXYGEN (mg O₂/l)

CRUISE ZONE \	302	305	306	310	312	313
ZONE /						
1	13.60(0.14)5 13.64(0.14)5	12.51(0.31)8 13.14(0.24)8	10.42(0.47)8 12.28(0.23)8	9.22(0.28)8 10.39(0.53)8	10.21(0.11)6 10.57(0.24)6	11.28(0.13)5 11.34(0.13)5
2	13.67(0.06)7 13.67(0.15)7	13.39(0.27)8 13.56(0.17)8	11.08(0.38)8 13.15(0.33)8	9.73(0.25)8 11.52(0.93)8	10.62(0.35)7 11.47(0.56)7	11.58(0.21)7 11.62(0.07)7
3	13.71(0.09)7 13.73(0.11)7	13.54(0.10)12 13.57(0.11)12	11.81(0.46)12 13.02(0.23)12	11.06(0.83)12 12.87(0.37)12	11.18(0.23)8 11.76(0.40)8	12.36(0.23)9 12.37(0.23)9
4	13.71(0.04)7 13.71(0.06)7	13.63(0.13)9 13.67(0.11)9	11.95(0.40)9 13.18(0.18)9	11.36(0.45)9 12.96(0.28)9	11.79(0.17)8 12.25(0.27)8	12.33(0.13)8 12.38(0.11)8
5	13.75(0.14)6 13.68(0.22)6	13.63(0.08)6 13.67(0.10)6	11.43(0.40)6 13.32(0.28)6	12.14(0.66)6 13.28(0.34)6	12.24(0.15)6 12.69(0.20)6	12.59(0.11)6 12.62(0.13)6
6	13.66(0.05)6 13.39(0.34)6	13.44(0.19)6 13.48(0.11)6	11.24(0.31)6 12.90(0.29)6	11.71(0.67)6 13.14(0.18)6	12.02(0.13)5 12.32(0.37)5	12.54(0.05)6 12.59(0.09)6
7	13.30(0.57)6 13.31(0.57)6	12.20(0.45)7 12.72(0.63)7	10.91(0.48)7 11.89(0.61)7	10.23(0.20)7 12.19(0.53)7	11.37(0.53)4 11.47(0.41)4	12.36(0.08)5 12.35(0.06)5
8	13.47(0.25)7 13.57(0.14)7	12.44(0.60)11 13.22(0.28)11	10.47(0.58)10 12.79(0.39)10	10.68(0.37)11 11.66(1.04)11	11.67(0.22)4 11.86(0.31)4	12.33(0.10)8 12.37(0.09)8
9	12.93(0.59)6 13.01(0.61)6	12.01(0.51)7 12.93(0.49)6	11.49(1.04)8 12.81(0.20)8	9.97(0.40)7 10.65(0.73)7	11.06(0.18)5 11.11(0.20)5	12.26(0.14)5 12.28(0.15)5
10	13.52(0.12)8 13.51(0.11)8	13.39(0.16)8 13.47(0.10)8	11.74(0.61)8 12.95(0.21)8	10.09(0.82)8 11.54(0.82)8	11.38(0.40)8 11.50(0.46)8	12.27(0.21)8 12.27(0.23)8
11	13.67(0.12)14 13.65(0.12)14	12.91(0.45)19 13.28(0.35)19	10.69(0.46)19 12.56(0.74)18	9.89(0.41)19 11.10(1.23)19	10.64(0.15)10 10.58(0.21)10	11.93(0.13)14 11.93(0.21)14
12	13.67(0.13)4 13.66(0.14)4	13.33(0.45)5 13.53(0.10)5	11.10(0.51)5 13.45(0.23)5	10.63(0.23)5 12.68(0.46)5	11.25(0.41)4 11.50(0.43)4	12.06(0.18)4 12.12(0.11)4
13	13.67(0.11)20 13.62(0.12)20	13.50(0.14)22 13.54(0.14)22	12.62(0.43)23 13.33(0.14)23	10.93(0.57)23 12.95(0.45)23	11.60(0.48)20 12.03(0.43)20	12.24(0.43)21 12.42(0.26)21
14	13.63(0.14)11 13.62(0.16)11	13.38(0.31)12 13.47(0.14)12	11.68(0.61)12 13.29(0.19)12	11.21(0.68)12 13.03(0.50)12	11.86(0.36)11 12.33(0.20)11	12.55(0.18)11 12.67(0.21)11
15	13.39(0.20)3 13.39(0.25)3	12.14(0.51)3 12.97(0.18)3	11.26(0.73)3 12.65(0.44)3	10.89(0.54)3 12.61(0.99)3	11.70(0.25)3 11.92(0.31)3	12.26(0.06)3 12.28(0.08)3
WHOLE LAKE	13.58(0.28)117 13.57(0.28)117	13.11(0.61)143 13.38(0.35)142	11.44(0.86)144 12.93(0.53)143	10.62(0.88)144 12.17(1.15)144	11.38(0.61)109 11.73(0.70)109	12.21(0.38)120 12.27(0.37)120

OXYGEN SATURATION (PERCENT)

CRUISE ZONE \	302	305	306	310	312	313
1	102.7 (0.7)5 103.2 (0.6)5	113.4(3.3)8 105.1(1.6)8	107.8(1.5)8 103.3(2.6)8	101.5(1.1)8 97.9(6.6)8	100.4(0.5)6 98.3(3.0)6	97.1(1.0)5 97.2(0.8)5
2	101.2(0.7)7 101.2(1.3)7	105.7(3.5)8 104.3(1.4)8	109.4(2.0)8 106.6(1.7)8	101.8(1.9)8 96.3 (5.5)8	101.5(3.4)7 101.8(3.5)7	97.9(1.1)7 98.1(0.9)7
3	101.3(0.5)7 101.4(0.7)7	104.0(1.1)12 104.2(1.1)12	109.6(1.1)12 105.8(1.3)12	105.9(2.1)12 103.5(3.3)12	100.8(0.7)8 99.9(3.3)8	99.4(1.0)9 99.4(0.9)9
4	100.7(0.4)7 100.8(0.4)7	103.6(1.2)9 103.9(1.2)9	110.7(1.9)9 103.9(1.1)9	106.8(1.6)9 103.6(2.5)9	101.9(1.1)8 101.9(1.4)8	98.5(0.7)8 98.5(1.2)8
5	101.4 0.6)6 100.9(1.1)6	103.5(0.7)6 103.8(1.0)6	110.2(1.2)6 105.5(2.1)6	108.3(1.4)6 104.6(2.6)6	102.7(1.2)6 100.8(0.9)6	98.8(0.9)6 99.0(0.7)6
6	101.3(0.4)6 99.5(2.4)6	103.4(0.8)6 103.1(1.0)6	112.1(1.5)6 104.2(2.5)6	107.9(1.1)6 104.5(1.8)6	101.9(0.5)5 100.7(0.8)5	98.2(0.5)6 98.4(0.8)6
7	103.5(1.3)6 103.7(1.5)6	108.4(3.3)7 101.7(3.0)7	111.6(2.6)7 102.8(3.3)7	103.9(1.0)7 99.5(2.6)7	98.0(2.6)4 98.5(1.3)4	96.3(0.7)5 96.2(1.1)5
8	103.9(2.1)5 104.0(1.9)5	108.8(1.8)11 104.7(2.9)11	107.5(3.1)10 103.4(3.1)10	105.9(2.4)11 101.8(2.6)11	100.9(0.3)4 98.8(2.5)4	97.6(0.8)8 97.6(0.7)8
9	103.3(1.3)6 101.8(2.4)6	109.7(1.2)7 105.9(4.1)6	109.8(3.7)8 102.8(3.3)8	103.4(1.7)7 101.9(3.3)7	100.7(1.1)5 99.2(2.4)5	97.4(0.7)5 97.6(0.9)5
10	101.1(1.0)8 101.0(0.9)8	105.3(2.6)8 104.9(1.9)8	107.4(1.4)8 103.9(1.7)8	103.9(2.8)8 103.6(0.9)8	101.2(0.4)8 101.3(0.7)8	98.9(1.2)8 98.9(1.1)8
11	103.0(1.1)12 103.0(1.0)12	108.6(1.9)19 106.6(2.3)19	108.6(1.9)19 106.9(3.5)18	104.4(2.0)19 103.9(2.1)19	101.2(1.3)10 100.1(2.7)10	98.6(1.3)14 98.4(1.9)14
12	101.8(1.3)4 101.8(1.2)4	105.5(1.9)5 105.3(1.4)5	108.8(2.9)5 104.9(1.1)5	106.5(1.0)5 102.8(4.4)5	100.6(0.8)4 99.7(1.4)4	98.4(0.5)4 98.6(0.5)4
13	100.9 0.6)20 100.8(0.7)20	102.7(0.9)22 102.9(1.1)22	108.9(2.2)23 104.6(1.5)23	106.4(3.0)23 104.2(2.3)23	101.3(0.9)20 99.4(2.1)20	98.6(2.9)21 99.1(1.3)21
14	101.5(0.8)11 101.5(0.9)11	105.0(2.6)12 103.6(1.1)12	111.0(2.1)12 103.8(1.7)12	107.2(2.4)12 103.7(3.3)12	101.5(2.3)11 100.5(2.2)11	98.7(1.1)11 99.7(1.4)11
15	101.7(0.3)3 101.8(0.8)3	107.4(1.7)3 104.7(1.5)3	108.9(1.4)3 102.3(5.2)3	105.6(1.7)3 103.4(3.7)3	100.8(1.6)3 100.0(2.3)3	96.5(0.5)3 96.7 0.6)3
WHOLE LAKE	101.8(1.3)113 101.6(1.6)113	106.1(3.5)143 104.3(2.2)142	109.4(2.4)144 104.6(2.7)143	105.3(2.7)144 102.7(3.8)144	101.2(1.6)109 100.1(2.3)109	98.3(1.6)120 98.5(1.4)120

TOTAL PHOSPHORUS (ug P/l)

74

CRUISE ZONE	302	305	306	310	312	313
1	3.6(0.4) 3 4.3(0.9) 5 3.6	9.6(2.3) 8 10.8(4.2) 7 9.3	6.3(3.8) 8 4.9(0.6) 8 5.3		4.8(2.5) 6 4.2(1.0) 6 4.0	7.7(3.1) 5 7.2(2.1) 5 8.6
2	10.9(3.3) 7 10.0(3.5) 7 11.2	5.2(1.2) 8 5.3(1.4) 8 5.8	4.1(0.5) 8 4.0(0.6) 8 4.3	6.3(1.5) 6 6.1(1.6) 6 5.6	4.7(2.5) 7 4.6(0.8) 7 4.6	5.1(1.9) 7 5.2(2.5) 7 6.1
3	7.0(1.5) 7 6.6(2.1) 7 6.4	4.7(0.9) 12 5.5(1.9) 12 4.3	4.8(1.1) 12 4.5(0.6) 12 4.4	6.0(1.9) 12 6.8(1.7) 12 6.1	5.3(1.2) 8 4.7(0.8) 8 4.1	4.1(0.5) 8 5.1(2.6) 8 4.0
4	7.9(3.4) 7 8.6(3.0) 7 6.6	5.5(0.8) 9 5.5(1.0) 8 4.9	4.5(1.1) 9 4.3(0.7) 9 3.6	7.5(3.2) 9 7.5(3.8) 9 7.3	5.1(1.0) 8 4.6(0.9) 8 3.8	4.9(0.9) 8 7.1(3.6) 8 5.3
5	9.4(3.2) 6 7.7(1.5) 6 7.8	4.6(0.6) 6 4.0(0.7) 6 4.1	6.9(1.1) 6 6.7(3.5) 6 5.6	9.1(5.1) 5 10.1(5.3) 6 8.3	3.9(0.4) 6 4.1(0.6) 6 4.6	3.6(0.7) 6 4.2(1.0) 6 4.1
6	12.1(1.8) 6 13.0(3.5) 6 12.2	4.7(0.9) 6 3.9(0.7) 6 4.3	7.3(5.5) 6 6.3(1.9) 6 5.6	8.3(1.0) 6 6.9(1.3) 6 6.9	6.1(1.9) 5 5.3(0.8) 4 5.1	6.1(1.0) 6 6.7(1.6) 6 5.9
7	15.5(6.4) 6 13.3(4.9) 6 13.5	9.1(3.4) 7 6.5(4.1) 7 7.2	7.1(2.0) 7 6.9(1.4) 7 6.9	7.9(2.0) 7 7.3(0.9) 7 8.0	12.5(6.9) 4 11.6(6.6) 4 6.8	15.7(13.1) 5 16.2(13.0) 5 10.0
8	10.7(3.2) 7 9.7(2.6) 7 11.3	4.7(1.4) 11 4.4(1.8) 11 4.2	6.1(2.1) 10 5.2(0.6) 10 4.5	8.8(3.5) 11 8.8(3.8) 11 8.1	5.4(2.0) 4 4.7(1.7) 4 5.0	6.0(1.5) 8 6.7(0.7) 8 6.2
9	11.1(4.7) 6 9.7(2.6) 6 11.4	5.9(2.9) 7 4.7(1.0) 7 4.3	5.0(1.1) 8 6.0(1.8) 8 4.2	12.2(4.1) 7 9.1(3.2) 7 9.7	5.1(0.7) 4 4.9(0.7) 5 4.8	4.3(0.4) 5 4.2(1.1) 5 3.9
10	6.9(1.2) 8 7.3(1.3) 8 7.5	6.3(1.8) 8 5.1(0.9) 8 5.1	3.4(0.4) 8 3.4(0.5) 8 3.7	7.8(1.0) 8 7.3(0.9) 7 5.9	4.6(1.5) 8 4.8(1.6) 8 4.2	5.2(2.0) 8 4.9(1.6) 8 3.9
11	6.1(2.4) 13 5.8(2.2) 13 5.3	5.5(1.7) 19 5.8(4.4) 19 6.3	4.2(0.7) 19 4.8(1.1) 18 4.3	8.0(2.5) 14 8.5(3.2) 14 7.1	4.5(0.8) 10 6.3(1.8) 10 5.9	5.3(1.0) 14 5.5(0.6) 14 5.6
12	6.9(2.1) 4 7.3(1.6) 4 6.8	5.6(2.1) 5 4.6(1.3) 4 4.5	4.9(1.6) 5 5.0(0.8) 5 4.2	8.1(3.3) 5 8.8(4.5) 5 6.0	6.1(2.6) 4 5.0(0.9) 4 5.8	6.8(0.8) 4 6.8(2.2) 4 6.2
13	6.4(1.4) 19 7.8(4.3) 20 7.0	5.2(1.3) 21 5.3(1.3) 22 4.8	4.4(1.2) 23 4.3(0.7) 23 4.2	6.2(1.2) 19 6.5(2.5) 19 5.5	5.4(1.6) 20 5.0(1.3) 20 5.1	4.6(1.4) 21 4.7(1.4) 21 4.3
14	8.3(2.8) 11 9.2(5.4) 11 7.5	4.8(1.4) 12 4.0(0.7) 12 4.1	5.2(0.9) 12 5.8(0.9) 12 4.9	8.7(2.0) 11 8.6(2.5) 11 9.6	5.0(1.0) 11 4.2(1.1) 11 4.9	4.1(1.7) 11 4.4(1.6) 11 3.7
15	7.6(2.7) 3 7.5(1.8) 3 7.5	5.7(1.2) 3 5.8(2.5) 3 5.2	5.4(0.9) 3 4.9(0.2) 3 5.5	10.4(8.8) 3 8.6(4.9) 3 9.5	6.9(0.6) 3 6.9(1.0) 3 7.1	6.4(0.6) 3 15.0(13.0) 3 7.8
WHOLE LAKE	8.4(3.8) 113 8.4(3.8) 116 7.4	5.7(2.1) 142 5.4(2.7) 140 4.7	5.1(2.0) 144 5.0(1.4) 143 4.4	7.9(3.0) 123 7.8(3.0) 123 6.5	5.4(2.4) 108 5.2(2.1) 108 4.9	5.5(3.6) 119 6.1(4.4) 119 4.4

TOTAL FILTERED PHOSPHORUS (µg P/l)

CRUISE ZONE \	302	305	306	310	312	313
1	2.9 (0.2) 3 3.1 (1.4) 5 2.7	8.0 (1.4) 8 9.3 (2.7) 7 7.9	4.0 (1.5) 8 3.8 (0.9) 7 4.1		2.7 (0.7) 6 2.9 (1.4) 6 2.5	5.3 (0.6) 5 5.0 (1.8) 5 5.5
2	7.2 (2.1) 6 7.0 (2.7) 7 6.7	4.3 (1.8) 8 4.1 (1.4) 7 4.2	2.9 (0.6) 7 2.7 (0.4) 7 3.6	5.0 (1.4) 6 5.3 (1.6) 4 5.2	2.4 (0.8) 6 2.8 (0.7) 7 2.8	3.7 (1.6) 7 4.0 (2.3) 7 4.7
3	5.7 (0.9) 7 4.9 (0.8) 7 5.0	3.6 (0.8) 12 3.6 (1.2) 12 3.1	2.9 (0.9) 12 2.7 (0.6) 12 2.9	5.0 (1.5) 8 3.9 (1.6) 7 4.4	3.4 (0.7) 7 3.6 (0.8) 8 3.1	4.0 (3.0) 9 3.5 (1.4) 9 3.2
4	5.8 (1.4) 7 7.3 (3.2) 7 4.9	4.2 (0.7) 8 4.7 (0.9) 8 4.0	3.0 (0.8) 9 3.2 (0.8) 9 2.6	6.0 (2.0) 9 6.4 (2.1) 7 5.8	3.2 (0.7) 8 3.1 (0.6) 8 2.7	3.5 (0.5) 8 4.1 (1.5) 8 3.4
5	6.8 (1.7) 6 6.5 (1.5) 6 6.0	3.4 (0.4) 6 3.0 (0.3) 6 3.0	3.9 (0.6) 6 3.8 (0.5) 6 3.9	7.9 (5.0) 5 7.1 (3.9) 5 6.3	3.0 (0.4) 6 3.0 (0.4) 6 3.1	2.9 (0.9) 6 2.6 (0.8) 6 2.7
6	8.7 (2.7) 6 9.0 (3.1) 6 8.0	3.7 (1.4) 6 2.4 (0.5) 5 2.5	3.1 (0.7) 6 3.3 (0.6) 6 3.4	5.7 (1.6) 5 4.8 (0.6) 3 4.8	3.6 (0.9) 5 3.3 (0.5) 4 3.4	4.6 (2.0) 6 4.3 (0.5) 6 4.3
7	11.1 (4.8) 6 10.6 (4.4) 6 9.9	4.7 (1.4) 7 3.2 (1.3) 7 3.7	4.3 (0.8) 7 4.0 (0.9) 7 4.3	5.5 (1.2) 7 4.3 (0.2) 6 5.3	5.6 (3.1) 4 5.5 (2.5) 4 3.8	6.7 (3.0) 5 7.3 (3.4) 5 5.6
8	8.2 (2.5) 7 7.6 (1.8) 7 8.2	3.6 (1.3) 10 2.8 (0.7) 10 2.9	3.4 (1.0) 10 3.4 (1.0) 10 3.0	7.0 (3.7) 11 6.1 (3.0) 10 5.8	3.0 (1.2) 4 2.8 (0.9) 4 2.8	4.5 (1.2) 8 4.5 (0.7) 8 4.4
9	7.3 (2.8) 6 5.2 (1.1) 6 7.6	4.9 (1.8) 6 3.8 (1.1) 6 3.2	3.3 (0.9) 8 4.0 (1.2) 8 3.0	9.1 (3.2) 7 6.9 (2.1) 4 7.0	3.4 (1.3) 4 3.6 (1.0) 5 3.3	2.5 (0.9) 5 2.7 (0.9) 5 2.8
10	5.7 (0.8) 8 5.5 (1.2) 8 5.7	5.4 (1.6) 7 4.3 (0.8) 6 4.3	2.1 (0.3) 8 2.3 (0.4) 8 2.6	6.9 (0.7) 7 6.5 (1.6) 6 4.8	2.8 (1.1) 8 3.1 (1.5) 8 2.7	3.6 (1.2) 8 3.5 (1.0) 8 2.9
11	5.0 (2.0) 13 4.7 (2.1) 13 4.3	4.5 (1.7) 19 4.2 (2.1) 19 4.9	2.9 (0.4) 19 3.1 (0.5) 16 3.4	5.6 (1.7) 13 6.6 (1.6) 9 4.9	3.2 (0.9) 10 3.4 (0.4) 10 3.7	4.1 (0.6) 14 3.8 (0.4) 14 4.2
12	4.5 (1.4) 4 5.3 (1.0) 4 5.1	5.0 (2.0) 5 2.9 (0.3) 3 3.2	3.5 (0.9) 5 3.5 (1.0) 5 3.0	6.1 (2.5) 4 6.6 (3.6) 5 4.4	3.9 (1.4) 4 3.4 (0.5) 4 3.7	4.2 (0.6) 4 4.7 (1.3) 4 4.1
13	5.2 (1.2) 19 5.8 (2.2) 20 5.1	4.0 (0.9) 20 4.0 (1.1) 21 3.7	2.9 (0.8) 22 3.0 (0.7) 22 3.0	5.1 (1.1) 15 4.8 (1.9) 16 4.4	3.3 (0.8) 20 3.4 (1.0) 20 3.3	3.5 (1.2) 21 3.5 (1.2) 21 3.3
14	6.7 (2.2) 11 6.9 (3.0) 11 5.5	3.5 (0.8) 12 3.0 (0.3) 10 2.9	3.5 (0.5) 12 3.7 (0.7) 11 3.4	5.8 (2.1) 10 6.3 (3.5) 9 7.5	3.3 (1.2) 11 3.0 (0.9) 11 3.4	2.9 (1.3) 11 2.7 (1.2) 10 2.5
15	5.7 (1.6) 3 5.3 (5.6) 3	3.4 (0.2) 3 4.2 (3.2) 3	3.3 (0.8) 3 3.2 (3.4) 3	8.0 (1.8) 2 4.9 (4.3) 3	4.3 (1.0) 3 5.0 (4.7) 3	4.1 (0.7) 3 4.2 (4.4) 3
WHOLE LAKE	6.3 (2.6) 112 6.3 (2.7) 116 5.4	4.3 (1.6) 137 4.0 (1.9) 130 3.6	3.2 (0.9) 142 3.3 (0.8) 137 3.1	6.1 (2.4) 109 5.7 (2.4) 94 5.2	3.3 (1.2) 106 3.3 (1.1) 108 3.2	3.9 (1.6) 120 3.8 (1.6) 119 3.2

SOLUBLE REACTIVE PHOSPHORUS ($\mu\text{g P/l}$)

76

CRUISE ZONE	302	305	306	310	312	313
1	4.1 (4.6) 5 2.5 (1.1) 5 3.1	3.2 (1.9) 8 3.3 (2.5) 8 3.1	1.8 (1.5) 8 1.8 (1.2) 8 1.7	1.5 (1.0) 8 1.3 (0.6) 8 1.5	0.7 (0.4) 6 0.7 (0.5) 6 0.7	2.3 (1.9) 5 1.6 (0.6) 5 2.7
2	4.8 (1.8) 7 3.7 (1.3) 7 3.0	1.3 (0.3) 8 1.5 (0.6) 8 1.6	0.9 (0.1) 8 1.2 (0.3) 8 1.2	1.1 (0.3) 8 1.4 (0.8) 8 1.3	0.9 (0.3) 7 0.9 (0.2) 7 0.9	1.4 (0.3) 7 1.3 (0.5) 7 1.3
3	2.8 (0.7) 7 2.5 (0.7) 7 2.5	1.5 (0.7) 12 1.4 (0.5) 12 1.2	0.8 (0.2) 12 0.9 (0.3) 12 0.9	0.8 (0.3) 12 1.0 (0.4) 12 1.1	0.8 (0.2) 8 0.8 (0.1) 8 1.0	1.0 (0.3) 9 0.9 (0.3) 9 1.0
4	3.1 (1.2) 7 4.0 (3.7) 7 2.6	2.1 (0.6) 9 1.7 (0.5) 9 1.5	1.1 (0.1) 9 1.2 (0.2) 9 1.4	0.9 (0.3) 9 0.9 (0.4) 9 1.1	0.8 (0.3) 8 1.0 (0.3) 8 0.9	1.0 (0.4) 8 0.9 (0.4) 8 1.0
5	4.3 (1.8) 6 2.9 (0.6) 6 2.6	1.0 (0.6) 6 1.3 (0.6) 6 1.0	1.0 (0.3) 6 1.2 (0.4) 6 1.3	1.0 (0.4) 6 1.2 (0.7) 6 1.2	0.7 (0.1) 6 1.0 (0.1) 6 1.0	1.2 (0.2) 6 1.2 (0.3) 6 1.3
6	3.0 (2.2) 6 3.4 (2.6) 6 2.7	1.4 (0.5) 6 1.4 (0.7) 6 1.5	0.8 (0.0) 6 1.1 (0.2) 6 1.1	0.7 (0.3) 6 0.7 (0.4) 6 0.7	0.8 (0.2) 5 1.0 (0.2) 5 1.2	0.8 (0.4) 6 1.0 (0.6) 6 1.0
7	3.4 (1.7) 6 3.1 (1.2) 6 2.8	1.9 (0.8) 7 1.3 (0.5) 7 1.4	1.1 (0.5) 7 1.1 (0.3) 7 1.2	0.7 (0.2) 7 0.6 (0.3) 7 0.6	2.7 (1.9) 4 2.2 (1.6) 4 1.5	1.4 (1.2) 5 1.4 (1.3) 5 1.0
8	3.4 (1.5) 7 3.1 (2.0) 7 3.5	1.3 (0.5) 11 1.2 (0.3) 11 1.2	1.2 (0.4) 10 1.4 (0.4) 10 1.2	0.8 (0.6) 11 0.9 (0.7) 11 1.1	1.0 (0.4) 4 1.1 (0.3) 4 1.0	0.9 (0.3) 8 0.7 (0.3) 8 0.7
9	3.1 (2.1) 6 2.0 (0.4) 6 2.6	1.8 (1.3) 7 1.4 (0.7) 7 1.3	0.9 (0.2) 8 1.1 (0.2) 8 1.2	0.6 (0.4) 7 0.6 (0.4) 7 0.7	1.9 (1.7) 5 1.3 (0.8) 5 1.5	0.6 (0.1) 5 0.5 (0.1) 5 0.6
10	2.5 (1.0) 8 2.0 (0.6) 8 2.0	3.1 (1.5) 8 1.8 (0.9) 8 1.9	0.9 (0.3) 8 0.9 (0.3) 8 1.0	1.2 (0.4) 8 1.2 (0.3) 8 1.4	1.2 (0.4) 8 1.1 (0.3) 8 1.2	1.0 (0.3) 8 0.9 (0.3) 8 0.7
11	3.2 (1.2) 14 2.9 (1.6) 14 2.7	2.0 (1.0) 19 2.2 (1.4) 19 1.9	0.9 (0.2) 19 1.1 (0.4) 18 1.0	1.1 (0.4) 19 1.3 (0.6) 19 1.2	1.0 (0.7) 10 0.7 (0.2) 10 0.9	1.2 (0.5) 14 1.0 (0.3) 14 1.4
12	3.3 (2.0) 4 2.6 (1.1) 4 2.4	4.1 (2.3) 5 3.5 (2.0) 5 3.4	1.1 (0.4) 5 1.2 (0.3) 5 1.0	0.9 (0.4) 5 0.9 (0.3) 5 0.9	1.0 (0.6) 4 1.0 (0.4) 4 1.0	1.3 (0.3) 4 1.3 (0.4) 4 1.2
13	2.6 (1.3) 20 2.5 (0.8) 20 2.3	1.9 (1.0) 22 1.6 (0.6) 22 1.6	1.0 (0.5) 23 1.0 (0.3) 23 1.1	1.1 (0.4) 23 1.2 (0.4) 23 1.3	1.1 (0.5) 20 1.1 (0.5) 20 1.3	1.1 (0.3) 21 1.0 (0.4) 21 1.1
14	4.0 (2.1) 11 3.7 (2.5) 11 2.8	1.3 (0.5) 12 1.1 (0.4) 12 1.0	0.9 (0.2) 12 1.1 (0.2) 12 1.1	0.8 (0.9) 12 1.0 (0.9) 12 1.0	1.1 (0.7) 11 1.4 (0.8) 11 1.7	0.8 (0.3) 11 0.8 (0.4) 11 1.0
15	2.7 (1.0) 3 2.1 (0.7) 3 3.6	0.7 (0.2) 3 1.4 (1.7) 3 0.9	1.3 (0.2) 3 1.4 (0.4) 3 1.3	0.8 (0.4) 3 1.0 (0.4) 3 0.8	1.4 (0.4) 3 1.3 (0.4) 3 1.3	1.2 (0.5) 3 1.0 (0.5) 3 1.4
WHOLE LAKE	3.3 (1.8) 117 2.9 (1.7) 117 2.5	1.9 (1.2) 143 1.7 (1.1) 143 1.5	1.0 (0.5) 144 1.1 (0.4) 143 1.1	1.0 (0.5) 144 1.1 (0.6) 144 1.2	1.1 (0.8) 109 1.1 (0.6) 109 1.3	1.1 (0.6) 120 1.0 (0.5) 120 1.1

NITRATE ($\mu\text{gN/l}$)

CRUISE ZONE	302	305	306	310	312	313
1	316(8) 5 320(13) 5 315	274(8) 8 288(11) 8 281	256(34) 8 301(51) 8 283	254(22) 8 301(74) 8 275	253(11) 5 270(19) 5 259	271(2) 5 273(2) 5 273
2	323(5) 7 322(5) 7 320	280(9) 8 282(9) 8 280	254(8) 8 282(6) 8 279	238(15) 8 257(30) 8 253	263(7) 7 283(7) 7 279	277(2) 7 278(3) 7 285
3	318(5) 7 320(4) 7 318	290(6) 12 289(6) 12 289	261(10) 12 279(6) 12 279	260(11) 12 296(14) 12 291	262(8) 8 276(20) 8 275	286(4) 9 288(4) 9 288
4	325(5) 7 327(5) 7 327	290(6) 9 288(3) 9 287	257(10) 9 285(6) 9 285	255(9) 9 289(7) 9 291	274(4) 8 286(5) 8 294	286(3) 8 291(4) 8 292
5	319(6) 6 323(7) 6 325	292(4) 6 290(3) 6 289	255(12) 6 286(3) 6 284	264(17) 6 296(5) 6 296	285(6) 6 304(7) 6 306	295(5) 6 299(6) 6 299
6	322(5) 6 334(11) 6 334	289(5) 6 288(4) 6 288	256(5) 6 286(7) 6 285	263(13) 6 309(3) 6 304	275(9) 5 286(14) 5 295	297(3) 6 302(2) 6 302
7	300(11) 6 317(20) 5 309	257(21) 7 274(15) 7 273	245(6) 7 277(14) 7 266	243(4) 7 310(10) 7 276	272(13) 4 272(12) 4 280	290(6) 5 290(6) 5 292
8	316(5) 7 328(17) 7 324	270(13) 11 284(7) 11 281	245(8) 10 282(10) 10 275	254(18) 11 291(36) 11 289	279(6) 4 288(10) 4 284	285(6) 8 290(7) 8 296
9	298(24) 6 307(19) 6 313	268(9) 7 285(11) 7 287	260(12) 8 286(10) 8 281	239(5) 7 256(18) 7 272	264(8) 5 265(12) 5 275	282(6) 5 287(7) 5 292
10	318(4) 8 321(7) 8 323	289(5) 8 290(8) 8 306	258(7) 8 278(4) 8 282	251(15) 8 273(15) 8 286	258(17) 8 262(18) 8 278	287(4) 8 289(4) 8 294
11	316(7) 14 317(6) 14 318	275(18) 19 282(17) 19 285	250(11) 19 270(17) 18 268	244(6) 19 263(21) 19 264	255(9) 10 260(11) 10 263	277(7) 14 279(7) 14 282
12	316(2) 4 318(3) 4 318	286(6) 5 293(11) 5 292	256(8) 5 282(4) 5 279	248(3) 5 282(9) 5 280	262(7) 4 270(6) 4 274	277(7) 4 279(8) 4 280
13	318(6) 20 321(7) 20 323	290(10) 22 290(12) 22 292	274(7) 23 286(8) 23 286	252(13) 23 284(11) 23 291	270(9) 20 280(10) 20 284	287(6) 21 292(7) 21 295
14	320(6) 11 321(6) 11 324	289(8) 12 291(5) 12 289	265(9) 12 287(4) 12 287	248(13) 12 292(14) 12 292	271(6) 11 285(6) 11 293	291(4) 11 296(4) 11 296
15	306(12) 3 306(7) 3 315	251(9) 3 272(8) 3 267	235(5) 3 286(6) 3 259	242(21) 3 293(7) 3 264	278(7) 3 285(2) 3 280	281(4) 3 283(2) 3 282
WHOLE LAKE	316(10) 117 321(11) 116 323	281(15) 143 286(11) 143 291	258(14) 144 283(16) 143 285	251(14) 144 284(28) 144 289	267(12) 108 278(16) 108 285	285(8) 120 288(9) 120 294

AMMONIA ($\mu\text{g N/l}$)

CRUISE ZONE	302	305	306	310	312	313
1	4.8 (2.3) 5 4.9 (2.2) 5 4.2	5.8 (1.3) 8 8.9 (3.4) 8 6.9	20.9(29.9) 8 19.8(20.2) 8 18.6	11.0(5.9) 8 10.4(5.8) 8 11.5	7.6 (2.2) 5 5.9 (2.2) 5 6.4	9.3 (7.0) 5 7.6 (1.3) 5 11.2
2	4.0 (1.5) 7 3.2 (0.7) 7 3.3	3.9 (1.2) 8 4.6 (1.8) 8 5.1	6.5 (3.7) 8 10.2(4.0) 8 10.7	6.5 (4.0) 8 9.1 (5.5) 8 7.3	9.4 (1.9) 7 6.9 (2.2) 7 7.2	4.6 (1.4) 7 4.3 (2.7) 7 3.9
3	4.3 (1.7) 7 5.2 (2.3) 7 4.9	3.7 (0.9) 12 3.8 (1.1) 12 3.8	3.7 (0.5) 12 6.4 (1.1) 12 6.2	8.3 (1.9) 12 9.2 (3.3) 12 8.8	8.1 (1.6) 8 6.4 (1.7) 8 7.4	2.5 (0.6) 9 2.1 (0.6) 9 2.5
4	3.2 (0.9) 7 5.3 (2.9) 7 5.2	4.9 (2.0) 9 5.3 (2.2) 9 4.3	4.2 (2.0) 9 6.3 (2.4) 9 6.2	8.7 (2.6) 9 6.4 (2.3) 9 6.1	5.1 (2.1) 8 5.0 (2.2) 8 4.1	3.1 (0.7) 8 3.2 (1.8) 8 2.7
5	3.9 (1.6) 6 4.8 (2.4) 6 4.0	4.8 (1.9) 6 4.4 (1.2) 6 4.0	4.0 (2.0) 6 6.6 (1.5) 6 6.9	11.2(3.6) 6 11.8(5.5) 6 9.8	3.7 (1.3) 6 5.2 (3.1) 6 4.1	6.6 (3.0) 6 4.2 (1.1) 6 5.3
6	3.2 (1.0) 6 2.6 (0.7) 6 3.0	7.1 (0.8) 6 7.9 (3.8) 6 8.4	5.6 (2.8) 6 8.2 (2.7) 6 7.1	7.3 (1.5) 6 5.1 (1.4) 6 5.5	6.5 (1.1) 5 7.3 (2.3) 5 5.8	2.5 (1.0) 6 2.6 (0.8) 6 2.5
7	8.3 (8.8) 6 8.1 (7.5) 6 5.7	11.8(4.5) 7 12.8(5.0) 7 10.9	7.9 (4.0) 7 12.1(3.3) 7 9.8	8.3 (1.4) 7 5.8 (2.2) 7 8.0	16.4(8.8) 4 14.8(7.8) 4 9.3	10.4(9.7) 5 10.2(8.6) 5 6.9
8	3.3 (1.8) 7 3.1 (1.0) 7 3.1	5.9 (1.4) 11 8.5 (2.2) 11 7.5	5.4 (1.2) 10 9.0 (1.9) 10 8.0	12.0(2.7) 11 10.8(2.0) 11 10.7	6.4 (3.8) 4 6.3 (1.7) 4 5.8	4.1 (1.0) 8 4.7 (3.5) 8 3.7
9	2.6 (0.6) 6 2.9 (1.1) 6 3.1	5.6 (3.1) 7 8.6 (4.6) 7 8.6	4.1 (1.4) 8 8.1 (2.3) 8 7.1	10.5(1.8) 7 10.1(2.7) 7 9.6	7.2 (2.4) 5 7.9 (1.7) 5 6.4	2.7 (1.5) 5 3.6 (1.1) 5 3.0
10	2.6 (1.9) 8 2.3 (1.4) 8 2.2	3.6 (1.1) 8 4.1 (2.0) 8 4.3	4.7 (1.9) 8 5.6 (1.8) 8 5.9	8.7 (1.9) 8 8.2 (3.1) 8 7.6	9.1 (4.8) 8 9.8 (2.6) 8 7.6	4.7 (1.7) 8 5.0 (2.6) 8 4.4
11	2.9 (1.4) 14 3.5 (1.4) 14 3.1	4.3 (1.3) 19 4.9 (2.1) 19 4.4	5.4 (1.3) 19 7.9 (2.7) 18 7.7	8.2 (3.0) 19 8.6 (4.3) 19 8.1	9.4 (2.0) 10 9.2 (2.3) 10 7.8	3.6 (1.3) 14 3.9 (1.9) 14 5.3
12	2.0 (0.6) 4 2.3 (0.3) 4 2.4	3.5 (0.5) 5 4.1 (1.1) 5 4.1	5.9 (2.5) 5 7.9 (2.8) 5 7.1	8.1 (1.1) 5 6.8 (1.9) 5 7.8	6.7 (1.9) 4 6.4 (0.7) 4 6.2	3.9 (0.9) 4 3.8 (1.7) 4 4.1
13	2.6 (1.0) 19 3.3 (1.4) 19 3.5	3.8 (1.7) 22 4.4 (2.3) 22 4.0	4.2 (1.9) 23 5.7 (2.2) 23 6.7	6.9 (2.4) 23 6.9 (2.9) 23 7.0	7.6 (5.0) 20 6.0 (1.2) 20 6.2	3.6 (2.8) 21 2.9 (1.7) 21 3.2
14	3.3 (1.8) 11 3.7 (1.6) 11 3.9	4.9 (1.6) 12 5.1 (2.1) 12 4.8	4.2 (1.4) 12 6.2 (1.5) 12 7.2	8.5 (3.4) 12 7.7 (3.4) 12 6.8	4.0 (1.2) 11 4.0 (1.0) 11 3.5	4.2 (1.3) 11 3.5 (1.7) 11 3.5
15	2.8 (0.5) 3 3.8 (0.3) 3 3.4	5.1 (1.4) 3 6.8 (2.8) 3 5.9	6.4 (2.0) 3 11.3(2.9) 3 11.2	8.0 (1.7) 3 6.6 (0.1) 3 6.5	7.2 (2.8) 3 5.8 (0.3) 3 6.2	6.0 (0.5) 3 5.3 (0.6) 3 6.3
WHOLE LAKE	3.4 (2.6) 116 3.8 (2.5) 116 3.6	5.0 (2.5) 143 5.9 (3.4) 143 4.4	5.8 (7.9) 144 8.2 (6.0) 143 7.0	8.6 (3.2) 144 8.3 (3.8) 7.3	7.4 (4.1) 108 6.8 (3.1) 108 5.7	4.4 (3.3) 120 4.1 (2.9) 120 3.5

SILICA (mg SiO₂/l)

CRUISE ZONE	302	305	306	310	312	313
1	2.415(.038)5 2.426(.038)5 2.377	2.434(.051)8 2.519(.082)8 2.470	2.222(.031)8 2.447(.099)8 2.351	2.478(.165)8 2.478(.165)8 2.402	2.336(.089)6 2.424(.087)6 2.387	2.334(.033)5 2.356(.032)5 2.353
2	2.435(.016)7 2.445(.016)7 2.443	2.454(.062)8 2.494(.059)8 2.485	2.301(.053)8 2.441(.062)8 2.441	2.397(.057)8 2.397(.057)8 2.397	2.267(.064)7 2.370(.074)7 2.366	2.339(.009)7 2.357(.008)7 2.387
3	2.442(.036)7 2.447(.028)7 2.448	2.440(.020)12 2.430(.023)12 2.443	2.353(.052)12 2.433(.046)12 2.434	2.374(.073)11 2.374(.073)11 2.365	2.349(.047)8 2.413(.046)8 2.430	2.410(.028)9 2.419(.031)9 2.422
4	2.425(.024)7 2.438(.020)7 2.430	2.456(.008)9 2.465(.008)9 2.461	2.393(.043)9 2.475(.070)9 2.458	2.448(.026)9 2.448(.026)9 2.446	2.391(.030)8 2.451(.025)8 2.460	2.425(.047)8 2.446(.040)8 2.406
5	2.438(.049)6 2.453(.053)6 2.438	2.451(.007)6 2.461(.008)6 2.464	2.393(.051)6 2.485(.078)6 2.471	2.521(.101)5 2.521(.101)5 2.486	2.410(.016)6 2.478(.027)6 2.476	2.436(.007)6 2.452(.017)6 2.450
6	2.465(.034)6 2.477(.048)6 2.486	2.483(.045)6 2.493(.044)6 2.494	2.392(.028)6 2.493(.018)6 2.496	2.522(.172)6 2.522(.172)6 2.609	2.399(.031)5 2.445(.030)5 2.461	2.463(.023)6 2.474(.025)6 2.464
7	2.558(.126)6 2.568(.134)6 2.531	2.516(.031)7 2.583(.211)7 2.480	2.302(.081)7 2.456(.071)7 2.390	2.587(.109)7 2.587(.109)7 2.418	2.890(.444)4 2.870(.383)4 2.542	2.693(.337)5 2.780(.373)5 2.572
8	2.436(.044)7 2.449(.036)7 2.449	2.386(.074)11 2.476(.052)11 2.448	2.221(.090)10 2.448(.072)10 2.413	2.461(.148)11 2.461(.148)11 2.471	2.354(.035)4 2.433(.051)4 2.412	2.411(.070)8 2.429(.064)8 2.459
9	2.609(.203)6 2.569(.157)6 2.512	2.405(.071)7 2.466(.043)7 2.449	2.311(.090)8 2.450(.062)8 2.438	2.354(.126)7 2.354(.126)7 2.388	2.259(.021)5 2.313(.037)5 2.347	2.366(.042)5 2.376(.050)5 2.422
10	2.433(.017)8 2.444(.012)8 2.460	2.438(.016)8 2.446(.016)8 2.457	2.380(.032)8 2.457(.001)8 2.449	2.288(.161)8 2.288(.161)8 2.302	2.300(.068)8 2.433(.061)8 2.419	2.386(.023)8 2.399(.025)8 2.418
11	2.429(.022)14 2.439(.026)14 2.436	2.412(.067)19 2.457(.086)19 2.448	2.268(.083)19 2.359(.088)18 2.387	2.312(.131)19 2.312(.131)19 2.310	2.289(.012)10 2.335(.017)10 2.358	2.363(.037)14 2.376(.036)14 2.396
12	2.432(.011)4 2.443(.001)4 2.445	2.397(.047)5 2.406(.039)5 2.407	2.347(.038)5 2.434(.018)5 2.427	2.301(.070)5 2.301(.070)5 2.315	2.325(.038)4 2.374(.040)4 2.405	2.385(.021)4 2.401(.014)4 2.390
13	2.431(.020)20 2.446(.020)20 2.453	2.437(.022)22 2.455(.029)22 2.464	2.415(.046)23 2.453(.037)23 2.447	2.413(.125)21 2.413(.125)21 2.433	2.370(.036)20 2.419(.032)20 2.437	2.409(.041)21 2.430(.040)21 2.426
14	2.430(.029)11 2.442(.024)11 2.442	2.439(.017)12 2.454(.014)12 2.468	2.392(.042)12 2.452(.053)12 2.419	2.426(.108)11 2.426(.108)11 2.475	2.369(.031)11 2.453(.031)11 2.466	2.439(.023)11 2.449(.021)11 2.450
15	2.488(.053)3 2.502(.044)3 2.467	2.489(.067)3 2.485(.035)3 2.474	2.308(.040)3 2.538(.035)3 2.402	2.476(.011)3 2.476(.011)3 2.393	2.435(.010)3 2.500(.044)3 2.476	2.513(.019)3 2.527(.021)3 2.514
WHOLE LAKE	2.450(.074)117 2.459(.063)117 2.450	2.437(.053)143 2.470(.071)143 2.462	2.337(.087)144 2.444(.072)143 2.441	2.411(.138)139 2.411(.138)139 2.433	2.366(.141)109 2.425(.125)109 2.439	2.415(.099)120 2.433(.111)120 2.428

IRON ($\mu\text{g/l}$)

80

CRUISE ZONE \	302	305	306	310	312	313
ZONE /						
1						
2	2.1 1.7	6.8	2.6	2.3		0.5 0.5
3	5.1(0.6) 2 5.0 (3.9) 3	3.0(0.1) 2 3.8(2.2) 3	2.0(0.1) 3 2.6(0.6) 3	2.7(2.0) 3 1.5(1.5) 2	0.7(0.3) 3 0.8(0.3) 3	1.3(1.0) 3 1.4(1.0) 3
4	1.9	1.5 1.8	2.5	2.8 1.9	1.0 0.8	1.0 1.0
5	1.8(0.5) 2 1.7(0.0) 2	1.9(0.4) 2 3.7(0.9) 2	2.2(0.5) 2 2.0(0.1) 2	3.8(1.7) 2 1.8(0.7) 2	1.3(1.1) 2 0.6(0.0) 2	0.8(0.4) 2 1.1(0.4) 2
6	2.2(0.8) 2 4.2(2.0) 2	2.4(0.5) 2 3.4(0.6) 2	3.0(0.0) 2 3.3(0.7) 2	1.6(0.6) 2 2.1(1.0) 2	1.8(0.0) 2 1.7(0.3) 2	2.0(0.7) 2 1.5(0.4) 2
7	19.0 14.3	21.0 4.6	4.0 5.0	4.0 3.5		
8						
9		4.9 3.6	2.0 3.0	3.3 2.5	2.0 3.0	1.5 1.0
10						
11	3.6(1.1) 3 5.8(4.7) 2	3.5(1.1) 4 2.8(1.0) 4	1.7(0.7) 3 0.9(0.3) 4	3.5(1.4) 2 3.4(0.4) 3	2.3(0.8) 3 3.2(1.3) 3	1.6(1.1) 4 2.4(0.5) 4
12	2.3 6.3	1.2	1.5 0.7	1.0 1.4	1.0 1.1	1.0 1.4
13	2.6(2.5) 7 2.8(1.1) 9	1.8(0.8) 8 2.7(1.2) 9	0.9(0.6) 9 1.3(0.8) 9	2.1(1.5) 8 2.4(1.3) 9	1.4(0.8) 8 1.1(0.7) 8	1.1(0.4) 8 1.1(0.4) 9
14	1.8(0.2) 2 1.4(0.2) 3	0.8(0.7) 3 1.1(0.6) 3	1.7(0.3) 3 1.7(0.4) 3	1.7(0.3) 3 1.3(0.2) 3	1.0(0.7) 2 0.4(0.1) 3	0.7(0.3) 3 0.8(0.4) 3
15	7.5	12.0 5.4	3.3	11.0 3.0	4.0 2.5	6.0 5.0
WHOLE LAKE	3.5(4.0) 21 3.8(3.2) 26	3.4(4.3) 25 3.0(1.6) 29	1.7(0.9) 26 1.9(1.1) 28	2.8(2.2) 25 2.3(1.1) 27	1.5(0.9) 24 1.4(1.1) 25	1.4(1.1) 27 1.4(0.9) 28

COPPER ($\mu\text{g/l}$)

CRUISE ZONE	302	305	306	310	312	313
1						
2	2.2 2.2	2.8 4.4	2.5 1.9	0.5 0.9		2.0 2.0
3	2.7(0.7) 3 2.3(0.2) 3	3.1(1.1) 3 2.5(0.4) 3	2.0(0.6) 3 3.0(1.5) 3	1.8(0.9) 3 1.1(0.3) 3	1.2(0.8) 3 0.7(0.2) 3	8.5(2.1) 2 8.5(0.7) 2
4	2.5 2.1	2.5 2.1	2.0 2.1	0.3 0.3	0.5 1.3	2.5 2.1
5	6.7 3.8(2.1) 2	2.8(1.4) 2 2.9(0.8) 2	2.7(0.9) 2 1.9(0.2) 2	1.0(0.1) 2 0.6(0.2) 2	1.3(0.4) 2 1.4(1.2) 2	3.0(1.4) 2 3.0(1.6) 2
6	4.9(0.5) 2	1.4(0.0) 2 1.6(0.2) 2	2.4(0.5) 2 2.0(0.4) 2	0.0 0.0	2 2	0.8(0.4) 2 0.6(0.1) 2
7	7.2	1.9 1.4	1.6 2.3	0.0 0.0		
8						
9	4.3 2.9	3.3 1.7	2.6 2.3	0.2 1.5	1.3 2.0	8.5 8.5
10						
11	2.9(1.2) 4 3.0(1.3) 4	3.6(1.5) 4 3.1(1.1) 4	1.9(0.4) 4 1.9(0.2) 4	1.0(0.5) 4 1.0(0.4) 4	1.8(0.6) 3 1.6(0.5) 3	4.8(4.5) 3 5.0(4.2) 4
12	2.4 2.8	7.3 3.3	2.0 1.4	0.3 0.7	1.0 0.6	5.5
13	2.9(0.9) 9 2.8(0.6) 9	2.9(1.2) 9 2.9(0.8) 9	1.8(0.5) 9 2.0(0.6) 9	1.0(0.7) 9 1.0(0.3) 9	1.4(1.4) 8 1.6(0.8) 8	3.3(1.7) 8 3.6(1.7) 9
14	3.1(0.2) 2 3.8(2.3) 3	1.7(1.5) 3 1.8(0.9) 3	2.1(0.4) 3 1.7(0.0) 3	0.2(0.3) 3 0.7(0.3) 3	1.3(0.4) 2 1.5(0.3) 3	5.8(2.5) 2 4.4(0.4) 3
15	1.6 1.7	4.0 3.7	1.9 2.1	1.0 0.8	5.5 3.5	2.0 2.0
WHOLE LAKE	3.0(1.2) 24 3.1(1.4) 29	2.9(1.5) 29 2.6(1.0) 29	2.0(0.5) 29 2.1(0.6) 29	0.8(0.7) 29 0.8(0.5) 29	1.5(1.2) 24 1.4(0.8) 25	4.1(2.7) 23 4.2(2.5) 27

CHROMIUM ($\mu\text{g/l}$)

82

CRUISE ZONE \	302	305	306	310	312	313
1						
2	0.0 0.2	0.1 0.3	0.0 0.0	0.0 0.0		0.4 0.4
3	0.1(0.1) 3 0.1(0.1) 3	0.2(0.1) 3 0.2(0.0) 3	0.0 3 0.0 3	0.3(0.4) 3 0.1(0.0) 3	0.0 3 0.0 3	0.3(0.0) 3 0.3(0.0)
4	0.2 0.2	0.1 0.1	0.0 0.0	0.0 0.1	0.0 0.0	0.2 0.2
5	0.2(0.1) 2 0.3(0.0) 2	0.2(0.0) 2 0.2(0.1) 2	0.0 2 0.0 2	0.3(0.4) 2 0.0 2	0.0 2 0.1(0.1) 2	0.2(0.0) 2 0.2(0.0) 2
6	0.3(0.1) 2 0.2(0.0) 2	0.2(0.0) 2 0.1(0.1) 2	0.0 2 0.0 2	0.0 2 0.0 2	0.0 2 0.0 2	0.2(0.0) 2 0.2(0.0) 2
7	0.3 0.4	0.1 0.2	0.0 0.0	0.0 0.0	0.2	
8						
9	0.2 0.3	0.1 0.1	0.0 0.0	0.1 0.0	0.1	0.2 0.2
10						
11	0.1(0.1) 4 0.2(0.1) 4	0.1(0.1) 4 0.1(0.1) 4	0.0 4 0.0 4	0.0 4 0.0 4	0.2(0.3) 3 0.0 3	0.2(0.0) 4 0.2(0.0) 4
12	0.2 0.1	0.2 0.1	0.0 0.0	0.0 0.0	0.0 0.0	0.2 0.3
13	0.1(0.1) 9 0.1(0.1) 9	0.2(0.1) 9 0.2(0.1) 9	0.0 9 0.0 9	0.0 9 0.0 9	0.2(0.2) 8 0.1(0.1) 8	0.3(0.1) 8 0.3(0.1) 9
14	0.3(0.1) 3 0.2(0.1) 3	0.1(0.1) 3 0.1(0.1) 3	0.0 3 0.0 3	0.0 3 0.1(0.1) 3	0.1(0.1) 3 0.1(0.1) 3	0.3(0.2) 3 0.2(0.0) 3
15	0.2 0.1	0.1 0.1	0.0 0.0	0.0 0.1	0.0 0.0	0.2 0.2
WHOLE LAKE	0.2(0.1) 29 0.2(0.1) 29	0.1(0.1) 29 0.2(0.1) 29	0.0 29 0.0 29	0.1(0.2) 29 0.0(0.0) 29	0.1(0.2) 25 0.1(0.1) 25	0.3(0.1) 27 0.2(0.1) 28

MANGANESE ($\mu\text{g/l}$)

CRUISE ZONE \	302	305	306	310	312	313
1						
2	0.7 0.5		0.8 0.3	0.2 0.1		0.3 0.2
3	0.3(0.2) 3 0.3(0.2) 3	1.9	0.7(0.1) 2 0.2(0.1) 2	0.5(0.3) 3 0.7(0.3) 3	0.1(0.1) 3 0.2(0.0) 3	0.3(0.1) 3 0.2(0.1) 3
4	2.0 0.5	0.2 0.3	0.1	0.5 0.0	0.2 0.2	0.5 0.3
5	0.4(0.2) 2 0.4(0.1) 2	0.4(0.0) 2 0.4(0.0) 2	0.9(0.2) 2 0.1(0.1) 2	0.7(0.1) 2 0.2(0.1) 2	0.3(0.1) 2 0.2(0.1) 2	0.5(0.0) 2 0.3(0.1) 2
6	0.4(0.1) 2 0.4(0.1) 2	0.5(0.2) 2 1.0(1.0) 2	0.5 1.0(0.0) 2	0.3(0.1) 2 0.5(0.1) 2	0.4(0.1) 2 0.4(0.1) 2	0.6(0.2) 2 0.4(0.1) 2
7	0.3 0.9	0.8 0.3	0.8	0.1 0.0		
8						
9	2.6 1.1	0.4 0.2	1.0 0.7	0.1 0.3	0.2 0.2	0.4 0.4
10						
11	0.5(0.1) 4 0.5(0.3) 4		0.4(0.2) 4 0.5(0.2) 3	2.1(1.7) 2 0.7(0.2) 3	0.3(0.1) 3 0.2(0.1) 3	0.4(0.1) 4 0.3(0.1) 4
12	0.2 0.0	1.0	1.0 0.2	0.5	0.0 0.1	0.4 0.4
13	0.2(0.2) 8 0.4(0.2) 9	0.8(0.4) 3 0.4(0.3) 4	0.4(0.2) 9 0.2(0.1) 9	0.4(0.3) 8 0.3(0.2) 9	0.2(0.3) 8 0.1(0.1) 8	0.5(0.2) 8 0.3(0.1) 9
14	0.4(0.3) 3 0.2(0.0) 3	0.2(0.2) 3 0.3(0.3) 3	0.2(0.1) 3	0.4(0.3) 3 0.3(0.2) 3	0.2(0.1) 3 0.2(0.0) 3	0.5(0.2) 3 0.3(0.0) 3
15	1.1 1.0	3.0	1.4 0.5	0.8 0.1	0.2 0.3	1.0 0.3
WHOLE LAKE	0.5(0.6) 27 0.4(0.3) 29	0.7(0.8) 15 0.5(0.4) 15	0.6(0.3) 23 0.3(0.3) 26	0.5(0.6) 25 0.4(0.3) 28	0.2(0.2) 25 0.2(0.1) 25	0.5(0.2) 27 0.3(0.1) 28

CADMIUM ($\mu\text{g/l}$)

84

CRUISE ZONE	302	305	306	310	312	313
1						
2	0.1 0.0	0.5 0.6	0.2 0.1	0.0 0.0		0.0 0.0
3	0.2(0.1) 3 0.2(0.1) 3	0.5(0.1) 3 0.5(0.1) 3	0.2(0.2) 3 0.1(0.1) 3	0.0 3 0.0 3	0.1(0.1) 3 0.1(0.0) 3	0.0(0.1) 3 0.0(0.0) 3
4	0.2 0.2	0.1 0.1	0.0 0.1	0.0 0.0	0.0 0.1	0.5 0.3
5	0.0 2 0.1(0.1) 2	0.2(0.1) 2 0.2(0.1) 2	0.1(0.1) 2 0.0(0.0) 2	0.0 2 0.0 2	0.0 2 0.0 2	0.2(0.1) 2 0.1(0.2) 2
6	0.1(0.1) 2 0.2(0.2) 2	0.3(0.2) 2 0.2(0.0) 2	0.1(0.1) 2 0.0(0.0) 2	0.0 2 0.0 2	0.0 2 0.0 2	0.0 2 0.0(0.0) 2
7	0.2 0.3	0.4 0.3	0.0 0.1	0.0 0.0		
8						
9	0.1 0.1	0.2 0.0	0.0 0.1	0.0 0.0	0.2 0.0	0.4 0.3
10						
11	0.3(0.2) 4 0.3(0.2) 4	0.7(0.2) 4 0.5(0.1) 4	0.1(0.1) 4 0.0(0.0) 4	0.0 4 0.0 4	0.0 3 0.0 3	0.0(0.1) 4 0.0(0.1) 4
12	0.1 0.2	0.4 0.5	0.0 0.1	0.0 0.0	0.0 0.1	0.0 0.1
13	0.2(0.2) 9 0.2(0.1) 9	0.3(0.2) 9 0.4(0.2) 9	0.1(0.2) 9 0.2(0.3) 9	0.1(0.2) 9 0.0(0.0) 9	0.0(0.1) 7 0.1(0.1) 8	0.1(0.1) 8 0.0(0.0) 9
14	0.1(0.1) 3 0.1(0.1) 3	0.1(0.1) 3 0.1(0.0) 3	0.0 3 0.0(0.1) 3	0.1(0.1) 3 0.0(0.0) 3	0.0 3 0.1(0.1) 3	0.2(0.2) 3 0.2(0.1) 3
15	0.1 0.6	0.1 0.1	0.1 0.1	0.0 0.0	0.0 0.0	0.2 0.2
WHOLE LAKE	0.2(0.1) 29 0.2(0.2) 29	0.3(0.2) 29 0.3(0.2) 29	0.1(0.1) 29 0.1(0.2) 29	0.0(0.1) 29 0.0(0.0) 29	0.0(0.1) 24 0.0(0.1) 25	0.1(0.2) 27 0.1(0.1) 28

COBALT ($\mu\text{g/l}$)

CRUISE ZONE	302	305	306	310	312	313			
1									
2	0.1 0.0	0.1 0.3	0.0 0.0	0.0 0.0		0.5 1.0			
3	0.4(0.2) 3 0.5(0.1) 3	0.1(0.1) 3 0.1(0.1) 3	0.0 0.0	3 3	0.5(0.3) 3 0.6(0.3) 3	0.0 0.0	3 3	0.5(0.5) 3 0.8(0.4) 3	
4	0.3 0.3	0.4 0.3	0.0 0.0		1.2 0.7	0.3 0.1		0.0 0.0	
5	0.4(0.2) 2 0.5(0.2) 2	0.2(0.3) 2 0.4(0.0) 2	0.1(0.1) 2 0.2(0.2) 2	0.1(0.1) 2 0.0(0.0) 2	0.3(0.1) 2 0.3(0.0) 2	0.8(0.4) 2 0.8(0.7) 2			
6	0.5(0.3) 2 0.5(0.2) 2	0.7(1.0) 2 0.6(0.0) 2	0.1(0.1) 2 0.2(0.0) 2	0.0 0.0(0.0)	2	0.4(0.2) 2 0.2(0.0) 2	0.8(0.4) 2 0.7(0.1) 2		
7	0.5 0.4	0.4 0.7	0.2 0.3	0.0 0.2					
8									
9	0.5 0.3	0.6 0.4	0.0 0.0		0.0 0.0	0.5 0.3	0.0 0.0		
10									
11	0.1(0.3) 4 0.2(0.2) 4	0.4(0.1) 4 0.4(0.2) 4	0.0 0.0	4 4	0.0 0.0	4 4	0.0 0.0	3 3	0.5(0.4) 4 0.3(0.3) 4
12	0.7 0.4	0.3 0.2	0.0 0.0		0.0 0.0	0.0 0.1			0.0 0.1
13	0.2(0.2) 9 0.3(0.2) 9	0.3(0.3) 9 0.4(0.3) 9	0.0 0.0	9 9	0.2(0.3) 9 0.2(0.2) 9	0.0(0.1) 8 0.1(0.1) 8		0.3(0.3) 8 0.3(0.2) 9	
14	0.5(0.4) 3 0.4(0.2) 3	0.2(0.3) 3 0.1(0.1) 3	0.0 0.1(0.2)	3 3	0.0 0.0(0.0)	3 3	0.5(0.5) 3 0.4(0.3) 3	0.2(0.3) 3 0.3(0.5) 3	
15	0.0 0.2	0.0 0.0	0.0 0.0		0.0 0.0	0.3 0.3		0.5 0.0	
WHOLE LAKE	0.3(0.3) 29 0.3(0.2) 29	0.3(0.3) 29 0.3(0.2) 29	0.0(0.1) 29 0.0(0.1) 29		0.2(0.3) 29 0.2(0.2) 29	0.2(0.3) 25 0.2(0.2) 25		0.4(0.4) 27 0.4(0.4) 28	

LEAD ($\mu\text{g/l}$)

CRUISE ZONE \	302	305	306	310	312	313	
ZONE /							
1							
2	1.6 0.5	1.9 1.2	0.8	0.0 0.0		0.5 0.5	
3	0.6 (0.2) 3 0.6 (0.1) 3	1.3 (0.2) 3 1.1 (0.6) 3	0.7 (0.8) 3 0.6 (0.4) 3	2.3 (0.3) 3 1.5 (1.1) 3	1.3 (0.6) 3 0.4 (0.2) 3	1.8 (0.4) 2 1.0	
4	0.7 0.3	1.0 0.7	0.6 0.2	3.5 1.1	0.0 0.1	1.0 1.4	
5	1.4 (1.4) 2 0.8 (0.3) 2	1.5 (0.4) 2 1.1 (0.2) 2	0.8 0.7 (0.1) 2	0.0 0.0	2 2	0.8 (0.4) 2 1.2 (0.8) 2	1.5 (0.7) 2 1.1 (0.2) 2
6	1.3 (1.1) 2 0.9 (0.0) 2	1.2 (0.4) 2 0.9 (0.1) 2	2.9 (1.2) 2 1.6 (1.0) 2	0.0 0.0	2 2	0.8 (0.4) 2 0.6 (0.4) 2	2.8 (1.1) 2 1.6 (0.3) 2
7	2.2 1.8	0.9 0.8	2.8 1.0	0.0 0.0			
8							
9	0.3 0.6	1.5 0.8	0.0 1.0	0.0 0.0		0.5 0.5	2.0 2.5
10							
11	1.2 (1.0) 4 1.2 (0.5) 4	0.9 (0.6) 4 0.8 (0.5) 4	0.5 (0.5) 4 0.1 (0.3) 4	0.0 0.0	4 4	0.0 0.4 (0.7) 3	1.3 (0.3) 3 0.9 (0.5) 4
12	2.3 0.4	1.1 0.9	0.5 0.5	0.0 0.0		0.0 0.0	6.0 2.5
13	0.8 (0.5) 9 0.8 (0.1) 9	0.9 (0.3) 8 1.2 (0.7) 9	0.3 (0.4) 8 0.5 (0.2) 9	1.2 (1.7) 9 0.6 (0.9) 9		0.5 (0.5) 8 0.8 (0.7) 8	1.1 (0.6) 8 1.4 (0.9) 9
14	1.3 (1.4) 3 0.7 (0.3) 3	0.7 (0.3) 3 0.8 (0.1) 3	0.4 (0.5) 3 0.4 (0.2) 3	0.0 0.0	3 3	0.3 (0.3) 3 0.7 (0.4) 8	1.3 (0.4) 2 2.2 (1.3) 3
15	0.2 0.2	1.3 1.8	0.3 0.0	0.0 0.0		2.3 1	1.5 1.0
WHOLE LAKE	1.0 (0.8) 29 0.8 (0.4) 29	1.1 (0.4) 28 1.0 (0.5) 29	0.7 (0.9) 27 0.5 (0.5) 29	0.7 (1.3) 29 0.4 (0.8) 29		0.5 (0.5) 24 0.7 (0.6) 25	1.6 (1.2) 24 1.4 (0.8) 26

CRUISE ZONE	302	305	306	310	312	313
1						
2	0.5 0.9	4.1 4.4	0.0 0.1	0.0 0.0		0.5 0.5
3	0.5 (0.5) 3 0.4 (0.4) 3	4.3 (0.3) 3 3.9 (0.8) 3	1.1 (1.0) 3 1.0 (0.8) 3	3.3 (2.5) 2 1.8 (0.3) 3	2.0 (1.7) 3 1.1 (0.2) 3	2.0 1.1 (0.1) 2
4	0.6 0.9	4.5 3.8	1.4 2.0	2.0 1.8	0.5 0.4	1.0 1.4
5	1.7 1.2 (1.2) 2	4.5 (2.1) 2 6.1 (1.3) 2	3.0 1.4 (0.8) 2	2.2 (2.6) 2 0.6 (0.9) 2	1.0 (1.4) 3 1.0 (0.5) 2	2.8 (0.4) 2 2.4 (0.1) 2
6	2.7 (0.7) 2	4.0 (1.0) 2 2.7 (0.4) 2	2.2 1.4 (0.4) 2	0.7 (1.0) 2 0.2 (0.1) 2	2.0 (0.7) 2 0.0 (0.0) 2	2.0 (0.0) 2 3.1 (1.1) 2
7	6.6	7.8 4.3	2.5 2.2	0.0 0.0		
8						
9	0.6 0.1	2.7	3.4 2.4	0.1 0.0	1.0 1.5	3.5 4.5
10						
11	0.8 (0.1) 4 0.8 (0.2) 4	3.9 (1.2) 4 3.9 (0.4) 4	0.4 (0.4) 4 0.3 (0.2) 4	0.1 (0.3) 4 0.0 (0.1) 4	0.2 (0.3) 3 0.2 (0.3) 3	1.7 (1.6) 3 1.9 (1.5) 4
12	1.0 0.5	2.3 2.4	0.0 0.3	0.0 0.0	0.0 1.1	10.0 2.9
13	0.6 (0.3) 9 0.7 (0.2) 9	4.0 (2.8) 8 3.9 (1.8) 9	0.9 (0.8) 9 0.9 (1.0) 9	1.0 (1.1) 9 0.9 (0.8) 9	0.5 (0.5) 7 0.6 (0.4) 8	1.0 (0.4) 8 1.9 (1.5) 9
14	0.5 (0.6) 2 1.4 (2.0) 3	2.8 (2.7) 3 3.5 (0.9) 3	1.7 (1.2) 3 1.2 (0.5) 3	1.0 (1.7) 3 0.2 (0.3) 3	0.2 (0.3) 3 1.6 (1.0) 3	2.8 (0.4) 2 4.3 (1.8) 3
15	0.2 0.0	6.9	2.0 2.7	0.0 0.0	2.5	3.0 2.5
WHOLE LAKE	0.7 (0.4) 24 1.1 (1.4) 29	4.1 (2.1) 27 3.9 (1.3) 28	1.2 (1.1) 27 1.1 (0.9) 29	1.0 (1.4) 28 0.6 (0.8) 29	0.8 (1.0) 23 0.8 (0.7) 25	2.1 (1.9) 24 2.3 (1.5) 27

MERCURY ($\mu\text{g/l}$)

CRUISE ZONE	302	305	306	310	312	313
1						
2						
3	0.09(0.12) 3 0.15(0.09) 3					
4	0.07 0.10					
5	0.05 2 0.08(0.01) 2					
6	0.09(0.01) 2 0.22(0.13) 2					
7	0.10 0.22					
8						
9	0.06 0.17					
10						
11	0.06(0.05) 4 0.10(0.00) 4					
12	0.13 0.10					
13	0.12(0.07) 9 0.12(0.07) 9					
14	0.14(0.06) 3 0.09(0.02) 3					
15	0.00 0.10					
WHOLE LAKE	0.10(0.07) 28 0.12(0.06) 28					

Appendix B: Concentrations for zone 13 in 1973

Mean Concentrations in the Epilimton of Zone 13 in Lake Superior During 1973

Parameter	Cruise					
	May 12 - 22	June 15 - 27	July 27 - Aug. 7	Sept. 6 - 16	Oct. 14 - 25	Nov. 14 - 28
Alkalinity (mg/l)	43.2 [.8] (20)	40.8 [.9] (20)	41.7 [.6] (22)	41.3 [.6] (23)	41.3 [.6] (20)	41.62 [.15] (20)
Chloride	1.15 [.12] (20)	1.11 [.06] (9)	1.15 [.11] (9)	1.10 [.08] (9)	1.10 [.08] (8)	1.62 [.15] (9)
Sulphate	3.0 [.1] (9)	2.6 [.3] (9)	3.0 [.1] (9)	3.2 [.3] (9)	3.1 [.04] (8)	3.1 [.1] (9)
Calcium	13.3 [.2] (9)	12.6 [.7] (9)	12.5 [.1] (9)	13.3 [.4] (9)	12.5 [.1] (8)	12.9 [.2] (9)
Magnesium	2.9 [.1] (9)	2.6 [.1] (9)	2.6 [.1] (9)	2.6 [.1] (9)	2.7 [.1] (8)	2.6 [.1] (9)
Sodium	1.28 [.13] (9)	1.19 [.03] (9)	1.27 [.05] (9)	1.37 [.07] (9)	1.24 [.05] (8)	1.30 [.1] (9)
Potassium	.5 [.05] (9)	.4 [.05] (9)	.5 [.05] (9)	.4 [.1] (9)	.5 [.05] (8)	.5 [.05] (9)
Total phosphorus (ugP/l)	6.4 [1.4] (19)	5.2 [1.3] (21)	4.4 [1.2] (23)	—	5.4 [1.6] (20)	4.6 [1.4] (21)
T. dissolved phosphorus "	5.2 [1.2] (19)	4.0 [.9] (20)	2.9 [.8] (22)	—	3.3 [.8] (20)	3.5 [1.2] (21)
Dissolved reactive P.	2.6 [1.3] (20)	1.9 [1.0] (22)	1.0 [0.5] (23)	—	1.1 [0.5] (20)	1.1 [0.3] (21)
Nitrate (ugN/l)	318 [6] (20)	290 [6] (22)	274 [7] (23)	252 [3] (23)	270 [9] (20)	287 [6] (21)
Ammonia "	2.6 [1.1] (19)	3.8 [1.7] (22)	4.2 [1.9] (23)	6.9 [2.4] (23)	7.6 [5.0] (20)	3.6 [2.8] (21)
Silicate (mgSiO ₂ /l)	2.43 [.03] (11)	2.44 [.02] (22)	2.41 [.05] (23)	2.33 [.13] (21)	2.37 [.04] (20)	2.41 [.04] (21)
Oxygen (mg/l)	13.66 [.11] (20)	13.50 [.14] (22)	12.62 [.43] (23)	10.03 [0.57] (23)	11.60 [.48] (20)	12.24 [.43] (21)
Percent oxygen saturation	100.9 [.6] (20)	102.7 [.9] (22)	108.9 [2.2] (23)	106.4 [3.0] (23)	101.3 [.9] (20)	98.6 [2.9] (21)
Conductivity (vs at 25°C)	7.74 [.10] (9)	7.85 [.12] (9)	8.12 [.07] (9)	8.26 [.14] (9)	7.87 [.28] (8)	7.97 [.17] (9)
Estimated value 97 based upon 1970 - 71 CCIW data.						

The arithmetic means are calculated from the station means for the 0 - 10 m layer. The numbers represent the mean [standard deviation] (no. of stations).

Mean Concentrations in the Hypolimnion of Zone 13 in Lake Superior During 1973

Parameter	May 12 - 22			June 15 - 27			July 27 - Aug. 7			Sept. 6 - 16			Oct. 14 - 25			Nov. 14 - 28		
Alkalinity (mg/l)	44.0	[1.3]	[20]	41.0	[3.4]	[9]	42.0	[.8]	(22)	1.13	[.12]	(23)	41.5	[.7]	(20)	1.59	[.08]	(9)
Chloride "	1.16	[.15]	[20]	1.14	[.10]	[9]	3.0	[.5]	(9)	3.1	[.1]	(9)	1.09	[.10]	(20)	3.0	[.1]	(9)
Sulphate "	3.0	[0.1]	[9]	2.7	[0.5]	[9]	12.6	[.2]	(9)	13.4	[.2]	(9)	3.1	[.0.1]	(9)	12.5	[.1]	(9)
Calcium "	13.2	[.1]	[9]	12.8	[.2]	[9]	2.6	[.02]	(9)	2.6	[.03]	(9)	2.7	[.04]	(8)	2.6	[.05]	(9)
Magnesium "	2.8	[.05]	[9]	2.6	[.02]	[9]	1.20	[.03]	(9)	1.29	[.03]	(9)	1.26	[.05]	(8)	1.30	[.01]	(9)
Sodium "	1.23	[.03]	[9]	1.20	[.03]	[9]	.4	[.03]	(9)	.5	[.01]	(9)	.4	[.05]	(9)	.5	--	(9)
Potassium "	.5	[.01]	[9]	.4	[.03]	[9]	.5	[.03]	(9)	.5	[.01]	(9)	.4	[.05]	(9)	.5	--	(9)
Total phosphorus (ugP/l)	7.8	[4.3]	[20]	5.3	[1.3]	[22]	4.3	[0.7]	(23)	---	---	---	5.0	[1.3]	(20)	4.7	[1.4]	(21)
T. dissolved phosphorus "	5.8	[2.2]	[20]	4.0	[1.1]	[21]	3.0	[0.7]	(22)	---	---	---	3.4	[1.0]	(20)	3.5	[1.2]	(21)
Dissolved reactive P. "	2.5	[0.8]	[20]	1.6	[0.6]	[22]	1.0	[0.3]	(23)	286	[.8]	(23)	1.1	[0.5]	(20)	1.0	[0.4]	(21)
Nitrate (ugN/l)	321	[7]	[20]	290	[2]	[22]	284	[1]	(23)	280	[0]	(23)	292	[7]	(20)	292	[7]	(21)
Ammonia "	3.3	[.1]	[19]	4.4	[.2]	[22]	5.7	[.2]	(23)	6.9	[.3]	(23)	6.0	[.1]	(20)	2.9	[.2]	(21)
Silicate (mgSiO ₂ /l)	2.45	[.02]	(20)	2.46	[.03]	(22)	2.45	[.06]	(23)	2.41	[.13]	(21)	2.42	[.03]	(20)	2.43	[.04]	(21)
Oxygen (mg/l)	13.62	[.12]	(20)	13.54	[.14]	(22)	13.33	[.14]	(23)	12.95	[.45]	(23)	12.03	[.43]	(20)	12.42	[.26]	(21)
Percent oxygen saturation	100.8	[.7]	(20)	102.9	[1.1]	(22)	104.6	[1.5]	(23)	104.2	[2.3]	(23)	99.4	[2.1]	(20)	99.1	[1.3]	(21)
Conductivity (us at 25°C)	7.70	[.08]	(9)	7.83	[.07]	(9)	7.98	[.04]	(10)	8.06	[.07]	(9)	7.83	[.18]	(8)	8.01	[.09]	(9)

The arithmetic means are calculated from the station means for the 10 m - bottom layer. The numbers represent the means [standard deviation] (no. of stations).

Appendix C: Concentrations for 1968 - 1971 in zones I and VIII

<u>Year</u>	<u>Cruise Number</u>	<u>Date</u>
1968	301	Aug. 18 - 28
1969	302	Nov. 15 - 23
1970	301	April 15 - 23
	302	Oct. 28 - Nov. 6
1971	301	May 26 - June 2
	303	June 30 - July 7
	305	Oct. 5 - 13
1973	302	May 12 - 22
	305	June 15 - 27
	306	July 27 - Aug. 7
	310	Sept. 6 - 16
	312	Oct. 14 - 25
	313	Nov. 14 - 28

Parameter	Zone	CRUISE						
		68-301	69-302	70-301	70-302	71-301	71-303	71-305
Calcium (mg/l)	1	---	---	---	---	13.8 (0.3) 13.0 (0.1)	3 11	---
	8	---	---	13.3 (0.6)	43	---	13.2 (0.4)	103
Magnesium (mg/l)	1	---	---	---	---	3.0 (0.0) 2.7 (0.1)	3 11	---
	8	---	---	2.5 (0.1)	43	---	2.5 (0.1)	103
Sodium (mg/l)	1	---	---	---	---	1.2 (0.0) 1.2 (0.0)	17 11	---
	8	---	---	1.3 (0.1)	43	---	1.2 (0.0)	103
Potassium (mg/l)	1	---	---	---	---	0.60 (0.0) 0.54 (0.05)	3 11	---
	8	---	---	0.42 (0.05)	43	---	0.53 (0.05)	103
						0.44 (0.05)	30	0.49 (0.02) 0.50 (0.02)
							30	0.50 (0.02) 56

CRUISE

Parameter

Zone

		68-301	69-302	70-301	70-302	71-301	71-303	71-305
Alkalinity (mg CaCO ₃ /l)	1	---	---	41.0 (0.3)	3	43.0 (0.0) 41.9 (0.3)	5 25	41.5 (0.5) 41.5 (0.4)
	8	---	---	42.4 (1.7)	43	42.0 (0.5)	51	41.8 (0.9) 41.4 (0.4)
Sulphate (mg SO ₄ /l)	1	---	---	---	---	3.7 (0.1) ---	3 ---	2.3 (0.2) 2.3 (0.1)
	8	---	---	1.9 (0.3)	43	---	2.7 (0.2) 103	---
Chloride (mg/l)	1	---	---	---	---	2.2 (0.1) 1.4 (0.3)	3 11	---
	8	---	---	1.3 (0.2)	43	---	1.2 (0.1) 103	---
Specific Conductivity (μs at 25°C)	1	95.8 (3.9)	64	109.2 (3.5)	26	96.0 (0.0)	5 28	106.4 (0.6) 98.7 (1.2)
	8	94.6 (2.0)	473	108.5 (2.5)	261	97.4 (2.6)	214 241	97.7 (1.8) 98.2 (2.3)

Parameter Zone

CRUISE									
		68-301	69-302	70-301	70-302	71-301	71-303	71-305	
pH	1	---	---	---	7.60 (0.13)	3	8.08 (0.02) 8.04 (0.04)	5	8.01 (0.12) 7.94 (0.06)
	8	---	---	---	7.76 (0.20)	48	8.10 (0.04) 8.02 (0.07)	5	8.12 (0.06) 7.97 (0.05)
Dissolved Oxygen (mg O₂/l)	1	11.99 (1.02)	64	---	13.22 (0.67)	5	12.09 (0.41)	28	11.88 (0.04) 13.53 (0.17)
	8	12.53 (0.87)	472	---	13.41 (0.54)	215	12.07 (0.74)	241	12.54 (0.09) 13.43 (0.39)

Parameter Zone CRUISE

		68-301	69-302	70-301	70-302	71-301	71-303	71-305
Total Phosphorus ($\mu\text{g P/l}$)	1	4.6 (3.6)	9	---	4.6 (0.7)	3	3.3 (0.6)	8
	8	6.5 (8.2)	29	---	4.2 (1.3)	43	3.6 (6.5)	36
Total Filtered Phosphorus ($\mu\text{g P/l}$)	1	---	---	---	1.0 (0.3)	3	---	5.2 (3.6)
	8	---	---	---	1.6 (1.0)	43	1.0 (0.3)	3
Soluble Reactive Phosphorus ($\mu\text{g P/l}$)	1	0.7 (0.7)	26	---	0.7 (0.3)	3	3.6 (0.3)	5
	8	0.3 (0.3)	148	---	1.0 (0.6)	43	0.3 (0.3)	36
Nitrate ($\mu\text{g N/l}$)	1	236 (15)	26	---	247 (6)	3	217 (16)	5
	8	259 (77)	146	---	264 (17)	43	270 (16)	36

CRUISE

Parameter	Zone	CRUISE					
		68-301	69-302	70-301	70-302	71-301	71-303
Iron ($\mu\text{g/l}$)	1	---	---	5 (1)	3	65.7 (0.6) 9.9 (18.5)	3
	8	---	---	7 (8)	43	4 (3)	36
Copper ($\mu\text{g/l}$)	1	---	---	1	3	11.8 (4.9) 12.3 (2.8)	11
	8	---	---	1	3	2 (1)	36
Manganese ($\mu\text{g/l}$)	1	---	---	0.0	3	0.4 (0.3) 4.3 (0.2)	11
	8	---	---	1 (2)	43	0.0	36
Zinc ($\mu\text{g/l}$)	1	---	---	---	---	17.7 (3.1) 20.7 (9.3)	3
	8	---	---	5 (2)	43	---	13.2 (8.5)
							100

CRUISE
Zone

Parameter		68-301	69-302	70-301	70-302	71-301	71-303	71-305
Lead ($\mu\text{g/l}$)	1	2.7 (0.1)	9	---	---	1	3	1.7 (0.6) 1.0 (0.9)
	8	2.7 (0.1)	29	---	2 (2)	43	---	1.3 (0.4) 1.4 (0.4)
Nickel ($\mu\text{g/l}$)	1	---	---	---	2 (1)	36	1.4 (1.3) 1.7 (1.1)	1.4 (0.4) 1.4 (0.4)
	8	---	---	---	---	---	2.0 (0.0) 1.7 (1.1)	---
Mercury ($\mu\text{g/l}$)	1	0.0	---	---	---	1.1 (1.0)	1.0 (0.2) 1.0 (0.2)	0.9 (0.6) 1.0 (0.6)
	8	---	---	---	---	0.0	0.49 (0.43) 0.56 (0.43)	0.49 (0.11) 0.56 (0.07)
Cadmium ($\mu\text{g/l}$)	1	3.2 (0.1)	9	---	0.0	15	0.0 0.27 (0.36)	0.42 (0.26) 0.37 (0.21)
	8	3.2 (0.1)	29	---	0.0	43	0.0 36	0.5 (0.2) 0.27 (0.38)

Parameter	Zone	CRUISE					
		68-301	69-302	70-301	70-302	71-301	71-303
Chromium ($\mu\text{g/l}$)	1	---	---	---	0.0	3	0.85 (1.2) 0.15 (0.19)
	8	---	0.0	55	0.0	36	11 17
Cobalt ($\mu\text{g/l}$)	1	---	---	0.0	3	0.29 (0.58) 0.41 (0.41)	102 11
	8	---	1 (1)	55	0.8	36	3 31
Vanadium ($\mu\text{g/l}$)	1	---	---	0	55	0 (1) 57	0.0 (0.1) 188
	8	---	---	0	55	---	0.0 (0.1) 175
Strontium ($\mu\text{g/l}$)	1	---	---	---	---	---	---
	8	---	---	---	26 (7)	144 24 (9)	31 37 (3)

