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DETERMINATION OF NUTRIENT LOADS INTO AND OUT OF SKAHA LAKE

PREPARED FOR:
CANADA — BRITISH COLUMBIA
OKANAGAN BASIN IMPLEMENTATION BOARD

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Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

CANADA - BRITISH COLUMBIA OKANAGAN BASIN

IMPLEMENTATION AGREEMENT

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INLAND WATERS DIRECTORATE

VANCOUVER

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NOTICE

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ABSTRACT

In the Okanagan River Basin, British Columbia, remedial actions had been undertaken to reduce phosphorus loads from municipal waste treatment plants with the aim of reducing biological productivity in the main valley lakes. In 1976, under the Canada-British Columbia Okanagan Basin Implementation Agreement, a monitoring program of nutrient loading was initiated in the southern part of the basin. The program was carried out by Water Quality Branch, IWD, for and funded by the Okanagan Basin Implementation Board. The present report deals with the results obtained during the three year study of nutrient transport into and out of Skaha Lake.

The major objective of this study was to design a method for improving the precision of nutrient load estimation in order to provide water management with a reliable measure of nutrient flux to Skaha Lake.

Concentrations of total phosphorus, dissolved phosphorus, nitrate plus nitrite, ammonia, total nitrogen and dissolved silica were measured below Okanagan Lake, near the Penticton airport and below Skaha Lake using two sampling methods, hereafter described as simultaneous and sequential. Data derived from these two methods were used to calculate nutrient loads by employing the partial load method with simultaneous sampling data and the flow interval method with sequential sampling data.

The simultaneous sampling method revealed very pronounced short range spatial heterogeneities of point concentration measurements of nutrients at all three channel cross-sections. Implication of this finding is that the determination of nutrient loads based on a single grab sampling procedure will not reflect heterogeneities of water composition and, therefore, cannot provide a reliable estimate of the amounts of nutrients passing through a channel cross-section. Seasonal changes of concentration measurements, obtained by the sequential sampling method, indicate that below Okanagan and Skaha Lakes concentrations of total phosphorus are significantly higher during the fall-winter periods than during the spring-summer periods. This seasonal pattern, however, is disturbed at stations located below the outfall from the waste treatment plant and tributary creeks.

A statistically significant correlation was found between the load data obtained by the partial load method and by the flow interval method. The overall mean load of phosphorus determined on lumped data from these two methods during the three year sampling period indicates a reduced input of total phosphorus to Skaha Lake, by comparison with load data reported in the previous study, conducted under the Canada-British Columbia Okanagan Basin Agreement, 1974. Nevertheless, since the earlier data are not reported with confidence limits, the conclusion of a change cannot be statistically validated. Furthermore, loads of total phosphorus and total dissolved phosphorus increased markedly in the downstream direction at each of the three investigated channel cross-sections. The major contribution of phosphorus loads came from non-point sources such as Okanagan Lake and via Shingle and Ellis Creeks, but also from Skaha Lake.

Loads of ammonia also showed marked increases at each cross-section in the downstream direction. The major portion of the ammonia load, on an annual basis, comes from the waste treatment plant, but during the spring-summer seasons, sources of ammonia pollution in the near shore areas of Okanagan Lake are also very significant. Loads of nitrate plus nitrite increased below Shingle Creek, particularly during the fall-winter seasons. Large increase in the load of total nitrogen were observed not only near the airport but also below Skaha Lake indicating that this lake is a significant source of total nitrogen.

Loads of silica showed interesting seasonal variations above the inlet and below the outlet from Skaha Lake. During spring freshets, loads of silica significantly increased at the station located below the tributaries Shingle and Ellis Creeks, on the other hand, there was a pronounced decrease of silica load in the discharge from Skaha Lake. This seasonal change in silica output from this lake suggests that silica limitation may be significant in controlling peak levels of diatoms in Skaha Lake during the spring.

RESUME

Dans le bassin de l'Okanagane, en Colombie-Britannique, on a entrepris de réduire les apports de phosphore des usines municipales d'épuration en vue de diminuer la productivité des principaux lacs de la vallée. En 1976, en vertu de l'Accord Canada - Colombie-Britannique sur l'aménagement du bassin de l'Okanagane, la Direction de la qualité des eaux de la D.G.E.I. réalisait un programme de surveillance des apports d'éléments nutritifs dans la partie sud du bassin, pour le compte du Comité d'aménagement du bassin de l'Okanagane, qui le finançait. Le présent rapport fait état des résultats obtenus au cours de trois années d'étude sur les éléments nutritifs qui entrent dans le lac Skaha et qui en sortent.

Le principal objectif de l'étude était de trouver une méthode pour mieux estimer l'apport des éléments nutritifs afin de procurer aux gestionnaires des ressources en eaux une mesure fiable de la quantité d'éléments nutritifs qui entre dans le lac Skaha.

On a mesuré les concentrations du phosphore total, du phosphore dissous, des nitrates + nitrites, de l'ammoniaque, de l'azote total et de la silice dissoute en aval du lac Okanagane, près de l'aéroport de Penticton et en aval du lac Skaha. Pour ce faire, on a utilisé deux méthodes d'échantillonnage dites simultanée et séquentielle. Les données obtenues ont servi à calculer l'apport des éléments nutritifs, par la méthode des apports partiels, dans le cas des données de l'échantillonnage simultané et par la méthode des intervalles de débit, dans le cas des données séquentielles.

L'échantillonnage simultané a mis en évidence, dans les trois sections mouillées, des écarts très prononcés, à courte distance, entre les concentrations ponctuelles, ce qui signifierait que les déterminations fondées sur un seul échantillonnage au hasard ne refléteraient pas la composition hétérogène de l'eau et, par conséquent, ne pourraient pas fournir une estimation sûre de la quantité éléments nutritifs transportée au travers de la section mouillée. Les variations saisonnières des concentrations, observées grâce à l'échantillonnage séquentiel, signifient qu'en aval des lacs Okanagane et Skaha, les concentrations du phosphore total sont beaucoup plus élevées à l'automne et à l'hiver qu'au printemps et à l'été. Cependant, cette variation saisonnière est perturbée aux stations en aval des stations d'épuration et des ruisseaux tributaires.

On a trouvé une corrélation statistiquement significative entre l'apport calculé par la méthode des apports partiels et l'apport calculé par celle des intervalles de débit. L'apport moyen de phosphore durant les trois années de l'étude, calculé au moyen de l'agrégation des résultats de ces deux méthodes montre une diminution depuis l'étude précédente, menée en vertu de l'Accord Canada - Colombie-Britannique sur le bassin de l'Okanagane, en 1974. Toutefois, comme les résultats de cette dernière étude sont dépourvus de limites de fiabilité, la diminution ne peut pas être confirmée statistiquement. De plus, les concentrations de phosphore total et de phosphore total dissous augmentaient sensiblement vers l'aval, à chacune des trois sections mouillées étudiées. Les plus importants apports de phosphore provenaient de sources non ponctuelles comme le lac Okanagane et les ruisseaux Shingle et Ellis, mais il en provenait aussi du lac Skaha.

L'augmentation des concentrations d'ammoniaque était également prononcée vers l'aval de chaque section mouillée. La majeure partie des apports d'ammoniaque, pour toute l'année, provient de l'usine d'épuration mais, au printemps et à l'été, les sources de pollution ammoniacale des rives du lac Okanagane sont aussi très importantes. Le transport des nitrates + nitrites augmentait en aval du ruisseau Shingle, surtout en automne et en hiver. On a observé une importante augmentation de la concentration d'azote total, non seulement près de l'aéroport, mais aussi en aval du lac Skaha, ce qui indique que ce lac est une source importante d'azote total.

Les concentrations de silice ont montré d'intéressantes variations saisonnières en amont et en aval immédiats du lac Skaha. Au cours des crues printannières, les apports de silice ont sensiblement augmenté à la station en aval des ruisseaux Shingle et Ellis; par contre, ils ont considérablement diminué dans l'émissaire du lac Skaha. Cette variation saisonnière du transport de silice provenant du lac Skaha semble indiquer que la silice est peut-être un facteur qui limite notablement la prolifération printanière de diatomées dans le lac.

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SUMMARY

General

In the Okanagan River-Skaha Lake sub-system, concentrations of total phosphorus, total dissolved phosphorus, nitrate plus nitrite, ammonia, total nitrogen and dissolved silica were measured at three sampling stations, during the period from July 1976 to March 1979.

The first station selected below Okanagan Lake dam, is in close proximity to the recording stream gauging station 08NM050, maintained by Water Survey of Canada. The second station is located near the Penticton airport, approximately 1.7 km. downstream from the outfall of the waste treatment plant. The third station is located at Okanagan Falls, below Skaha Lake, and close to the Water Survey of Canada recording stream gauging station 08NM002.

Two sampling methods are used for collection of water samples: (a) simultaneous and (b) sequential methods. The simultaneous sampling method is a manual method employing a replicate sampler. This sampler is used to collect three sample replicates at, approximately, one meter below the water surface. This sampling procedure is used at monthly intervals and provides information on the short range spatial heterogeneities of concentrations observed through measurements taken at a number of sampling points in the investigated channel cross-sections. The sequential sampling method, on the other hand, is used to obtain time series records of concentration measurements taken at a single point, approximately, 0.6 of the depth of the stream water. Water samples are drawn at quarter-day intervals, at 0300, 0900, 1500 and 2100 hours, during two consecutive days, randomly chosen within a week. This procedure provides information on the long term temporal variation of nutrient concentrations along the river reach caused by the effect of variable nutrient sources and changes of discharge regulated by dams located below Okanagan and Skaha Lakes.

Two methods are used for the determination of nutrient loads passing through each of the three channel cross-sections, the partial

load method and the flow interval method. The partial load method utilizes data obtained from the combined simultaneous chemical sampling and the hydrometric measurements in a channel cross-section.

The loads estimated by the flow interval methods are based on the concentration data derived from sequential sampling and discharge determined for four daily intervals. The time period for the first interval extends from 0000 to 0600 hours. According to this procedure the discharge for a flow interval is calculated from the original hourly discharge data (m^3s^{-1}), converted into hourly discharge and cumulated over the six-hour interval which encompasses the time of chemical sampling. The cumulated discharge and concentration data are used to calculate the nutrient loads for the daily flow intervals. The sum of the load intervals provides, then, the daily nutrient loads passing through the channel cross-section.

The major goal of the present study is the determination of the precision and consistency of nutrient loads derived from simultaneous and sequential sampling methods. The simultaneous method permits the calculation of confidence limits around the total load passing through each channel cross-section. This precision is based on concentration measurements achieved by the sample replicates taken at a number of points in the channel cross-section. The statistically derived errors in this procedure are superimposed on the cross-sectional variations of concentration measurements, laboratory analytical error and an assumed discharge error. The sequential sampling method, on the other hand, is based on single point concentration measurements and does not permit the calculation of the confidence limits for the daily loads. However, the precision of these load data derived from sequential sampling can be periodically compared with the results obtained by the simultaneous methods and their consistency can be assessed.

Consistency of load data is determined by the comparison of results obtained by simultaneous and sequential sampling methods at the same time. This study indicates that in most cases the load data derived from sequential measurements are systematicaly higher than those data obtained by simultaneous method. The statistical tests employed indicate

that there is a high correlation between results obtained by the two methods. It is, therefore, legitimate to lump the load data obtained from the simultaneous and the sequential sampling.

The following discussion is based on the lumped concentration and load data for the entire sampling period. Sub-periods from April to September and from October to March are analysed separately because most of the nutrient concentration data show significant bi-seasonal variation. Nutrient loads, on the other hand, do not show pronounced seasonal changes but they are characterized by highly significant annual variation.

TOTAL PHOSPHORUS

Below Okanagan Lake dam

At the station located below Okanagan Lake dam, seasonal and annual variation of total phosphorus concentrations, which are determined on the lumped data derived from the simultaneous and sequential measurements, are characterized by higher arithmetic means during the three fall-winter periods than during the three spring-summer periods of 1976 to 1979. The three-year mean concentration of total phosphorus, and its 95 percent confidence intervals, determined from 656 observations are 0.009 ± 0.0001 mg l^{-1}.

Loads of total phosphorus below Okanagan Lake show pronounced year-to-year variations. These variations are a result of different hydrological events occurring during the three year period. The arithmetic mean loads and their 95 percent confidence intervals, based on lumped data from 12, 69 and 79 measurements in each of the three years are 23.18 ± 4.064, 5.25 ± 0.522 and 13.84 ± 2.945 kg day^{-1} in 1976, 1977 and 1978, respectively. The overall arthmetic mean of total phosphorus loads, with its 95 percent confidence intervals, determined

from 160 data for the three year period are 10.84 $\pm$ 1.704 kg day^{-1}.

Near the Penticton Airport

At the station located near the Penticton airport, in contrast with the station below the Okanagan Lake dam, seasonal variation of total phosphorus concentration is not significant. The overall arithmetic mean concentration of total phosphorus, and its 95 percent confidence intervals, derived from 1356 observations during the three-year period are 0.017 $\pm$ 0.001 mg l^{-1}.

The arithmetic means of total phosphorus loads, and their 95 percent confidence intervals, determined from 10, 89 and 83 observations are 28.33 $\pm$ 4.946, 13.15 $\pm$ 1.436 and 29.31 $\pm$ 4.984 kg day^{-1} in 1976, 1977 and 1978, respectively. From these data it can be noticed that the confidence intervals for 1976 and 1978 are of a similar magnitude, although the numbers of observations differ significantly during these two years. First, information on loads for 1976 is based on a limited set of data which do not represent the entire year. Second, the loads of total phosphorus in 1978 are characterized by extreme values, reaching a maximum of 130.00 kg day^{-1}. Nevertheless, the overall mean of total phosphorus loads for the three-year sampling period, determined on all 182 measurements, are 21.36 $\pm$ 2.64 kg day^{-1}.

At Okanagan Falls

At the station located below Skaha Lake, at Okanagan Falls, the bi-seasonal variation of total phosphorus concentration is again significant, following a similar pattern to that observed below Okanagan Lake. The arithmetic means, and their 95 percent confidence intervals, determined from 370 spring-summer and 248 fall-winter measurements of total phosphorus concentration are 0.015 $\pm$ 0.001, 0.03 $\pm$ 0.002 mg l^{-1}, respectively. The three-year arithmetic mean of total phosphorus concentration determined on all 618 samples for the six distinct periods are 0.021 $\pm$ 0.001 mg l^{-1}. During this entire period, a slight year-to-year increase in total phosphorus concentration can be observed, but this pattern is not followed by its load measurements.

Loads of total phosphorus below Skaha Lake in terms of the arithmetic means, with their 95 percent confidence intervals, determined from 3, 84 and 76 measurements are 31.67 ± 6.723, 12.15 ± 0.938 and 41.55 ± 6.51 kg day^{-1} in 1976, 1977 and 1978, respectively. Again, the similarity of the confidence intervals, observed in 1976 and 1978, and the large differences between number of observations from which loads are determined can be explained, as previously mentioned, by considerable variation of total phosphorus loads in 1978. A maximum load of this nutrient observed in 1978 is 111.00 kg day^{-1}. The three-year arithmetic mean, and its 95 percent confidence interval, of total phosphorus loads calculated from all 163 measurments are 26.22 ± 3.785 kg day^{-1}.

TOTAL DISSOLVED PHOSPHORUS

Below Okanagan Lake dam

At the station located below Okanagan Lake dam the bi-seasonal variation of total dissolved phosphorus concentration is statistically not significant. The arithmetic mean concentration of dissolved phosphorus, and its 95 percent confidence interval, determined for all 551 measurements during the three-year period are 0.004 ± 0.0002 mg l^{-1}. Also, the ratio of the means of total dissolved phosphorus to total phosphorus concentrations, an indicator of compositional content, does not show any significant seasonal variation. The overall mean of this ratio and its precision determined from all the 551 paired observations during the three-year period are 0.51 ± 0.015.

The mean loads, and their 95 percent confidence intervals, determined on 4, 61 and 79 data are 15.00 ± 7.458, 2.46 ± 0.262 and 5.50 ± 0.878 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year mean of total dissolved phosphorus and its precision determined from all 144 measurements are 4.48 ± 0.631 kg day^{-1}.

Near the Penticton Airport

At the station located near the Penticton airport the bi-seasonal variation of total dissolved phosphorus concentration is characterized by slight increase in the fall-winter periods. The three-year arithmetic mean of total dissolved phosphorus and its 95 percent confidence intervals determined from all 1161 measurements are 0.005 ± 0.0001 mg l^{1}. The ratio of the means of total dissolved phosphorus and total phosphorus, with its precision, calculated for 1111 data are 0.35 ± 0.011 for the three-year period. This ratio indicates that at this station, by contrast to the station below Okanagan Lake, there is a significant decrease in the percentage content of total dissolved phosphorus.

Loads of total dissolved phosphorus show pronounced year-to-year variation which is associated with variation in discharge. The very high variation of loads in 1976, illustrated by the confidence interval, is based on a limited set of data and, therefore, do not represent the changes occurring during the entire year. The mean loads, and their 95 percent confidence intervals, of total dissolved phosphorus determined for 2, 87 and 83 data are 17.00 ± 5.082, 3.51 ± 0.362 and 6.70 ± 0.831 kg day^{-1}. The overall mean of total dissolved phosphorus and its percision calculated from all 172 data are 5.21 ± 0.534 kg day^{-1}.

At Okanagan Falls

At the station located below Skaha Lake, at Okanagan Falls, concentration of total dissolved phosphorus shows statistically significant bi-seasonal variation during the 1977 and 1978 sampling period. This seasonal variation is illustrated by the arithmetic means and their precision, determined from 347 spring-summer and 239 fall-winter measurements of total dissolved phosphorus concentration ranging from 0.006 ± 0.0001 to 0.014 ± 0.001 mg l^{-1}. The two-year arithmetic mean of total dissolved phosphorus concentration, and its 95 percent confidence interval, calculated from all 586 measurements are 0.009 ± 0.001 mg l^{-1}.

The ratios of means of total dissolved phosphorus to total phosphorus, and their precision, determined from 323 spring-summer and 238 fall-winter measurements ar 0.40 ± 0.018 and 0.46 ± 0.029, and the

two-year mean with its 95 percent confidence intervals determined for all 561 measurements are 0.42 $\pm$ 0.016.

The arithmetic mean of total dissolved phosphorus loads from Skaha Lake and their 95 percent confidence intervals, determined from 79 and 76 observations are 5.71 $\pm$ 0.654 and 13.88 $\pm$ 3.219 kg day^{-1} in 1977 and 1978, respectively. The two-year arithmetic mean of total dissolved phosphorus and its precision calculated from all 155 data are 9.71 $\pm$ 1.722 kg day^{-1}.

CONCLUSIONS

Concentration data of total phosphorus and total dissolved phosphorus, lumped from simultaneous and sequential measurements taken at the three sampling stations in the Okanagan River show significant bi-seasonal variation.

At the stations located below Okanagan and Skaha Lakes significantly higher concentrations of total phosphorus are observed during the fall-winter period than during the spring-summer period. This pattern of seasonal changes in total phosphorus concentration established below the two lakes is disturbed at the station near the airport. This disturbance is ascribed to the effect of total phosphorus inputs from the municipal outfall and tributaries, Shingle and Ellis Creeks.

Bi-seasonal differences of total dissolved phosphorus concentration are statistically significant at the station near the airport and below Skaha Lake. At these stations concentration of total dissolved phosphorus is higher during fall-winter periods than during spring-summer periods.

The overall ratio, and its confidence intervals, of total dissolved phosphorus to total phosphorus, an indicator of compositional content, varies in the range of 0.51 ($\pm$0.015), 0.347 ($\pm$0.011) and 0.423 ($\pm$0.016) at the stations below Okanagan Lake, near the airport and below Skaha Lake, respectively.

The downstream increase, between the station below Okanagan Lake and that near the airport, of the overall means of total phosphorus and

total dissolved phosphorus concentrations is, approximately, 89 and 25 percent, respectively. Further downstream, the concentration increase between the station near the airport and that below Skaha Lake is, for total phosphorus and total dissolved phosphorus, approximately 24 and 80 percent, respectively.

The most pronounced changes occurring in the river reach are the year-to-year changes in loads of total phosphorus and total dissolved phosphorus caused by variation in the discharge. The downstream increase, between the station located below Okanagan Lake and that near the airport, in terms of means of total phosphorus and total dissolved phosphorus is, approximately, 97 and 16 percent, respectively. The increase, between the stations near the airport and that below Skaha Lake is, for total phosphorus and total dissolved phosphours, approximately, 22 and 87 percent, respectively. The contrasting increases of loads of these phosphorus forms evidently underline the differing behaviour of river reach compared with lake system. Sources of the two phosphorus forms analysed include effluent from the waste treatment plant, and a number of non-point sources, such as Okanagan Lake, Shingle and Ellis Creeks watersheds and Skaha Lake. The major increase in total phosphorus loading is associated with point source waste treatement plant and the non-point source Shingle and Ellis Creek watersheds. The nonpoint source Skaha Lake contributes the major increase in total dissolved phosphorus.

NITRATE PLUS NITRITE

Below Okanagan Lake dam

At the station located below Okanagan Lake dam, the arithmetic means, and their 95 percent confidence intervals, of nitrate plus nitrite concentrations, determined from 542 spring-summer and 242 fall-winter measurements, taken during the period from 1976 to 1979, are 0.006 ± 0.001 and 0.036 ± 0.001 mg l^{-1}, respectively. The three-year arithmetic mean and its 95 confidence interval, determined from all 784 measurements are 0.016 ± 0.001 mg l^{-1}.

The three-year mean ratio, and its precision, determined from 784 paired observations of nitrate plus nitrite to total nitrogen concentrations are 0.079 ± 0.006. The bi-seasonal variation of this ratio is statistically significant, showing considerably higher content of nitrate plus nitrite during the fall-winter than in spring-summer periods.

Loads of nitrate plus nitrite below Okanagan Lake dam show very pronounced year-to-year variation. The arithmetic means, and their 95 percent confidence intervals, of nitrate plus nitrite determined from 14, 69 and 79 observations are 69.55 ± 27.91, 4.49 ± 1.038 and 23.34 ± 7.12 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year mean of nitrate plus nitrite load and its precision, derived from all 162 observations are 19.31 ± 4.924 kg day^{-1}.

Okanagan River near the Penticton Airport

At the station located near the Penticton airport, the arithmetic means, and their precision, of nitrate plus nitrite concentrations derived from 1078 spring-summer and 574 fall-winter measurements, taken druing the period from 1976 to 1979, are 0.024 ± 0.002 and 0.060 ± 0.007 mg l^{-1}, respectively. The three year mean, and its 95 percent precision, of nitrate plus nitrite concentration based on all 1652 observations are 0.036 ± 0.003 mg l^{-1}.

The three-year mean ratio, and its precision, determined from 1652 paired measurements of nitrate plus nitrite concentration are 0.088 ± 0.004. The bi-seasonal variation of this ratio is significant showing significantly higher content of nitrate plus nitrite during the fall-winter than during the spring-summer periods.

Loads of nitrate plus nitrite, at the station located near the Penticton airport, show significant variation during the period from 1976 to 1978. The arithmetic mean and its precision, of nitrate plus nitrite, determined from 18, 97 and 83 observations are 64.89 ± 25.345, 26.152 ± 4.935 and 50.65 ± 7.38 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year mean of these loads and its precision, determined from all 198 observations are 39.94 ± 4.837 kg day^{-1}.

Okanagan Falls

At Okanagan Falls, below Skaha Lake, the arithmetic means, and their 95 percent confidence intervals, of nitrate plus nitrite concentrations, determined from 417 spring-summer and 260 fall-winter measurements during the period from 1976 to 1979 are 0.005 $\pm$ 0.002 and 0.041 $\pm$ 0.005 mg l^{-1}. The three-year arithmetic mean, and its precision, of nitrate plus nitrite concentration determined from 677 measurements are 0.019 $\pm$0.003 mg l^{-1}.

The three-year mean concentration ratio, and its 95 percent confidence intervals, determined from 677 paired measurements of nitrate plus nitrite and total nitrogen are 0.051 $\pm$ 0.007. Also, at this station the bi-seasonal differences in content of nitrate plus nitrite are statistically significant. Nitrate plus nitrite content is higher during the fall-winter than during the spring-summer periods.

Loads of nitrate plus nitrite at the station located below Skaha Lake show statistically significant differences during the period from 1976 to 1978. The arithmetic means, and 95 percent confidence intervals, of nitrate plus nitrite loads determined from 3, 89 and 76 observations are 37.17 $\pm$ 71.033, 8.13 $\pm$ 2.845 and 36.80 $\pm$ 13.615 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year mean of nitrate plus nitrite load, determined from all 168 observations are 21.617 $\pm$ 6.651 kg day^{-1}.

AMMONIA

Below Okanagan Lake dam

At the station located below Okanagan Lake, ammonia concentration is characterized by statistically significant differences between the spring-summer and the fall-winter periods, from 1976 to 1979. The arithmetic means, and their 95 confidence intervals, of ammonia concentration determined from 542 spring-summer and 242 fall-winter measurements are 0.039 $\pm$ 0.004 and 0.009 $\pm$ 0.002 mg l^{-1}. The three-year mean, and its precision, of ammonia concentration determined from all 784 measurements are 0.03 $\pm$ 003 mg l^{-1}.

There is a very pronounced bi-seasonal variation of the ratio of ammonia to nitrate plus nitrite concentration. The mean ratios, and their precision, determined from 542 paired spring-summer and 242 paired fall-winter measurements are 15.51 ± 1.920 and 0.330 ± 0.073, respectively. A similar ratio, and its precision, on the three-year basis, determined from all 784 paried measurements of ammonia and nitrate plus nitrite, are 10.825 ± 1.415.

Also, a ratio indicating the ammonia content of total nitrogen shows statistically significant bi-seasonal variation. The mean ratios, and their 95 percent confidence intervals, determined from 542 paired spring-summer and 242 fall-winter measurements are 0.166 ± 0.012 and 0.045 ± 0.007, respectively. Similarly, in terms of all 784 paired measurements of ammonia and total nitrogen concentrations the ratio, and its precision, are 0.128 ± 0.010.

Loads of ammonia, at the station below Okanagan Lake dam, are characterized by pronounced annual changes during the period, 1976 to 1978. The arithmetic means and their 95 percent confidence intervals, determined from 14, 69 and 79 observations are 39.28 ± 23.132, 23.39 ± 6.826 and 64.79 ± 17.333 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year arithmetic mean, and its precision, determined from all 162 ammonia load data are 44.95 ± 9.523 kg day^{-1}.

Near the Penticton Airport

At the station located near the Penticton airport, ammonia concentration shows a barely significant bi-seasonal variation. The arithmetic means, and their 95 percent confidence intervals, of ammonia concentration derived from 1078 spring-summer and 574 fall-winter measurements during the perid from 1976 to 1979 are 0.145 ± 0.007 and 0.205 ± 0.016 mg $^{-1}$, respectively. The three-year mean, and its 95 percent confidence interval, calculated from all 1652 mesurements are 0.166 ± 0.007 mg $^{-1}$.

The ratio, and its precision, determined on 1078 paired spring-summer and 574 paired fall-winter measurements of ammonia and nitrate plus nitrite concentrations are 8.015 ± 0.325 and 4.921 ± 0.290,

respectively. The three-year ratio, and its precision, of all 1652 paired measurements of ammonia and nitrate plus nitrite are 6.721 ± 0.250.

On the other hand, content of ammonia in total nitrogen does not show bi-seasonal variation. The three-year mean ratio, and its precision, determined from all 1652 paired measurements of ammonia and total nitrogen are 0.366 ± 0.009.

Loads of ammonia, near the airport, expressed as the arithmetic means, and their 95 confidence intervals, determined from 18, 97 and 83 observations are 234.67 ± 45.250, 152.110 ± 12.385 and 113.370 ± 12.825 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year arithmetic mean load, and its precision, of ammonia derived from all 198 observations are 143.38 ± 10.075 kg day^{-1}.

Okanagan Falls

At the station located below Skaha Lake, at Okanagan Falls, the bi-seasonal changes of ammonia concentration are illustrated by the following data. The arithmetic means, and their precision, determined from 417 spring-summer and 260 fall-winter measurements are 0.039 ± 0.007 and 0.129 ± 0.041 mg l^{-1}, respectively. The three-year arithmetic mean and its 95 percent confidence interval, calculated from all 677 measurements, are 0.073 ± 0.017 mg l^{-1}.

The mean ratios of ammonia to nitrate plus nitrite and their precision, determined from 417 paired spring-summer and 260 fall-winter measurements are 12.61 ± 2.037 and 14.83 ± 5.479, respectively, and on the three-year basis this ratio, and its precision, determined from all 677 paired measurements are 13.46 ± 2.44.

The three-year mean ratio, and its precision, of ammonia and nitrate plus nitrite concentrations, determined on all 677 paired measurements, are 0.105 ± 0.011.

Loads of ammonia, below Skaha Lake, in terms of the arithmetic means and their 95 percent confidence intervals, determined from 3, 84 and 76 observations are 28.53 ± 41,277, 14.13 ± 6.092 and 350.24 ± 220.92 kg day^{-1} in 1976, 1977 and 1978, respectively. The three-year arithmetic mean of ammonia load, and its precision, determined on all 163 observations are 166.43 ± 101.982 kg day^{-1}.

ORGANIC NITROGEN

Below Okanagan Lake dam

At the station located below Okanagan Lake dam, organic nitrogen does not show significant bi-seasonal variation during the period 1976 to 1979. The arithmetic mean, and its 95 percent confidence interval, determined from all 784 observations are 0.15 $\pm$ 0.003 mg l^{-1}.

Content of organic nitrogen, expressed as the mean ratio, and its precision, of organic nitrogen and total nitrogen concentrations, determined on 784 pair observations are 0.792 $\pm$ 0.009.

Loads of organic nitrogen, below Okanagan Lake dam, is characterized by pronounced changes during the period 1976 to 1978. The three-year arithmetic mean, and its precision, determined on 162 observations are 186.83 $\pm$ 22.25 kg day^{-1}.

Near the Penticton Airport

At the station located near the Penticton airport, the three-year mean of organic nitrogen concentration and its precision, determined from 1652 measurements are 0.193 $\pm$ 0.006 mg l^{-1}.

The three-year mean ratio, and its 95 percent confidence interval, determined on 1652 paired observatons, are 0.545 $\pm$ 0.009.

Loads of organic nitrogen, at the station near the Penticton airport, in terms of the three-year arithmetic mean, and its 95 percent confidence interval, determined from 198 observations are 227.61 $\pm$ 22.605 kg day^{-1}.

Okanagan Falls

At the station located below Skaha Lake, at Okanagan Falls the three-year arithmetic mean, and its 95 percent confidence interval, of organic nitrogen concentration calculated from 677 observations are 0.489 $\pm$ 0.088 mg l^{-1}.

The three-year arithmetic mean ratio of organic nitrogen and total nitrogen concentrations, and its precision, determined from 677

measurements are 0.844 ± 0.012.

The three-year mean, and its 95 percent confidence interval, of organic nitrogen load determined from 168 observations are 779.44 ± 249.84 kg day^{-1}.

TOTAL NITROGEN

Below Okanagan Lake dam

At the station located below Okanagan Lake dam concentration of total nitrogen is characterized by statistically significant bi-seasonal variation during the period from 1976 to 1979. The arithmetic means, and their 95 percent confidence intervals, determined from 542 spring-summer and 242 fall-winter measurements of total nitrogen concentrations are 0.205 ± 0.004 and 0.195 ± 0.010 mg l^{-1}, respectively. The three-year arithmetic mean, and its precision, determined from all 784 measurements of total nitrogen concentrations are 0.202 ± 0.004 mg l^{-1}.

Loads of total nitrogen at the station below Okanagan Lake, in terms of the arithmetic means and their 95 percent confidence limits, determined from 14 spring-summer and 69 fall-winter measurements are 527.29 ± 47.23 and 137.12 ± 15.34 kg day^{-1}, respectively. The three-year mean, and its precision, of total nitrogen load calculated from 162 observations are 251.11 ± 29.79 kg day^{-1}.

Near the Penticton Airport

At the station located near the Penticton airport, the arithmetic means, and their 95 precent confidence intervals, determined from 1078 spring-summer and 574 fall-winter measurements of total nitrogen concentrations are 0.358 ± 0.009 and 0.465 ± 0.026 mg l^{-1}. The three-year arithmetic mean and its 95 percent confidence interval, of total nitrogen concentration calculated from all 1652 observations obtained during the period from 1976 to 1979 are 0.395 ± 0.011 mg l^{-1}.

Load of total nitrogen, expressed as the three-year arithmetic mean and its precision, calculated from 198 observations are 410.88 ± 26.715 kg day^{-1}.

Okanagan Falls

At the station located below Skaha Lake, at Okanagan Falls, concentration of total nitrogen shows statistically significant bi-seasonal variation during the sampling period from 1976 to 1979. The arithmetic means, and their 95 percent confidence intervals, determined from 417 spring-summer and 260 fall-winter measurements are 0.498 $\pm$ 0.137 and 0.716 $\pm$ 0.094 mg l^{-1}, respectively. The three-year arithmetic mean, and its precision, of total nitrogen concentration, determined from all 677 observations are 0.582 $\pm$ 0.002 mg $^{-1}$.

Loads of total nitrogen from Skaha Lake are characterized by very pronounced annual variation druing the period from 1976 to 1978. The arithmetic means, and their 95 percent confidence intervals, of total nitrogen loads determined from 3, 89 and 76 observations are 585.67 $\pm$ 53.125, 224.10 $\pm$ 39.120 and 1853.90 $\pm$ 581.9 kg day^{-1} in 1976, 1977 and 1978, respectively. However, load data for the first year are, as previously stated, based on very limited number of observations and, therefore, are not representative for the entire year of 1976.

SILICA

Below Okanagan Lake dam

At the station located below Okanagan Lake, concentration of dissolved silica does not show any significant temporal changes during the period from 1976 to 1978. The three-year arithmetic mean and its 95 percent confidence interval, determined from 771 measurements are 4.65 $\pm$ 0.022 mg l^{-1}.

The three-year arithmetic mean, and its precision, of dissolved silica load calculated from 158 observations are 5697.6 $\pm$ 752.4 kg day^{-1}.

Near the Penticton Airport

At the station located near the airport, the three-year arithmetic mean, and its 95 percent confidence interval, determined from 1274

measurements are 5.56 ± 0.055 mg l^{-1}.

The three-year arithmetic mean, and its precision, of dissolved silica load, calculated from 182 observations during the period from 1976 to 1978, are 6277.7 ± 376.7 kg day^{-1}.

Okanagan Falls

At the station located below Skaha Lake, concentration of dissolved silica is characterized by a very pronounced bi-seasonal variation observed during the period from 1976 to 1979. The arithmetic means, and their 95 percent confidence intervals, determined from 390 spring-summer and 2636 fall-winter measurements are 1.08 ± 0.076 and 2.13 ± 0.162 mg l^{-1}. The overall mean, and its precision, of dissolved silica concentration, derived from all 626 measurements are 1.475 ± 0.087 mg l^{-1}.

Loads of dissolved silica from Skaha Lake determined for the period from 1977 to 1978 in terms of the arithmetic means, and their precision, calculated from 88 and 76 observations are 1121.5 ± 235.02 and 2117.9 ± 376.7 kg day^{-1} in 1977 and 1978, respectively. The two-year arithmetic mean and its precision, of dissolved silica load, determined from all 164 observations are 1583.2 ± 226.35 kg day^{-1}.

CONCLUSIONS

Nitrogen

Nitrogen in the investigated Okanagan River reach, is characterized by different behaviour of nitrate plus nitrite loads in comparison with ammonia loads.

Load of nitrate plus nitrite shows, in terms of the overall mean load for the three year period, a statistically significant increase along the river reach between stations located below Okanagan Lake and near the airport, but, there is a significant decrease of the nitrate plus nitrite load below Skaha Lake. Also, during the nutrient dispersion study, conducted in the Okanagan River at Penticton, the major increase

of nitrate plus nitrite was found below Shingle Creek. This creek drains a watershed characterized by light soils and, in its lower part, by agricultural activities. In light soils, nitrate ions are weakly adsorbed and are readily leached by flow after prolonged and persistent rain. Consequently, in the Okanagan River, higher loads of nitrate plus nitrite are observed during the fall-winter rather than during spring-summer seasons.

Loads of ammonia, by contrast to nitrate plus nitrite, show a steep gradient along the river reach. The highest levels of ammonia load are observed at the station near the airport. According to results from the nutrient-dispersion-study, the major source of ammonia is the Penticton waste treatment plant. However, during the summer season, Okanagan Lake contributes a significant portion of the ammonia load to the Okanagan River. Below Skaha Lake, on the other hand, the highest ammonia loads are observed during winter seasons.

Loads of total nitrogen show a steep gradient along the river reach and a statistically significant seasonal variation during the three year period. A very high increase in total nitrogen load is observed near the airport but also below Skaha Lake, particularly in the fall-winter seasons, indicating that this lake is a significant source of total nitrogen.

Silica

Concentration of silica shows a significant increase in the river reach between the stations below Okanagan Lake and near the airport but there is a highly significant decrease of silica concentration below Skaha Lake.

At the station near the airport, a maximum silica concentration occurs in the spring seasons, during the periods of a peak discharge from Shingle and Ellis Creeks. On the other hand, below Skaha Lake during the early spring and summer seasons, silica shows a minimum concentration reaching the detection limit of the analytical method.

The occurrence of minimum concentration of silica during the spring-summer seasons observed in discharge from Skaha Lake indicates

that silica limitation may be significant in controlling peak levels of diatoms in spring. The seasonal changes of silica concentration observed in this discharge can provide important information on diatom growth in the lake. Diatoms have a special requirement for silica that most other algal groups do not share. Silica, in the form available to algae (measured as soluble, reactive silica) is required by diatoms to form siliceous cell walls. If available silicon levels fall too low, (0.1-0.2 mg l^{-1} SiO_2) the diatoms can no longer meet this requirement, and they are replaced by other forms, usually green and blue-green algae, which do not require silica. The problem associated with silica depletion is the reverse of that of phosphorus, thus, increasing concentrations of phosphorus allow increased algal growth and produce shifts to less desirable types. On the other hand, decreasing concentrations of silica cause shifts away from desirable types. The implication for water management is that there is no necessity to limit silicon input. But, the proposed phosphorus objectives should reduce algal growth and thus eliminate silica deficiencies.

Loads of silica are characterized by a statistically significant increase near the airport, particularly during the spring season. The tributary creeks are a significant source of silica loads to the Okanagan River in the Penticton area. There is a significant decrease of silica load below Skaha Lake as a result of the very low concentration of silica in the discharge from this lake.

1 INTRODUCTION

1.1 Problem

In the Okanagan Basin, water management faces water quantity problems (Marr, 1976) and water quality problems indicated in the Okanagan Basin Study (Canada - British Columbia Okanagan Basin Agreement, 1974).

Water quantity problems are associated with low net inflow to the Okanagan Basin lakes. Despite large capacity of the lakes, a water shortage in the valley has about ten percent chance of occurrence in any year because of irrigation requirements for approximately 25,000 ha of land (Marr, 1970). Flooding which has occurred once every fifteen and ten years in the areas around Okanagan and Osoyoos Lake has led to construction of control dams at the mouths of Okanagan and Skaha lakes.

In the past decade, prevention of undesirable water quality conditions in the Okanagan valley lakes and some tributary streams has assumed great importance to water management because of intensified socio-economic activity adjacent to the lakes. The water quality study in the basin (the Study, op. cit) indicated that in certain tributary streams the observed high coliform counts, oxygen deficiencies, turbidity and concentration levels of iron, manganese and phosphorus can adversely affect quality of water supplies for drinking, fish propagation and other uses. Significantly high nutrient loads were detected in the inputs to main valley lakes. In these loads, phosphorus was identified as one of the major nutrients promoting eutrophication of lakes. Also, control of this nutrient may be the most successful means to prevent deterioration in water quality resulting from undesirable growth of aquatic plants and algae.

The origin of nutrients and other water pollutants stems primarily from agricultural run-off, industrial and municipal waste effluents, septic tank sources, concentrations of livestock, and natural and accelerated erosion. The prevention of pollution from these sources through appropriate pollution control programs was the essential part of the recommendations for water management measures to be undertaken in the basin (Summary Report of the Okanagan Basin Study, 1974). Consequently,

in the remedial actions which were undertaken in the basin the reduction of phosphorus became the major objective in water management measures.

In the scientific literature, various alternatives are suggested for prevention of water quality deterioration and eutrophication of lakes (Likens, 1972). It is often emphasized that there are many uncertainties in the development of water management alternatives. As a contribution to the study of water quality condition in Skaha Lake, Hershman and Russell, (1976) defined probable future trends in water quality of the lake under a variety of management alternatives assuming a direct relationship between phosphorus loading and trophic state of the lake. Williams, (1973) in the geological study of the Okanagan mainstem lakes stated that there is an uncertainty as to whether nitrogen rather than phosphorus may be the nutrient limiting factor in the lakes.

Generally the water management problems in the Okanagan Basin can be grossly categorized as:

(a) Planning, administration and institutional design appropriate for multi-purpose use of the basin (Canada-British Columbia Okanagan Basin Agreement, 1974).

(b) Physical, chemical and biological process manipulation to mitigate lake eutrophication trends. (Marr, 1970; Patalas and Salki, 1973; Fleming and Stockner, 1975; Hershman and Russell, 1976).

In February 1976, the Canada-British Columbia Okanagan Basin Implementation Agreement was signed after remedial actions had been undertaken to reduce phosphorus loads from municipal treatment plants in the Okanagan Basin. In summer 1976, a five-year water quality monitoring program was initiated.

1.2 Objectives

Two categories of objectives are outlined within the five-year program: (a) specific objectives of the nutrient loading program addressed in this report and (b) overall objectives of the five-year water quality monitoring proram, within which framework this study was conducted.

(a) The objectives of the nutrient loading program, carried out by Water

Quality Branch, Inland Waters Directorate were:

i) determination of changes in concentrations of primary nutrients measured in the Okanagan River reaches below major point sources,

ii) quantification of nutrient loads, with known precision, to lakes located downstream of treatment plants,

iii) assessment of year-to-year trends in nutrient loads.

The nutrient loading program was carried out from July 1976 to March 1979 in the southern Okanagan Basin, in the Penticton and Oliver areas. This report deals only with the Penticton area.

(b) The overall objectives of the water quality monitoring program are:

i) to provide water management with information on the effectiveness of reducing nutrient loads to the mainstream lakes, and

ii) To evaluate the adequacy of the water quality data base for water resources planning.

The components of the water quality program were:

a) waste treatment project undertaken by Waste Management Branch, B. C. Ministry of Environment

b) nutrient loading study as described in this report

c) lake response measurements performed by the Environmental Protection Service of Environment Canada

2. BACKGROUND

2.1 Eutrophication

Eutrophication describes the process whereby a water body becoming better nourished either naturally by maturation or artificially by fertilization. The process, broadly defined as nutrient or organic matter enrichment, can then result in high biological productivity in an aquatic ecosystem (Rodhe, 1969).

The limnological literature supports a concept of trophic equilibrium such as that introduced by Hutchinson (1969). According to this concept the progressive changes that occur as a lake ages constitute

an ecological succession effected in part by the change in the shape of the lake brought about by its filling. As the lakes fills and the volume decreases, the resulting shallowness increases the cycling of available nutrients and this usually increases primary production. Artificial or cultural eutrophication of water, particularly lakes, results from increased nutrient supplies through human activities. The time scale of natural and cultural eutrophication is the main contrast.

Lakes have been classified in accordance with their trophic level or bathymetry as eutrophic, oligotrophic, mesotrophic, or dystrophic (National Academy of Sciences, 1969). A typical eutrophic lake has a high surface-to-volume ratio, and an abundance of nutrients producing heavy growth of aquatic plants and other vegetation; it contains highly organic sediments, and may have seasonal or continuous low dissolved-oxygen concentrations in its hypolimnion. The drainage basin which affects the composition of water can influence sediment of lakes, thus some hardwater eutrophic lakes have calcareous sediments. A typical oligotrophic lake has a low surface-to-volume ratio, a nutrient content that supports only a low level of aquatic productivity, a high dissolved-oxygen concentration extending to the deep waters, and sediments largely inorganic in composition. The characteristics of mesotrophic lakes lie between those of eutrophic and oligotrophic lakes. A dystrophic lake has brownish water from humic materials, a relatively low pH, a reduced rate of bacterial decomposition, bottom sediments usually composed of partially decomposed vegetation, and low aquatic biomass productivity.

In deep lakes with no major surface or subsurface drainage or with nutrient-poor drainage water, it could be expected that eutrophication would proceed very slowly. Nutrients and organic matter would be deposited as sediments with little recycling because of reduced ion exchange on the predominant oxidized surfaces. Overload and accelerated eutrophication could occur with excessive nutrient and organic matter inputs.

Classically, lakes are assumed to show a succession from oligotrophic to eutrophic status. However, Margalef (1968) points out

that oligotrophic lakes are more mature than eutrophic lakes if the definition of maturity is related to time of equilibration of nutrients continuously being added by runoff.

The eutrophication process in lakes can be reversed by natural (Hutchison, 1969) or management (Edmondson, 1969; Oglesby, 1969) controls of the inputs from the terrestrial ecosystem.

2.1.1 Cultural eutrophication

Causes of cultural eutrophication are discharge of municipal and industrial waste waters, agricultural practices, land development, and construction. Most lake restoration programs, however, are concerned with advance treatment of waste water by removing nutrients, particularly phosphorus from effluent discharge into receiving water. Other sources, primarily non-point sources, also have to be considered in order to evaluate the relative effect of the nutrient loads coming from natural sources and man's activities. Likens (1972) emphasizes the ecosystem study approach which, coupled with an understanding of nutrient and energy fluxes, provides a theoretical basis for the management of freshwater resources.

The role of scientific information in formulation of government policies in controlling cultural eutrophication is stressed by Prince and Bruce (1972). Various methods have been suggested to minimize the process of lake eutrophication. According to Lee (1970), for example, this process can be minimized by reducing the nutrient input to the lake, by increasing the nutrient output from the lake, by immobilizing nutrients within the lake and by controlling excessive growths of algae within the lake. Goltermann (1967) stressed that although various local remedial actions are possible, the efficient means for control of lake eutrophication is the decrease of nutrient input, especially input of phosphorus. In this connection, diversion of sewage has been applied elsewhere but with variable success, because of problems associated with internal nutrient cycling in lakes. The role of internal phosphorus cycling, after the diversion of sewage, has been studied in Sweden. The diversion of sewage from Lake Trummen in Sweden (Björk et al., 1972) did

not lead to an improvement in water quality until restoration measures such as suction dredging of the sediment and macrophyte elimination were applied. On the other hand, a contrasting example is the Lake Washington case, where diversion of sewage from the lake resulted in a prompt reversal of the eutrophication pattern (Edmondson, 1979). The artificial destratification of lakes also turned out to be an effective means of controlling blue-green algae (Fogg, 1969; Ridley, 1969).

In the assessment of nutrient loads originating from various sources the relative importance of human input must be known so that the usefulness of any program dealing with land use control can be determined and any success achieved evaluated. Studies of nutrient budgets indicate that input of nutrients nearly always exceeds output. The only considerable losses are outflow, evaporation (i.e. ammonia), or harvest. The following contributing input-output items are considered by Brezonik (1972) in determination of nutrient budgets for lakes (Table 1).

Golterman (op. cit.) concludes that if the nutrient budget shows a positive balance the concentration of nutrients in the lake will rise, and algal growth will increase. This situation will lead to increased sedimentation and increased nutrient outflow.

2.1.2 Nutrients

Chemical nutrients, necessary to the growth and reproduction of rooted or floating flowering plants, ferns, algae, fungi or bacteria, are classified as macronutrients, trace elements or micronutrients, and organic nutrients. The macronutrients are nitrogen, phosphorus, calcium, potassium, magnesium, sodium, sulfur, carbon and carbonates (Deevey, 1972). The micronutrients are silica, manganese, iron, zinc, copper, molybdenum, boron, chromium, cobalt, and perhaps vanadium (Chu, 1942, Arnon and Wessell, 1953, Hansen et al., 1954). Examples of organic nutrients are biotin, B_{12}, thiamine, and glycylglycine (Droop, 1962). correlates closely with that available to the algae. However, Shapiro (op. cit.) notes that the problem of determining available iron seems to be insoluble unless an analytical method is elaborated separately for each algae. Goldman (1972) stated that in general deficiencies in trace

Table 1 Sources and Sinks for the Nitrogen Budget of a lake (after Brezonik, 1972)

Sources	Sinks
Airborne	Effluent loss
Rainwater	
Aerosols and dust	Groundwater recharge
Leaves and miscellaneous debris	
	Fish harvest
Surface	
Agricultural (cropland) and drainage	Weed harvest
Animal waste runoff	Insect emergence
Marsh drainage	
Runoff from uncultivated and forest land	Volatilization (of NH_3)
Urban storm water runoff	Evaporation (aerosol formation from surface foam)
Domestic waste effluents	
Industrial waste effluent	
Wastes from boating activities	
	Denitrification
Underground	
Natural groundwater	Sediment deposition of detritus
Subsurface agricultural and urban drainage	
Subsurface drainage from septic tanks near lake shore	Sorption of ammonia onto sediments
In situ	
Nitrogen fixation	
Sediment leaching	

elements are more likely to occur in oligotrophic than in eutrophic Some of the amino acids and simple sugars have also been shown to be nutrients for heterotrophs or partial heterotrophs. Carbon (C) is required by all photosynthetic plants. It may be in the form of CO_2 in solution, HCO_3, or CO_3. Carbamine carboxylate, which may be formed by the complexing of calcium or other carbonates and amino compounds in alkaline water, is an efficient source of CO_2 (Hutchinson, 1967). Usually carbon is not a limiting factor in water (Goldman et al., 1971).

Cations such as calcium, magnesium, sodium, and potassium are required by algae and higher aquatic plants for growth, but the optimum amounts and ratios vary. Furthermore, few situations exist in which these would be in such low supply as to be limiting to plants. Trace elements either single or in combination are important for the growth of algae. For example, molybdenum has been demonstrated to be a limiting nutrient in Castle Lake, California (Goldman, 1964, 1972). Various forms of iron have been studied in lake waters to find a biologically available form of this trace element and its effect on the growth of algae. In culture experiments with iron-starved Microcystis aeruginosa, in waters taken from six lakes in Minnesota, Shapiro (1967) found that the iron in lake waters, which is capable of reacting with thiocyanate at pH 1.5, waters. Under natural conditions it is difficult to determine the effect of change in concentrations of a single chemical on the growth of organisms. The principal reasons are that growth results from the interaction of many chemical, physical, and biological factors on the functioning of an organism; and that nutrients arise from a mixture of chemicals from diversity of sources. However, the increase in amounts and types of nutrients can be traced by shifts in species forming aquatic communities (Beeton, 1969).

In the process of evaluation of eutrophication, it has been recognized that all macro- and micro-nutrients as well as dissolved organic matter are very significant factors (Goldman, 1972; Likens, 1972). However, phosphorus and nitrogen are considered to be the two elements most responsible for eutrophication, and either one may be limiting productivity within a particular aquatic system (Vollenweider,

1970). The environmental significance of phosphorus and nitrogen is the major concern of this study.

2.2 Phosphorus in Aquatic Ecosystem

2.2.1 Forms

Phosphorus occurs in natural water and in waste water in various forms, commonly classified into orthophosphate, inorganic condensed phosphate and organic phosphate (Stumm and Morgan, 1970). In nutrient loading studies, phosphorus is often differentiated into dissolved and particulate forms.

Total phosphorus includes soluble phosphorus plus that liberated following treatment with a strong oxidant such as potassium persulfate or perchloric acid. No matter which method of analysis is used, total phosphorus is made up of some or all of the following fractions: crystalline, occluded, absorbed, particulate organic, soluble organic, and soluble inorganic. Common analytical methods are not available to measure all these fractions but do, when considered as a group, give reasonably close approximations of the more important ones (Schaffner and Oglesby, 1978). The operational and analytical methods used (Murphy and Riley (1962); Rigler (1964); and Burton (1973), differentiate phosphorus in water samples as total phosphorus and total dissolved phosphorus. Some investigators distinguish phosphorus fractions according to their hydrolyzability. Golterman (1975), for example, classified phosphorus in lake water into the following components:

I. Inorganic orthophosphate:
   $PO_4 - P = (H_2PO_4 + HPO_4 + PO_4$
II. Total dissolved phosphate: $Tot\text{-}P_{diss}$
III. = II - I, Hydrolysable phosphate: Poly-P + $Org\text{-}P_{diss}$
IV. Particulate phosphate: Part-P (in algae, bacteria, other organisms; absorbed on clay or humic compounds or as pebbles and rock fragments)
V. Sum of II + IV = Tot-P (Part-P + $Tot\text{-}P_{diss}$).

Van Wazer (1958/61) divides the inorganic phosphates into the following groups: (a) orthophosphates, (b) polyphosphates (chain

phosphates), (c) metaphosphates (ring phosphates), and (d) ultraphosphates (branched ring structures). The ultraphosphates are extremely unstable in aqueous solutions and, therefore, without consequence for the water analyst. The metaphosphates have been found in some biological materials (Van Wazer, 1968). The orthophosphates and the polyphosphates have a particular significance in the studies of the aquatic environment. Sources of these two phosphate forms are: (a) breakdown of rocks, yielding the natural orthophosphates; (b) biological phosphate metabolism and formation of decomposition products, including orthophosphates and polyphosphates, and (c) introduction by man of various forms of phosphate compounds (fertilizers, material from water treatment, domestic and industrial waste water). The polyphosphates originating from detergents are considered a significant component of waste water.

In the laboratory analysis, the reaction between orthophosphate and acidified molybdate, the widely used reaction in biological phosphate analysis, is specific for the soluble reactive phosphorus form (SRP). This explains why analyses can only be performed directly in the case of orthophosphates. Polyphosphate detection in water requires alteration of the analytical method. The polyphosphates must be converted by hydrolysis or by the more drastic wet digestion, or by dry combustion. Because polyphosphates do not react directly with molybdates (unless hydrolysis has taken place) an unspecified quantity of such polyphosphates is invariably broken down during treatment with acid (Vollenweider, 1970). Ohle (1938) made a detailed differentiation of the phosphate fractions by making a sharp division between the dissolved and suspended matter, and by stressing the importance of the adsorption processes. This system has had a great influence on thought about these problems right up to the present time. This differentiation also cited by Vollenweider (1978) is illustrated in Table 2.

Since the vast majority of total phosphorus is in the form of orthophosphate and organic phosphorus, these are the two phosphorus forms considered to be important in nutrient cycling.

2.2.2 The Phosphorus Cycle

Phosphorus is a constituent of igneous rocks, soil, waters and living organisms. It cycles readily between inorganic and organic systems. The gross phosphorus cycle encompasses many interwoven cycles, the most prominent of which are lithosphere, hydrosphere and biosphere.

In the lithosphere, the original phosphorus source is igneous rocks containing phosphorus principally as apatite Ca_5 [(F, Cl, OH) $(PO_4)_3$], fluorapatite [$Ca_5(PO_4)_3F$] being the most abundant form in nature (Williams et al., 1976, Deer et al., 1966). Although apatite contains between 18.0 to 18.7 per cent of phosphorus, it is a minor source of phosphorus for biological growth because its solubility in water is low.

The phosphorus in rocks is slowly solubilized by weathering process. Carbon dioxide, when united with water forms a weak acid which enhances the solubility of phosphorus rocks. The micro-organisms in the soil have been found to solubilize inorganic phosphorus or rock fragments. The soluble phosphorus is partially absorbed by the biological processes occurring in the pedosphere and hydrosphere, and partially reprecipitated as secondary phosphate minerals. The common secondary minerals in the soil are calcium, iron, and aluminum phosphates and clay mineral phosphates.

In the soil phosphorus content ranges from 0.002 to 0.83 per cent (Van Wazer, 1961). Only a small fraction of this content is available for plants and microbial use. Calcium, iron, aluminum and certain clay minerals of the soil readily unite with soluble phosphorus to render it insoluble.

Phosphorus is not present in the atmosphere, except as it appears there in dust particles and microbial debris. In the hydrosphere, the phosphorus cycle is complicated. Waters contain both undissolved (sestonic) and dissolved phosphorus. In rivers phosphorus is depleted from upper reaches of the streams to lower concentration levels by stream flow of soluble forms and colloidal and debris suspension before it accumulates finally on lake bottoms. The natural range of total

Table 2. Forms of Phosphorus Present in Surface and Waste Waters

Total P

Dissolved P	P in suspension			
Orthophosphate (PO_4)	As organic colloids and or combined with an absorptive colloid	As mineral particles (e.g. apatite) &/or absorbed on inorganic complexes such $Fe(OH_3)$	Organisms	Absorbed on detritus and or present in organic compounds

Dissolved inorganic P

Total P in filtrate

Total P content of unfiltered water

Source: Vollenweider (1978)

phosphorus in river waters is from a trace to as much as one part per million (Hutchinson, 1957). Accelerated erosion of soil alters the phosphorus quantity and the ratio of its soluble to insoluble forms in rivers and lakes.

Biological processes in the lithosphere and hydrosphere are essential parts of the overall cycle of phosphorus. Biologically available phosphorus, which includes both water and diluted-acid soluble phosphorus as well as certain organic phosphorus compounds, is taken up from the environment by living organisms. Part of the phosphorus uptake is transformed into a diversity of organic compounds and part is retained as mobile, inorganic phosphorus in the cell fluids. The species of soluble phosphorus compounds and mechanisms by which they are produced in lake water is a subject of various studies. Lean (1973) states that an exchange mechanism exists in lake water between phosphate and plankton, but the excretion of an organic phosphorus compound by the plankton is also a significant process. It results in the extracellular formation of a colloidal substance, and most of the nonparticulate phosphorus in lake water is in this form.

2.2.3 Sediment - Phosphorus Interaction

There are significant factors which have a bearing on management strategies of nonpoint source of phosphorus, particularly in terms of association of phosphorus transport with sediment and biological availability of phosphorus. The availability of tributary phosphorus loads, direct point source loads and atmospheric loads needs to be considered to provide cost-effective management strategies. For example, in the Great Lakes, studies sediment-associated loads (important for assessing the biologically available portions of total phosphorus) have been investigated (International Referral Group on Great Lakes Pollution from Land Activities, 1978).

The magnitude of sediment-associated tributary loads to the lakes and partitioning of sediment phosphorus among particle size fractions warrants greater emphasis to provide useful information in the development of management strategies. In-lake resuspension and diffusion/convection

of soluble phosphorus from sediments (i.e. internal loading) needs to be better understood, especially with respect to the impact on shallow lakes wherein nutrient-rich sediment may greatly delay water quality improvements expected from reduced external loadings.

Meteorological and climatological factors have to be considered. Natural meteorological fluctuations can directly affect overland delivery to a stream, transmission within the stream and volume of the stream, and consequently are responsible for large temporal variations in tributary loads to the lakes. Specifically, wet, dry and normal years, and individual but very severe storms can affect nonpoint source loads. Atmospheric phosphorus loads also vary considerably from year to year and season to season (Acres Consulting Services Ltd. 1977).

Identification of potential contributing areas, particularly hydrologically active areas, located close to rivers and lakes, is an integral part of phosphorus load assessment. Soil type morphology, land use intensity and materials usage are important factors in determining nonpoint source loads. The most critical problem areas are rowcrops of fine textured soils, some concentrated livestock operations, developing urban areas, and highly impervious portions of major urban centers.

Phosphorus in urban stormwater and combined sewage originates from numerous sources, many of which are difficult to isolate and quantify in terms of actual loads. Many of the sources contribute phosphorus collectively to the runoff from various land uses and land activities.

Studies have indicated that the correlation of total phosphorus to total suspended solids in urban runoff from several urban land uses is the highest compared with the correlations for total nitrogen, BOD_5, and chemical oxygen demand (COD). Thus, phosphorus is probably associated with suspended solids or held in complex with eroding soils. Leachate from leaves on streets, in gutters, and on impervious surfaces can also contribute substantial phosphorus loads in urban runoff. Laboratory simulation of the rain leaching process on oak and poplar leaves yielded total soluble phosphorus loads of 54 and 140 ug/g of leaves, respectively. Soaking of the leaves for extended periods, up to about one day, yielded about 270 ug/g of leaves (Cowen and Lee, 1973).

Phosphorus concentrations in runoff from streets, parking lots, bare areas, corporation yards and construction sites can range from about 0.5 to over 3 mg/l. Over 56% of the phosphorus found on streets is associated with very fine silt-like particulates (43 u), and over 85% is associated with particle sizes less that 104 u (Manning et al., 1977).

In basinwide studies, Grizzard et al. (1978) report their findings in terms of runoff volume correlation of phosphorus load and runoff volume for two watersheds in northern Virginia. This might be a spurious correlation, nevertheless, the relationships found indicate a log-linear increase in phosphorus load with increasing runoff volume for a 118,400-ac mixed urban-rural watershed and a 219,400-ac watershed with predominantly agricultural land use. The correlation coefficients for these two regression lines are 0.94 and 0.93, respectively. Although the difference in phosphorus yields between the two basins is about fivefold, the rate of increase in yields is roughly parallel.

The preponderance of forested lands in the Okanagan basin and large proportion of agricultural land provide for the importance of nonpoint source loads of phosphorus. Sources of phosphorus from shore bluff erosion, although potentially high, are not considered to be important because the biological availability of phosphorus derived from this source is small (Schindler, 1977). Chemical analyses of water and sediment of Kamloops Lake (St. John et al., 1976) indicate that 70% of the total phosphorus entering the lake is in the form of apatite and that apatite may occur in all size fractions of the lake sediment. This latter suggestion is significant, for if apatite is present in the lake as particles smaller than 0.45 um, apatite particles could pass through the membrane filters used to separate "dissolved" from "particulate" materials and be included in the "dissolved" phosphorus pool. Therefore, estimates of productivity could be erroneous even if dissolved rather than total phosphorus values are used for the estimation, as suggested by Dillon and Kirchner (1975). Study of apatite concentration in sediment of Kamloops lake (Reid, 1979) indicates that apatite smaller than 0.45 um may be abundant in Kamloops Lake, comprising as much as 20% of the "dissolved" phosphorus load.

Another phosphorus source, pertinent to Skaha Lake, is the recycling of phosphorus within the lake, including the regeneration of phosphorus from bottom sediment. Core samples taken from the sediment of Skaha Lake indicate that typical deep muds consist of 58.5 percent silt, 41 percent clay and 0.5 percent sand (St. John 1973). According to Williams (1973), apatite mainly in the form of $Ca_{10}(PO_4)_6(OH)_2$, constitutes a large part of the lake sediment.

In more recent years, there has been a growing awareness of the role sediments play in the dynamics of lake systems. Recycling of mineralized organic matter, especially the nutrients, in sediments by organic decay and pore fluid transfer processes are now recognized as essential components of models that attempt to decribe the nutrient dynamics of lake and reservoir systems (Allen and Kramer, 1972).

One of the prime goals of studying the quantitative mineralogy and chemistry of sediments is the evaluation of the sources of sediment phases and the relative importance of each source. It is useful to distinguish:

1) the minerals brought into the lake by surface water (streams and overland flow), shore erosion, glacial transport, and aeolean processes (allogenic fraction);
2) the minerals originating from processes occurring within the water column (endogenic fraction);
3) the minerals resulting from processes that occur within the sediments once deposited (authigenic fraction).

Such imposition of order on nature inevitably leads to cases where distinction of origin is almost impossible, but it points out the important types of interactions between lakes and sediments.

Some of the most important authigenic processes in lake sediments involve phosphorus. According to various literature sources, phosphate concentration values in lake sediment vary from 0.25 to 0.75 percent (by weight).

Williams et al. (1971, 1976) subdivided the phosphorus of lake sediment into three categories:

1) surface sorbed and coprecipitated or minor component of an amorphous

phase,

2) constituent of an organic ester, or

3) component of a discrete mineral, such as apatite or vivianite.

Studies of surficial sediments from 14 Wisconsin lakes indicated that most of the phosphorus was covalently bonded to an amorphous or short-range order complex related in composition to some form of hydrated iron oxide (Williams et al., 1976). Organic phosphorus exists as an integral part of sediment organic matter associated with clay minerals and ferric oxide. Williams et al., (1971) suggested that organic phosphorus is tied up in humic and fulvic fractions with the clay minerals and showed no obvious relationship to lake trophic levels (Sommers et al., 1972). Williams and Mayer (1972) emphasized that apatite in its many varieties is the most common phosphate mineral in sedimentary environments. Williams et al. (1976), in their study of the forms of phosphorus in the phosphorus distribution in a sediment profile from Lake Erie, demonstrated the diagenesis of mineral phosphate from amorphous to crystalline form. According to these investigators, the processes of mineralization of organic phosphorus and release of sorbed phosphorus under reducing conditions in the lake sediment can provide regenerated solute phosphate through diffusion from pore fluids, but this will be counterbalanced by apatite formation. They concluded that regeneration of solute phosphorus from sediment is an important control on the rate at which sedimentation and mineralization remove phosphorus from the lake waters. Livingstone and Boykin (1962) estimated that sediment regeneration has contributed about 45 percent of the phosphorus loading to Linsley Pond, Connecticut, based on the assumption that variation of total phosphorus content of sediment bands were the result of a constant rate of phosphorus deposition with a variable rate of subsequent regeneration.

2.2.4 Ecology

Most investigators feel that phosphorus is the limiting nutrient to phytoplankton growth in most fresh water aquatic systems. In many cases an increase in phosphorus loading to a stream or lake results in a

direct increase in algal growth. Often increased phosphorus loadings can be attributed to man's activities. Excessive concentrations of instream phosphorus can result from point loads of sewage effluent and diffuse loads of fertilizer. Phosphorus is introduced into a river reach by loads from point and nonpoint sources. Sinking, benthal releases, and decomposition and death of both free-floating and benthic algae are additional sources of phosphorus. Sinks of phosphorus are uptake requirements for algal growth, and sediments. Biological processes which occur in water (Figure 1) are of importance in determining the quantity of phosphorus in a particular river reach or the amount available for a downstream reach.

Generally of the various forms of phosphorus present in the aquatic environment such as orthophosphates, polyphosphates and organic phosphorus, only orthophosphate is immediately available for algal uptake. The other phosphorus forms require varying degrees of transformation before they may be utilized. The impact of detergent, for example, as a source of polyphosphate is significant in particular with respect to its ability to produce orthophosphate by hydrolysis in natural waters (Clesceri and Lee, 1965).

Some phosphorus-deficient algae utilize organic phosphorus compounds for metabolic functions and growth (Chu 1946; Fogg and Miller, 1958) and this is of paramount importance in controlling the influx of phosphorus to natural waters (Kramer et al., 1972). The removal of the total phosphorus, as high as ninety-five percent, is theoretically possible by precipitation with alum or lime (Buzzell and Sayer, 1967). This removal efficiency, however, is far greater for orthophosphate than for the organic phosphorus fraction (Bennett, 1970).

In most lakes there appears to be a net movement of phosphorus into the sediment. Mechanisms responsible for sedimentation of inorganic phosphorus are: (a) chemical precipitation of phosphorus minerals and (b) adsorption of phosphate on sediment under aerobic and anaerobic conditions. Three basic phosphorus mineral groups may be involved in organic precipitation: the calcium phosphates, the iron phosphates, and the aluminum phosphates (Kramer et al., 1972). The phosphorus compounds

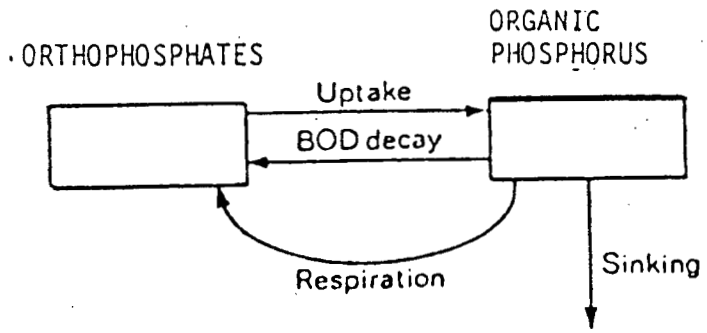

FIGURE 1. Phosphorus Cycle in Water

containing calcium (Vollenweider, 1971), in increasing order of solubility are: fluor-apatite, carbonate-apatite, hydroxy-apatite, oxy-apatite, tricalcium phosphate, dicalcium phosphate, and monocalcium phosphate. In the surficial sediments of Skaha Lake, according to Williams (1973), the majority of phosphorus (seventy percent) is in the form of hydroxy-apatite. The source of the apatite in this lake is soil and rock weathering occurring in the basin rather than chemical precipitation within the lake system. Evidence for the presence of this mineral in stream inputs to the Okanagan Valley lakes is not available even though the adjacent Tertiary volcanics are rich in apatite phosphorus (Hall, personal communication).

Adsorption reactions play an important role in controlling the exchange of phosphorus between sediments and overlying water (Hayes, 1964; Williams and Mayer, 1972). Iron and aluminum hydroxides and oxides, as well as silicates of these elements adsorb phosphorus (Stumm and Morgan, 1970). In Skaha Lake, for instance, eighteen percent of the phosphorus in the surficial sediments are composed of adsorbed phosphorus which is the most abundant form after the apatite in the lake (Williams, 1973). It is assumed that adsorption of orthophosphate by sediment is the dominant mechanism in phosphorus sedimentation during the mixing period from November to March (Fleming, 1974).

Inorganic phosphate is used by growing algae which are extremely efficient in removing phosphate from solution. Following the death of the algae most of the phosphate is released back into the water. In respect to organic phosphorus, sinking in lakes acts as either a source, from overlying lake layers, or a sink, settling out of a layer. This phosphorus form is of major importance in lakes or reservoirs. Sedimentation of organic phosphorus is subjected to seasonal variation. Much phosphorus accompanies the sedimentation of dead algae cells in sinking from the epilimnion to the hypolinmion and to benthic sediments. Survey of littoral areas of Skaha Lake (Stockner et al., 1972) indicated that about seventeen percent of organic phosphorus from the epilimnion ended up in littoral sediments and about eighty-three percent in the hypolimnion.

Inorganic orthophophosphate and organic phosphorus are the two phosphorus forms which are considered to be important in nutrient cycling in lake waters. Golterman (1967) suggests that a distinction can be made between two phosphate cycles in lakes: (a) internal (metabolic), and (b) external. The first cycle summarizes biological aspects and is expressed by Golterman (op. cit.) as follows:

$$(PO_4\text{-}P)_{water} \xrightarrow{\text{primary production}} \text{cell-}PO_4 \xrightarrow{\text{mineralisation}} (PO_4\text{-}P)_{water} + \text{Org-}P_{water}$$

Processes in the first (biological) cycle are usually of short duration (up to a few days), though animals may use a small fraction of the phosphate for longer periods.

The second cycle is geochemical and can be symbolized as follows:

$$(PO_4\text{-}P)_{water} \longrightarrow \text{sediments} \longrightarrow (PO_4\text{-}P)_{water} + \text{Org-}P_{water}$$

The second cycle is geochemical, characterised by slow process, especially with respect to the solution of sediment.

Because a very large fraction of the phosphorus in a given system may be inside living organisms at any given time, a special consideration by some investigators is given to residence time of dissolved phosphorus. According to Pomeroy (1960), residence time of dissolved phosphate, that is the average time phosphorus atoms remain in solution, varies from 0.05 to 200 hr. A system having a short residence time may be low in dissolved phosphate, as in the sea, or it may be very active biologically, as in algal blooms. When both conditions occur together, as in small lakes, the residence time becomes very short. Consequently, the concentration of dissolved phosphate in lake waters gives little indication of phosphate availability or turnover (Lean, 1973). Pomeroy (op. cit.) has suggested that the flux of phosphate is more important than the concentration of dissolved phosphate in maintaining high rates of production.

2.3 Nitrogen in Aquatic Ecosystem

2.3.1 Forms

Nitrogen is present in water in inorganic, organic and short-term dissolved gaseous forms, N_2, N_2O, NO, as intermediates during the process of denitrification. Inorganic nitrogen is present primarily as highly oxidized forms, nitrite and nitrate, as a reduced forms ammonia, and as molecular nitrogen. A variety of intermediate gaseous oxides of nitrogen are important in atmospheric chemistry but less important in natural waters. Naturally occurring organic nitrogen consists primarily of amino and amide (proteinaceous) nitrogen, along with some heterocyclic compounds such as purines and pyrimidines (Brezonik, 1972). Nitrogen compounds are present as cellular constituents, as nonliving particulate matter, as soluble organic compounds, and as inorganic ions in solution.

Total Kjeldahl nitrogen is a product of a particular analytical method by which both ammonia and organic nitrogen are measured. Both of these forms of nitrogen are present in nitrogenous organic detritus from natural biological activities. Total Kjeldahl nitrogen may contribute to the overall abundance of nutrients in water and thus eutrophication. Classification of nitrogen forms in water, proposed by Ohle (1937) and used by Vollenweider (1970) is shown in Table 3. All nitrogen forms are interrelated by a series of reactions known collectively as the nitrogen cycle, which portrays the flow of nitrogen from inorganic forms in soil, air, and water into living systems and then back again into organic forms.

2.3.2 The Nitrogen Cycle

The element nitrogen occurs naturally in the lithosphere, atmosphere, hydrosphere and biosphere. Hutchinson (1954), and Mason (1958) indicate that the bulk of the nitrogen (about ninety-eight percent) exists in the lithosphere. Most of the remainder is found in the atmosphere. The amounts that occur in the hydrosphere and the biosphere are relatively smaller than they are in the other spheres.

In the lithosphere, nitrogen is distributed extensively throughout the silicates. It is found in soils, sediments, minerals,

Table 3. Forms of Nitrogen Present in Water

Gaseous N	Dissolved N			N in suspension
N_2, N_2O, NO	Inorganic compounds	Organic compounds such as amino acids	Organisms	Organic detritus and/or inorganic and organic compounds adsorbed on particles
	...	peptides and polypeptides		
	...	Dissolved albumin & other organic compounds		

Nitrosyl salts
Organic salts

← Total N in filtrate →

← Total N content of unfiltered water →

Forms detectable by chemical analysis

Source: Vollenweider (1978)

fossils, and rocks of all types. Many natural products, such as coal and petroleum, contain nitrogen. Except for small quantities of elemental nitrogen that may be occluded in the tubular channels of some minerals, the nitrogen contained in the lithosphere is in a combined state, ammonia, nitrate, nitrite and organic nitrogen. Investigation (Stevenson, 1962) indicates that most of the nitrogen contained in primary (igneous) rocks may exist as ammonium ions held within the structures of such minerals as the micas and feldspars.

In sediments, the nitrogen occurs largely in the form of organic matter. A distinguishing feature of soils, sediments, and sedimentary rocks is the constancy of the C/N ratio. For marine and lake sediments, and for the surface layer of terrestrial soils, the ratio generally falls within well-defined limits, usually from about 10 to 20. Deep marine and lake sediments and subsurface soils often have substantially lower ratios. The C/N ratio in sedimentary rocks varies widely, both high (40) and low (5) values having been reported.

In the atmosphere, nitrogen comprises seventy-eight percent by volume (seventy-five percent by weight) of the gases present. Except for minute amounts of nitrous oxide, ammonia, nitrite, nitrate, and organically bound nitrogen (associated with cosmic dust), this nitrogen exists as diatomic N_2. The geochemical cycling of nitrogen in the earth is concerned mainly with the passage of molecular nitrogen into and out of the atmosphere. The processes involved are largely biological. The accession of combined nitrogen in rain and snow, consisting of ammonia, nitrite, nitrate and organic nitrogen associated with cosmic dust, supplements that which is fixed by biochemical agents (Hutchinson, 1944). Some of the nitrogen in precipitation (ammonia and the organic forms) orginates from soil dust.

In the hydrosphere, nitrogen occurs as molecular nitrogen, ammonium, nitrite, nitrate, and dissolved and paticulate organic matter. Molecular nitrogen occurs as a dissolved gas. Nitrogen fixation and denitrification takes place even though their effect on the total dissolved nitrogen may be small.

The importance of nitrogen in the biosphere is emphasized by the

fact that all of the biochemical processes carried out by living organisms are catalyzed by nitrogen-containing compounds called enzymes. The cycling of carbon, oxygen, phosphorus, and sulfur in the earth is intimately associated with biochemical nitrogen transformations.

A feature of particular interest is biochemical nitrogen fixation. The process of nitrogen fixation is important in the geochemical cycle to maintain a nitrogen balance in the biosphere as well as fertility of the soil. In natural waters, nitrogen fixation acts as a source of nitrogen and permits continued organic production when the supply of fixed nitrogen becomes depleted.

A variety of organisms are capable of nitrogen fixation, including a number of blue-green algae, apparently all photosynthetic bacteria, various aerobic bacteria (e.g. Azotobacter), anaerobic bacteria (e.g., Clostridium), many facultative bacteria but only under anoxic conditions (Wilson, 1969), legume root nodules, and nonleguminous root-nodulated plants such as Podocarpus and the alder tree (Alnus sp.) Most studies of nitrogen fixation in natural waters have emphasized the role of filamentous, heterocystous blue-green algae such as Anabaena, Gleoetrichia, and Nostoc. The agents and occurrence of nitrogen fixation in the biosphere have been extensively reviewed by Stewart (1966; 1970).

Nitrogen-fixing algae usually bloom in lakes only after nutrients have been depleted by blooms of other algae (i.e., late summer in temperate lakes). However, contrary to earlier opinion, small to moderate concentrations of ammonia do not necessarily inhibit fixation, although synthesis of the enzyme nitrogenase is repressed at high levels. Aquatic organisms would utilize the available ammonia and nitrate before fixing nitrogen because this process requires additional energy.

Stewart (1968) suggests that the levels of combined nitrogen in most natural ecosystems are insufficient to inhibit fixation immediately or even to persist long enough for existing nitrogenase to be diluted out. Low levels of combined nitrogen may actually be advantageous to nitrogen-fixing plants by enabling more efficient and healthy growth than could be achieved on N_2 alone.

The possibility of elemental nitrogen being fixed by Cyanophyceae seems to merit greater attention (Vollenweider, 1970). A review of studies dealing with the capability of blue-green algae to fix elemental nitrogen was done by Fogg (1956). Results obtained in measuring the nitrogen-fixing capacity of algae are not always convincing (Sawyer and Derulio, 1961; Goering and Ness 1961). Lund (1956) evaluated the nitrogen fixing capability of various blue-green algae. Based on this evaluation and comments of Vollenweider (1970), it should be noted that the three blue-green algae that most frequently cause the formation of water blooms, i.e. Microcystis aeruginosa, Oscillatoria rubescens and Aphanizomenon flos aquae, do not belong to nitrogen fixing species; the capacity of Anabaena flos aquae to do so is doubtful.

In the overall process of biochemical nitrogen transformation, mineralization is the conversion of organic nitrogen to inorganic forms. The initial reduction to ammonia is referred to as ammonification; the oxidation of this compound to nitrate is termed nitrification. The utilization of ammonia and nitrate by plants and microorganisms constitutes assimilation. Combined nitrogen is ultimately returned to the atmosphere through biological denitrification, thereby completing the cycle.

2.3.3 Ecology

Nitrogen is not only a major nutrient for aquatic plants, but the nitrification process (oxidation of reduced nitrogen forms by nitrifying bacteria) may exert a considerable oxygen demand on a water body. Consequently, nitrogen dynamics can have a large impact on the dissolved oxygen balance within an aquatic system.

Various physico-chemical and biological processes are involved in nitrogen dynamics in water body. Nitrogen can enter a river reach as a load from point - and nonpoint sources. Benthal releases and death and respiration of benthic algae are other nitrogen sources. The nitrification process acts to transform nitrogen forms within a reach from reduced to oxidized chemical species. Thus, while nitrification does not affect the total amount of nitrogen within the system, it can

act as a source of nitrate, and a sink of nitrite and ammonia. The removal of nitrogen from the system can result from advection, uptake by benthic algae, sinking, and under anaerobic conditions, denitrification.

Several biological reactions control nitrogen cycling (Figure 2). Nitrification and denitrification are mentioned here. Nitrification is the oxidation of ammonia and nitrite by chemoautotrophic bacteria. This oxidation provides energy for bacteria in much the same way that sunlight provides energy to photosynthetic algae. The oxidation reaction of ammonia to nitrite is completed only by the bacteria Nitrosomonas. Nitrite is then further oxidized to nitrate by the bacteria Nitrobacter. These reactions may be expressed by the following equations:

$$NH_4^- + 3/2\ O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 1/2\ O_2 \xrightarrow{\text{Nitrobacter}} NO_3^-$$

Denitrification, the reduction of nitrate, is accomplished by certain facultative anaerobic bacteria. These bacteria use NO_3 as an electron acceptor in the same manner that oxygen is used under aerobic conditions. They use oxygen until the environment becomes nearly or totally anaerobic. Then under anaerobic conditions, these bacteria have the capacity to utilize NO_3 as an electron acceptor. The primary reaction involved in denitrification is:

$$H^+ + NO_3 \xrightarrow{\text{bacteria}} 1/2\ N_2 + 5/4\ O_2 + 1/2\ H_2O$$

Coupled with this reaction is the oxidation of organic matter as an energy source. Examples of denitrifying bacteria are Pseudomonas and Micrococcus. The qualitative significance of the denitrification process in the nitrogen budget of stratified eutrophic lakes has been described by Brezonik and Lee (1968).

With respect to the utilization of nitrogen in the aquatic ecosystem the various nitrogen forms cannot be used to the same extent by the different organisms. Nitrate is normally the predominant inorganic nitrogen form in surface water. Organisms using nitrate as their source

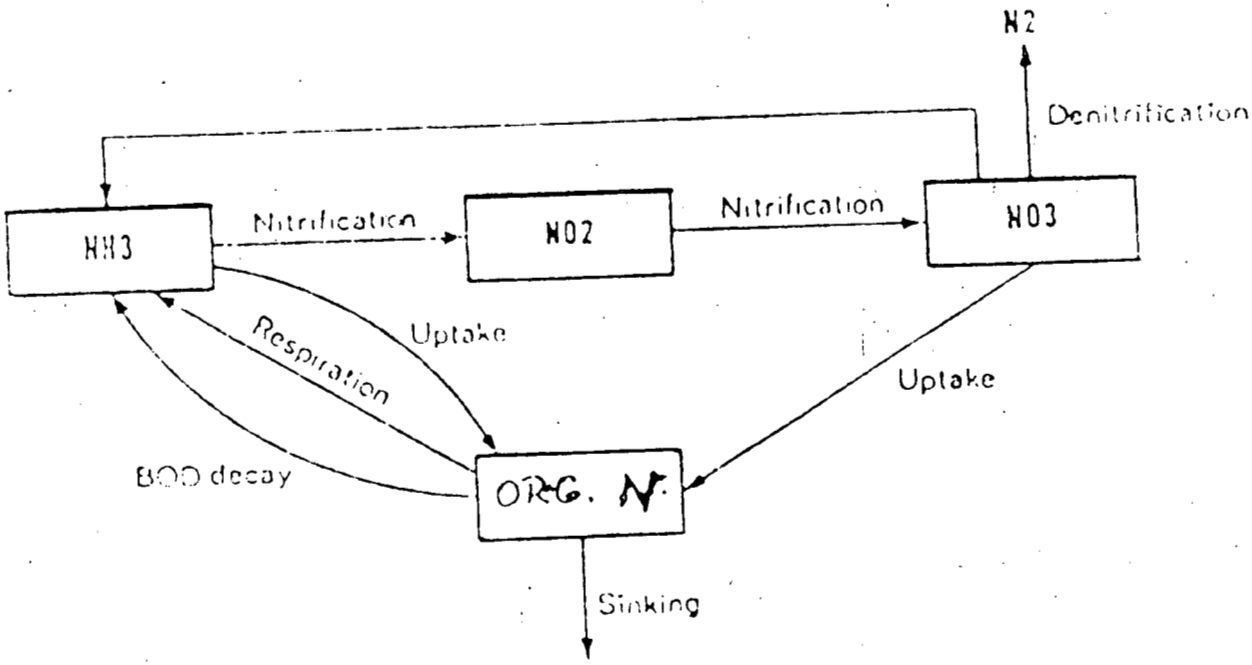

FIGURE 2. Nitrogen Cycle in Water

of nitrogen must reduce it to the level of ammonia before incorporating it into organic form (Eppley et al, 1969). Nitrate can be used by most higher plants, bacteria and some algae (Strickland, 1965) but ammonia is the preferred nitrogen for planktonic assimilation. The use of organic nitrogen compounds by some algae has been reported by Allen (1952). In the process of nitrification, ammonia is oxidized to nitrite and nitrate by a selected group of aerobic autotrophic bacteria and at much slower rates, by a variety of heterotrophic bacteria, actinomycetes and fungi (Delwiche, 1965). In the absence of oxygen nitrate is utilized by facultative and anaerobic bacteria. This process is known as denitrification. Nitrite is formed as the first intermediate in this process, nitrous oxides can sometimes be formed along with molecular nitrogen. The principal end product is N_2, a form of nitrogen which can be utilized only by some organisms (Delwiche, op. cit.)

In the discussion of the nitrogen and phosphorus cycles one of the major differences between these two cycles should be pointed out. In the nitrogen cycle, there is a change to different oxidation states while in the phosphorus cycle the oxidation state of phosphorus never changes, just the forms, such as soluble, particulate, organic or inorganic forms.

2.4 Implication for Management

Eutrophication has a significant relationship to the use of water for recreational and aesthetic enjoyment as well as the other water uses. This relationship may be desirable or undesirable, depending upon the type of recreational and aesthetic enjoyment sought. The possible disadvantages or advantages of eutrophicaton may be viewed subjectively as they relate to a particular water use.

2.4.1 Eutrophication Aspects

A desirable aspect of eutrophication, for example, is the ability of mesotrophic or slightly eutrophic lakes typically to produce greater crops of fish than their oligotrophic or nutrient poor counterparts. As long as nuisance blooms of algae and extensive aquatic weed beds do not hinder the growth of desirable fish species or obstruct the mechanics and

aesthetics of fishing or other beneficial uses, some enrichment may be desirable. Fertilization is a tool in commercial and sport fishery management used to produce greater crops of fish (LeBrasseur et al., 1978).

As a result of nutrient over-enrichment, aquatic growths can develop to nuisance proportions in streams and lakes. This development can lead to incipient and undesirable eutrophication (Vollenweider, 1970) which can be characterized by the following indicators:

(1) A quantitative increase in the biomass, as observed either in the macrophytes and periphytic algae near the shore, or in the planktonic algae of the pelagic regions. Such an increase is usually accompanied at the outset by a decrease in the number of species typical of oligotrophic waters and, simultaneously or subsequently, by the appearance of indicator organisms in the plant communities.

(2) Qualitative and quantitative changes in the littoral, benthic, and planktonic fauna, and in the fish population. While the members of the latter may be bigger at the outset, the changes are more pronounced at a more advanced stage of eutrophication, with a thinning out of the higher species and a corresponding increase in the lower ones. In some lake waters, for example, these changes are reflected in the average ratio of the number of Salmonidae and Coregenae to the number of Cyprinidae.

(3) From the physical and chemical standpoints, the decreasing transparency and changing colour of the waters, the development of oxygen maxima or minima within the metalimnic layers, and the overall decline in the oxygen content of the hypolimnic layers during the summer months, i.e. during the period of thermal stratification, and a buildup of the average nutrient level, particularly phosphorus and nitrogen.

2.4.2 Estimation of Eutrophication

Conceptually, various approaches have been undertaken in estimating the degree of eutrophication in an aquatic ecosystem (Vollenweider, 1968):

(1) The eutrophic state may be estimated by devising a scale for lakes in comparable climatic zones and measuring the symptoms. The weak point

of this approach is that wide regional variety of lakes naturally exists making it difficult, if not impossible, to set up a universal scale of eutrophication symptoms.

(2) Another approach is to measure the rate of changes of eutrophication symptoms.

(3) The third approach, proposed by Vollenweider (op. cit.) is based on measurements of the causal factors responsible for the eutrophication. In their simplest form these factors are estimates of nutrient areal loading rates. In the concept of areal nutrient loading Vollenweider (1976) considered total phosphorus concentrations of 10 mg m^{-3} and 20 mg m^{-3} to be the transition range between oligotrophy and eutrophy. However, prediction of the trophic status of a water body from phosphorus loading is only possible if phosphorus is in assimilable form and is also the factor limiting biological productivity (Vollenweider, 1971).

Process of nitrogen fixation received much attention in studies dealing with nutrient balance in aquatic ecosystems (Keirn and Brezonik, 1971). According to Dugdale and Nees (1961) the factors which influence the N_2 fixation are calcium, boron and molybdenum as well as sufficient quantities of phosphorus (Sawyer and Ferullo, 1961: Vollenweider 1971). Schindler (1977) has, however, hypothesised that, on the basis of data from several studies of the carbon, nitrogen, and phosphorus cycle, schemes for controlling nitrogen input to lakes may actually affect water quality adversely by causing low N/P ratios, which favour the vacuolate nitrogen-fixing blue-green algae that are most objectionable from a water quality standpoint. Conversely, when phosphorus control causes an increase in N/P ratio, the resulting shift from "water bloom" blue-green algae to forms that are less objectionable may be as important as quantitative decreases in algal standing crop. The nutrient limiting concept and appropriate nutrient ratios have been studied extensively elsewhere, including the effect of renewal of water and nutrient supplies and the fixation of gaseous nitrogen (Fogg and Horne, 1967). Phosphorus and nitrogen play a major part in production, periodicity and determination of the type of community present in water (Goldman, 1964). In most inland waters, phosphorus is the limiting nutrient (Schindler,

1974). In studies of algal productivity in lakes, a typical ratio of carbon, nitrogen and phosphorus is considered to be 100:15:1. According to Golterman (1975) and Dillon and Rigler (1974) the ratio of nitrogen to phosphorus required by algae in fresh water is in the range from 10:1 to 12:1. Because of the complex functional interactions of many environmental factors in lake ecosystems, the nitrogen to phosphorus ratio needs to be applied with caution. For example, the growth rate of phytoplankton in Lake Washington and Lake Sammamish is found by Welch et al., (1978) to be a function of phosphate and to be relatively unaffected by nitrate even as the nitrogen to phosphorus ratio approaches unity. Some investigators have observed a shift from blue-green algae, at low nitrogen to phosphorus ratio, to less objectionable algae forms in environments with high ratio (Shapiro, 1973). This observation is probably the most significant implication of the nutrient limiting concept because the growth rate and biomass production may be unaffected by the nitrogen to phosphorus ratio.

2.4.3 Water Quality Guidelines

There are no generally accepted guidelines for judging whether a state of eutrophy exists or by what criteria it may be measured, such as production of biomass, rate of productivity, appearance, or change in water quality. Ranges in primary productivity and oxygen deficit have been suggested as indicative of eutrophy, mesotrophy, and oligotrophy by Mortimer (1941); Sacamoto (1966); Vollenweider (1970) and Edmondson (1970), but these ranges have had no official recognition. Generally, for temperate lakes, a significant change in indicator communities or a significant increase in any of the following indices, such as primary productivity, biomass, oxygen deficit and nutrient input, detectable over a five-year period or less, is considered sufficient evidence that accelerated eutrophication is occurring. An undetectable change over a shorter period would not necessarily indicate a lack of accelerated eutrophication. A change detectable only after five years may still indicate unnaturally accelerated eurtophication, but five years is suggested as a realistic maximum for the average monitoring endeavour.

(The United States Environment Protection Agency, 1972).

Ranges in photosynthetic rate for determination of primary productivity in aquatic environment, measured by radioactive carbon assimilation as indicative of trophic conditions, were suggested by Rodhe (1969), and are shown in Table 4.

Chlorophyll 'a' is used as a versatile measure of algal biomass. The ranges presented for mean summer chlorophyll 'a' concentration determined in epilimnetic water supplies collected at least biweekly, are indices of the trophic stage of a lake: oligotrophic 0-4 mg chlorophyll a/m^3; eutrophic, 10-100 mg chlorophyll 'a'/m^3.

Criteria for rate of depletion of hypolimnetic oxygen in relation to trophic state were reported by Mortimer (1941) as follows:

oligotrophic	eutrophic
250 mg O_2/m^2/day	550 mg O_2/m^2/day

This is the rate of depletion of hypolimnetic oxygen determined by the change in mean concentration of hypolimnetic oxygen per unit time multiplied by the mean depth of the hypolimnion. The observed time interval should be at least a month, preferably longer, during summer stratification.

The representation of certain species in a community grouping in fresh water environments is often a sensitive indicator of the trophic state. Nutrient enrichment in streams causes changes in the size of faunal and floral populations, kinds of species, and number of species (Ellis, 1937; Tarzwell and Gaufin, 1953). For example, in a stream typical of the temperate zone in the eastern United States, degraded by organic pollution, the following shifts in aquatic communities are often found: in the zone of rapid decomposition below a pollution source, bacteria counts are increased; sludgeworms (Tubificadae), rattail maggots (*Eristalis tenax*) and bloodworms (Chironomidae) dominate the benthic fauna; and blue-green algae and the sewage fungus (*Sphaerotilus*) become common (Patrick *et al.*, 1967). Various blue-green algae such as *Schizothrix calciola*, *Micro-coleus vaginatus*, *Microcystis aeruginosa*, and *Anabaena* sp. are commonly found in nutrient-rich waters, and blooms of

TABLE 4. Ranges in Photosynthetic Rate for Primary Productivity Determinations

Period	Oligotrophic	Eutrophic
Mass daily rates in a growing season, ($mgC/m^2/day$)	30 - 100	300 - 3000
Total annual rates ($gC/m^2/year$)	7 - 75	75 - 100

Source: Rodhe (1969), National Academy of Science; National Academy of Engineering (1972).

these and other algae frequently detract from the aesthetic and recreational value of lakes. Diatoms such as Nitzschia palea, Gomphonema parvulum, Navicula cryptocephala, Cyclotella memeghiniana, and Melosira varians are also often abundant in nutrient-rich water (Patrick and Reimer, 1966). Midges, leeches, blackfly larvae, Physa snails, and fingernail clams are frequently abundant in the recovery zone.

Sawyer (1947) determined critical levels of inorganic nitrogen (300 ug/l N) and inorganic phosphorus (10 ug/l P) at the time of spring overturn in Wisconsin lakes. If exceeded, these levels would probably produce nuisance blooms of algae during the summer. Nutrient concentrations should be maximum when measured at the spring overturn and at the start of the growing season. Nutrient concentrations during active growth periods may only indicate the difference between amounts absorbed in biomass (suspended and settled) and the initial amount biologically available. The values, therefore, would not be indicative of potential algal production. Nutrient content should be determined at least monthly (including the time of spring overturn) from the surface, mid-depth, and bottom. These values can be related to water volume in each stratum and nutrient concentrations based on total lake volume can be derived.

A significant relationship has been demonstrated by Edmondson (1970) between maximum phosphate content at the time of lake overturn and eutrophication as indicated by algal biomass. During the years when algal densities progressed to nuisance levels, mean winter PO_4-P increases from 10-20 ug/l to 57 ug/l. Following diversion of the sewage mean PO_4-P decreased once again to the pre-enrichment level. Correlated with the PO_4-P reduction was mean summer chlorophyll a content, which decreased from a mean of 27 ug/l at peak enrichment to less than 10 ug/l, six years after diversion was initiated.

Vollenweider (1970) proposed as a general rule, that waters with total phosphorus and inorganic nitrogen concentrations in excess of 20 mg/m^3 and 300 mg/m^3, respectively, may be regarded to be in critical stage of becoming eutrophic. This rule should not be regarded as a rigid guideline and each case of study must be considered on its own merit.

Apart from all suggested guidelines in terms of nutrient concentrations, Vollenweider (op. cit.) concluded that in practice, the key to the eutrophication problem lies not in the nutrient concentrations but in subsequent nutrient loading.

Although difficult to assess, the rate of nutrient inflow more closely represents nutrient availability than does nutrient concentration because of the dynamic character of these nonconservative materials. Loading rates are usually determined on the basis of periodic monitoring of water flow, nutrient concentration in natural surface and groundwater, and wastewater inflows.

Vollenweider (1968, 1971) related permissible and critical nutrient loading to mean depths for various well-known lakes (Table 5) and identified trophic states associated with induced eutrophication. These findings showed shallow lakes to be clearly more sensitive to nutrient income per unit area than deep lakes, because nutrient reuse to perpetuate nuisance growth of algae increased as depth decreased. From 0.3 $g/m^2/yr$ P and 4 $g/m^2/yr$ N for a lake with a mean depth of 20 metres, and about 0.8 $g/m^2/yr$ P and 11 $g/m^2/yr$ N for a lake with a mean depth of 100 metres.

These suggested criteria apply only if other requirements of algal growth are met, such as available light and water retention time. If these factors limit growth rate and the increase of biomass, large amounts of nutrients may move through the system unused, and nuisance conditions may not this standpoint nutrient loading which produced nuisance conditions were about occur (Welch, 1969).

Even though all the nutrients necessary for plant growth are present, growth will not take place unless evironmental factors such as light, temperature, and substrate are suitable. Man's use of the watershed also influences the sediment load and nutrient levels in surface waters (Leopold et al., 1964; Bormann and Likens, 1967).

2.4.4 Management Priorities

The identification of sources, loads and management practices relative to phosphorus and other pollutants from other than point sources

is being documented in the literature from various basinwide studies (e.g. Northern Virginia Planning District Commission and Virginia Polutechnic Institute and State University, 1977). Thus, the first step in setting priorities on land areas for management purposes is the identification of areas contributing large proportions of pollutants directly to surface waters. These areas are normally located close to rivers, streams, lakes and impoundments and have been termed hydrologically active areas. Other nonpoint sources, such as land uses including the nonsewered waste disposal of septic systems, sanitary landfills, streambank erosion, groundwater inputs, land disposal of mine tailings, sludge disposal on land and recreational activities have also been considered.

3. STUDY AREA

3.1 Geomorphology

The Okanagan Valley is a structural trench overlying a system of sub-parallel, linked faults that separates the late Paleozoic or early Mesozoic Monashee group of metamorphic rocks of differing lithology on either side of the trench. This trench is partially filled by several hundred meters of unconsolidated materials. During and after the Pleistocene, the valley was the site of deposition, resulting from glacial outwash, direct glaciation, and lacustrine and fluvial sedimentation (Nasmith, 1962; St. John et. al., 1973).

3.2 Landscape

Three biogeoclimatological zones are represented in the Okanagan Basin (Krajina, 1969; Valentine et al., 1978): (1) Englemann Spruce - Subalpine Fir, (2) Interior Douglas and (3) Ponderosa Pine - Bunchgrass zone. Zone 1 lies above 1200-1350 m altitude and trees in this zone must be able to tolerate relatively severe winters with frozen ground. Zone 2 lies between 300-1350 m altitude and includes open and closed forest of both Ponderosa pine and Douglas fir. Zone 3 lies in the semi-arid valley bottoms and on south-facing slopes to a maximum of 750 m altitude.

TABLE 5. Preliminary Permissible and Critical Loading Rates in Lakes of Different Mean Depth For Total Nitrogen and Total Phosphorus

	Permissible Loading, (up to)		Critical Loading (in excess of)	
Mean Depth	Nitrogen $g/m^2.year$	Phosphorus $g/m^2.year$	Nitrogen $g/m^2.year$	Phosphorus $g/m^2.year$
5 m	1.0	0.07	2.0	0.13
10 m	1.5	0.10	3.0	0.20
15 m	4.0	0.25	8.0	0.50
100 m	6.0	0.40	12.0	0.80
150 m	7.5	0.50	15.0	1.00
200 m	9.0	0.60	18.0	1.20

*After Vollenweider (1968, 1971)

Seven major soils (Valentine et al., op. cit.) are represented in the basin: (1) humo-ferric podzols and dystric brunisols characterise the highest biogeoclimatic zone, (2) eutric and dystric brunisols and gray luvisols occur in the intermediate zone and (3) brown, and black chernozems characterise the lowest zone.

The main Okanagan Valley is the result of intensive glacial erosion during the Pleistocene. The valley formed a channel through which ice escaped from the major mountainous centres of accumulation to lower elevations (Tipper, 1971). A variety of sediments has been deposited in this glacial trough during the late - and post - glacial period, but very little evidence from earlier glacial episodes or even from earlier parts of the last glacial episode remains. These sediments are important to the hydrology and water quality of the Okanagan Basin because they constitute aquifers and aquicludes with totally different hydrologic residence times than the underlying bedrock. In the case of the fluvial terraces, kettled outwash, outwash terraces, and alluvial fans the saturated hydraulic conductivities are very high by contrast with moraine ridges (of which there are not many) and the extensively exposed glacial lake sediments.

The work of the ice sheet and the distributing agencies of deglaciation and post-glacial erosion are responsible for the final arrangement of the materials from which the Okanagan soils are derived (Kelley, and Spilsbury, 1949). The parent glacial till is a general mixture, whose mineral characters have been inherited by all of the soils, but water-sorting has affected the degree of inheritance in regard to some constituents. Water-sorting has endowed the loamy sands with a high content of silica by removing iron, aluminium and magnesium.

The content of organic matter and nitrogen in the soil profile varies in response to climatic distinctions, the black soils being most favoured for accumulation and fixation under well-drained conditions. From the dark brown to the brown soil zones, the amount of organic matter and nitrogen stored in the soil is progressively smaller, owing to more limited rainfall and more scanty vegetation. In the intermountain podsol there is an organic mat on the surface, but the soil itself contains less

organic matter and nitrogen than the grassland types. Phosphorus is the least mobile of the important soil minerals, and its greatest concentration in the soil profile is usually at or near the surface. This is due to the action of plants which draw a part of their supply from the subsoil. As vegetation decays, the phosphorus is held in combination with organic matter. Apparently the return of this substance to the subsoil by leaching is at a slower rate than its accumulation in the topsoil under natural conditions. Where crops are grown and shipped away, however, this cycle is interrupted and sooner or later the actual loss of phosphorus from the soil must be replaced by the use of fertilizer.

Soluble salts move in the groundwater from uplands to lowlands in every climatic region and some of them are retained in the profiles of the soils that lie in the valley bottom. This accumulation is related to humidity and solubility, the greatest number and amount of salts being leached into the streams and rivers in the humid climate. The most humid Okanagan climate prevails in the intermountain podsol region. In this zone, the bases have greatest liberation and the topsoil is rendered slightly acid by the sinking of soluble salts. Available sodium, potassium, and magnesium are more or less leached from the profile. Excess irrigation water, which leaches considerable quantities of salts into the Valley lakes, gives terrace soils a reaction over pH 8.0.

3.3 Limnology

General limnological studies of Okanagan, Wood and Kalamalka Lakes were conducted by Rawson (1935) and Clemens et al., (1939). Limnological studies conducted by Stein and Coulthard (1971) and Coulthard and Stein (1969) preceded the joint study of Federal-Provincial Okanagan Basin Agreement, (Canada-British Columbia Okanagan Basin Agreement, 1974). Some features of the morphometry and hydrology of the Okanagan Lakes are shown in Tables 6 and 7. Trophic conditions of some Okanagan Basin lakes, using criteria proposed by Vollenweider (1968, 1971) are shown in Figure 3.

3.4 Climate

The Okanagan River drainage extends from latitude N 50° 50' and flows in a southerly direction, about 204 km in Canada and 117 km in the United States, where it joins the Columbia River. Most of the precipitation is brought to the area by prevailing westerlies. Strong orographic effects complicate the precipitation pattern. The Cascade Mountains exhibit a "spillover" onto the leeward (eastern) slope of orographic enhancement of precipitation, whereas the areas to the east are in a strong precipitation shadow. Descending air on the lee side of the western mountains is relatively dry and, as a result of being warmed, becomes strongly evaporative. In the eastern mountains, orographic enhancement of precipitation occurs.

3.5 Hydrology

As a function of the geomorphology and the climate there are three distinct hydrologic regions in the Okanagan River basin: (a) the upland rim, (b) the northern Okanagan and (c) the Southern Okanagan Region.

(a) Uplands: East and west of Okanagan Lake there is a sharp rise in precipitation to 500 mm yr^{-1} on the uplands. Temperatures are lower (5°C), hence runoff is enhanced (175 mm yr^{-1} or greater) by comparison with the Okanagan Valley. Seasonal snow storage and melt are important in this area.

(b) Northern Okanagan Valley: Mean annual temperature is 5-6°C here, whilst precipitation is in the region of 375-500 mm. The precipitation is reasonably well distributed and snow storage is notably less important here. As a result, actual evaporation is fairly high (250 mm) and runoff is low. However, during spring freshet, the importance of snow melt fed tributaries, for example, Ellis and Shingle Creeks, is emphasized. Their contribution to water budget in the Okanagan River should not be underestimated.

(c) Southern Okanagan Valley: This area, including the southern-most Similkameen River Valley, is the warmest (8-9°C) and driest (300-375 mm yr^{-1}) region. Snow storage is relatively unimportant and runoff is as little as 75 mm yr^{-1}. Runoff is highly seasonal and variable, most

watercourses being dry in late summer.

The net effect of these hydrologic regions has been summarized by McNeill (1976). The Okanagan basin, on average, receives 300 mm of precipitation annually along the populated valley bottom. Orographic effects increase the total to an overall average figure of 550 mm per year over the Okanagan Lake watershed. Only about 120 mm precipitation reaches the valley bottom and of this amount, about 50 mm evaporates from the surface of the lake so that, on average, only about thirteen per cent of the incoming precipitation or about 70 mm over the watershed is available for use.

At present, (1976) there are twenty-five active snow courses (one per 120 square miles), seventy-five streamgauging and lake level stations (one per forty square miles), and about twenty-five meteorological stations (one per 120 square miles) in the basin. The meteorological stations include about ten class "A" evaporation pans.

3.6 Okanagan River - Skaha Lake Subsystem

Detailed study of Skaha Lake has been carried out by Fleming (1974), and Fleming and Stockner (1975). This work led to the development of a model of the phosphorus cycle and phytoplankton growth in Skaha Lake (Fleming, op. cit.). At the same time, data for the Okanagan River between Okanagan and Skaha Lake were published (Canada-British Columbia Okanagan Basin Agreement, 1974) and Hershman and Russell (1976) have considered alternative future trends in the trophic condition of the Okanagan River-Skaha Lake sub-system.

The salient points from the above research concern the relative trophic condition for Skaha Lake. The contrast between phosphorus external and internal loading rates in Skaha Lake (Figure 4), as estimated by Fleming (op. cit.), indicate comparative contributions of allochthonous and autochthonous sources. Table 8 shows the estimates of sources of nitrogen and phosphorus entering the lake and the important conclusions on the effects of changing hydrologic conditions.

It is significant that large changes in trophic status may theoretically occur in only one year as a result of variations in

TABLE 6. Morphometry of the Okanagan Basin Lakes

Lake	Volume ($10^6 m^3$)	Surface area ($10^6 m^2$)	Depths (m) mean	Depths (m) maximum
Wood	200	9.3	22	34
Kalamalka	1,520	25.9	59	142
Okanagan	26,200	348.0	76	242
Skaha	588	20.1	26	57
Vaseux	17.7	2.75	6.5	27
Osoyoos (N)	204.0	9.91	21	63
Osoyoos (S)	51.5	5.14	10	29
Osoyoos (Total)	397.0	23.0	14	63

Note: Osoyoos (N) is the basin north of the highway bridge. Osoyoos (S) is the basin between the highway bridge and the U.S. border.

Sources: Canadian National Topographic System, 1960. Scale 1 : 126,720.

Fish and Wildlife Branch, Department of Recreation and Conservation, B. C.

Canada-British Columbia Okanagan Basin Agreement (1974).

Stockner and Northcote (1974).

Table 7. Mean Annual Discharge and Residence Time of the Okanagan Basin Lakes

Lake	Mean annual outflow ($x10^6 m^3$)	Mean annual outflow ($x10^3$ acre ft)	Residence time (yr)
Wood	10.1	8.2	19.8
Kalamalka	21.3	17.3	71.3
Okanagan	439.0	336.0	59.7
Skaha	474.7	385.0	1.2
Vaseux	528.8	428.9	0.03
Osoyoos (total lake Canadian and U.S. parts)	590.3	478.6	0.7

Source: Canada-British Columbia Okanagan Basin Agreement Technical Supplement V. (1974).

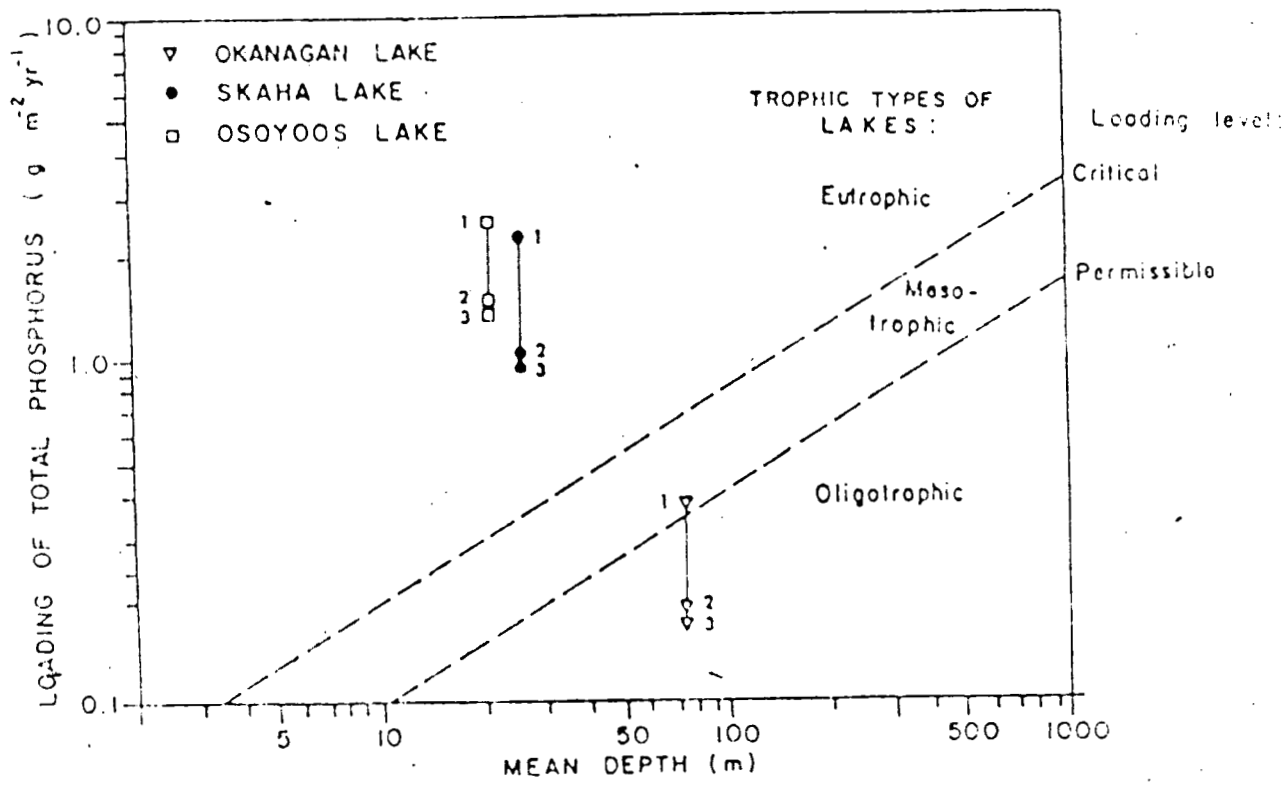

Figure 3. Trophic conditions in some Okanagan Basin lakes using criteria proposed by Vollenweider (1968, 1971)

Source: (1) Patalas and Salki (1973), (2) indicates 1990 loading with eighty percent removal of phosphorus from municipal waste water, (3) Canada-British Columbia Okanagan Basin Agreement (1974).

hydrology and phosphorus loading. The hydrologic and loading conditions occurring from March 1972 to March 1973 resulted in a decrease in spring phosphorus concentration in the lake of 26 ug/l (from 42 to 16). The lower phosphorus concentration resulted in significantly lower phytoplanton production during the summer of 1973, and no serious algal blooms. Similar changes are documented in the body of this report for 1976 to 1978.

4. METHODOLOGY

4.1 Field Measurements

Chemical water quality measurements, employing simultaneous and sequential sampling methods were conducted at three stations located in Okanagan River.

4.2 Sampling Stations

In the Okanagan River - Skaha Lake sub-system chemical water quality sampling stations were selected in the Okanagan river reach between Penticton and Okanagan Falls.

In summer 1976, two sampling stations were established in Okanagan River at Penticton. One station was located immediately below Okanagan Lake and instrumented with a portable discrete sampler (Manning model S-4040). This station was situated in close proximity to the recording stream gauging station, 08NM050, maintained by Water Survey of Canada.

The second sampling station was located near the Penticton airport, approximately 1.7 km. downstream from the Penticton municipal outfall. This station was equipped with two portable discrete samplers. One sampler was located on the west and the other on the east bank. This station was not instrumented with water level recorder but with a manual stream gauge.

In 1977, auxiliary water quality stations were established at the two tributaries, Shingle and Ellis Creeks. At the mouth of Shingle Creek, the sampling station was not equipped with a portable collector and was used for collection of simultaneous samples only. In order to provide Shingle Creek discharge data, the station 08NM150 was reactivated

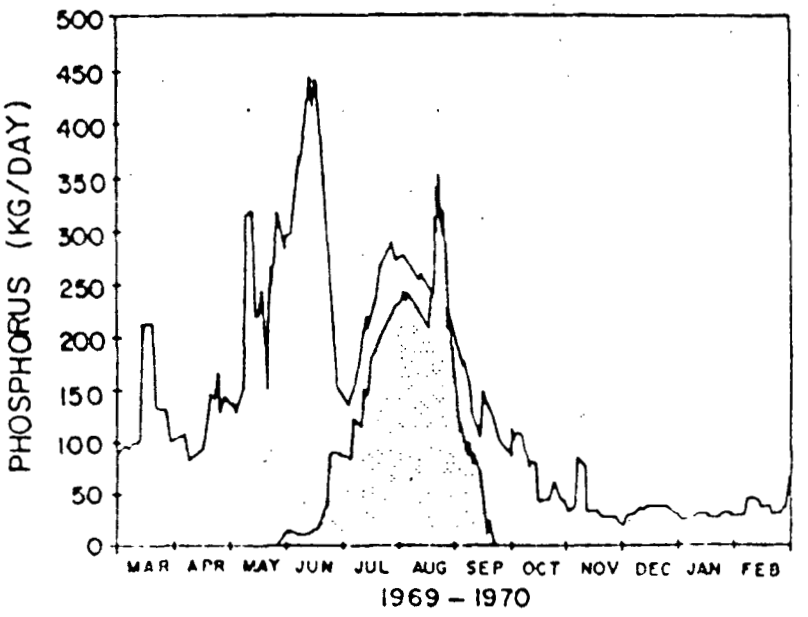

FIGURE 4: External loading (upper curve) and simulated internal loading (lower curve) of phosphorus to the epilimnion in Skaha Lake (from Fleming, 1974).

N.B. These data are approximately one order of magnitude higher than those reported in Canada - British Columbia Okanagan Basin Agreement (1974).

TABLE 8. Annual Input (percent) of Total Nitrogen and Total Phosphorus to Skaha Lake (1969-71)

	Total Nitrogen	Total Phosphorus
Okanagan Lake	45.6	21.9
Tributary Streams	0.9	7.6
Waste Treatment Plants	28.7	60.2
Tributary Slopes	4.6	1.1
Groundwater	14.5	5.7
Precipitation	5.7	3.5
	100.0 = 199 ton yr^{-1}	100.0 = 24.23 ton yr^{-1}

Source: Canada-British Columbia Okanagan Basin Agreement (1974)

N.B. These data include all sources of nutrients and, therefore, are not directly comparable with Table 12.7 of the Canada - British Columbia Okanagan Basin Agreement Report (1974).

by Water Survey of Canada and instrumented with a manual gauge. The water sampling station which was located at the mouth of Ellis Creek, 08NM135, was equipped with a portable discrete sampler. For the purpose of discharge measurements the station was instrumented with a water level recorder and maintained by Water Survey of Canada.

At Okanagan Falls, the water quality sampling station was located below Skaha Lake dam and equipped with a portable discrete sampler. This station was situated close to the Water Survey of Canada station, 08NM002, instrumented with a water level recorder.

The portable samplers located at all stations were housed in steel manholes, approximately 1.5 m below the ground. A permanent plastic pipe, 3 cm. in diameter, connected the housing with the sampling point in the stream.

4.3 Sampling Method

Two sampling methods were used for collection of water samples, (a) simultaneous, and (b) sequential method.

4.3.1 Simultaneous sampling method

The simultaneous sampling method was a manual method employing a replicate sampler developed by Water Quality Branch, Inland Waters Directorate, Vancouver, B. C. This method was designed with the aim of establishing heterogeneity of point concentration measurements of nutrients in the investigated channel cross-section. Hydrometric measurements were taken concurrently with simultaneous sampling. During these combined measurements each channel cross-section was divided into a minimum of twenty hydrometric subsections and four chemical slices. A standard, two-point hydrometric method (Ozga, 1971) was used for determination of discharges through each subsection. In order to obtain chemical data a channel cross-section was divided into four slices and three sample replicates were collected in the upper stratum of each slice, at approximately 0.6 of the depth below the water surface. The sets of simultaneous samples for analysis of total phosphorus and total dissolved phosphorus were collected in 50 and 100 ml glass-pyrex

bottles. Samples for analysis of nitrogen forms were collected in 100 ml polyethylene bottles.

4.3.2 Sequential sampling method

The sequential sampling method, employing portable discrete samplers, was used to obtain time series records of single point measurements of nutrient concentrations in the stream channel, at approximately 0.6 of the depth below the water surface. These records provided information on concentration changes caused by variable effect of discrete nutrient sources and rates of flow, regulated by dams located below Okanagan and Skaha Lakes.

4.4 Frequency of sampling

Simultaneous sampling method was applied in monthly intervals. At sampling stations, three replicate water samples were collected at each of the four slices of the particular channel cross-section.

Sequential sampling method was used in weekly intervals during two consecutive, randomly chosen days within the week. In order to determine diurnal variation in nutrient concentrations four sequential samples were collected during each sampling day. Time of sampling was at 03:00, 09:00, 15:00 and 21:00 hours. The daily sampling intervals were based on the results of short-term time series analysis of nutrient concentrations measurements on samples collected at station near the Penticton airport, in 1976. Concentration maxima occurred at times close to 09:00 and 21:00 hours, respectively, while concentration minima were observed at night and afternoon.

4.5 Sample Pretreatment

In situ water samples collected for the dissolved phosphorus analyses were immediately filtered through pre-soaked and prewashed 0.45 micron cellulose acetate membrane filter of 47 mm diameter. Samples for nitrogen determination were kept in coolers (Coleman Coolers Model 5243-720). All samples were shipped to the laboratory in Analytical Service Division, Pacific Region, Water Quality Branch, Vancouver, B. C.

4.6 Chemical Analyses

4.6.1 Total phosphorus (P) and total dissolved phosphorus (P)

The concentrations of total phosphorus and total dissolved phosphorus were measured after digestion with persulfuric acid by the automated colorimetric phosphomolybdate method utilizing ascorbic acid as the reducing agent (Murphy and Riley, 1962). Results were reported as total phosphorus (P) and total dissolved phosphorus (P) in mg l^{-1}.

The precision and accuracy of the analyses were estimated by Mah (1976). Samples of stream water used for this test were collected at four different locations and from these samples seven subsamples were poured from a well mixed sample bottle and analyzed.

4.6.2 Nitrate plus nitrite (N)

The concentrations of nitrate plus nitrite were measured by the automated cadmium reduction method developed by Technicon Instruments Corporation (1972). Nitrate plus nitrite concentrations (N) were reported in mg l^{-1}.

4.6.3 Ammonia (N)

Ammonia was measured by the automated indophenol blue method (Technicon Instruments Corporation, 1971). Ammonia concentrations were reported as ammonia (N) in mg l^{-1}.

4.6.4 Total dissolved nitrogen (N)

The automated ultra-violet digestion method was used to measure the soluble nitrogen forms in water samples (Afghan *et al.*, 1970; Environment Canada, 1974). Results were reported as total dissolved nitrogen (N) in mg l^{-1}.

4.7 Nutrient sampling

Generally, there is a variety of factors which can affect the study of various sources of phosphorus and other pollutant loads in a basin. These include factors previously discussed and other considerations emphasized in the literature (e.g. International Reference

Group on Great Lakes Pollution from Land Use Activities, 1978). The following consideration can be included in the development of pollutant sampling programs:

(a) one of the great concerns with the pollutant load data is the possibility of not sampling major storm or spring melt events which can contribute a very large proportion of the total tributary load but to improve sampling procedure following a study into the event response nature of each tributary.

(b) Although there is a tendency toward standardization of loading methodologies there has been little attempt to assess the accuracy of any method in various types of streams under various sampling strategies.

(c) Sampling frequency is critical to the accuracy of any loading calculations and the inaccuracies resulting from a limited data base likely exceed inaccuracies resulting from any loading calculation methodology.

Some of these considerations are addressed in the present study of nutrient loads.

4.8 Precision, consistency and accuracy

Precision, consistency and accuracy were considered in relation to the three phases of the study: field measurements, chemical analysis and data interpretation.

Generally, the term precision refers to the reproducibility of a result when operations in laboratory analysis are performed repeatedly on a sample under controlled conditions. In the field, precision refers to the variability observed among numerous measurements of chemical concentration or other quantity (Fritschen and Gay, 1979). The observed values can be widely displaced from true mean value as a result of systematic errors present through measurements. Precision, according to Eisenhart (1952), as an expression of the clustering of the data, is related to factors inherent to the measuring process.

Consistency of data can be determined when two or more measuring processes or methods are used over a finite time period and the resulting

data are compared. If the results of one method are either always higher or lower than those of another method, a systematic bias can be assumed. However, it is not known which of the methods is more accurate but if the behaviour of data compared show a consistent pattern then their real temporal trends can be detected.

Accuracy refers to the relation between the measured and "true" value or the closeness to an accepted standard such as those maintained by the National Bureau of Standards (American Society for Testing Materials, 1972).

Accuracy expresses a relation to a value external to the measured process. An accurate method (Eisenhart, op. cit.) is a method that is both precise and unbiased in the sense that it yields measurements that are closely clustered and centered on the true value. Laboratory standards are normally considered accurate. In field studies, on the other hand, the true field standards cannot be determined and indication of bias and defining levels of precision are, therefore, fundamentally important considerations in designing procedures of sampling and analytical interpretation.

The simultaneous sampling method, employing collection of three replicates of water samples for chemical analysis, allows precision of nutrient concentration measurements in the channel cross-section to be determined. Concurrently, instantaneous discharge data were obtained by the use of two-point hydrometric measurements at twenty-four subsections across the channel.

Precision and accuracy of laboratory methods used to analyse water samples for nutrient concentration, summarized by Mah (1976), were tabulated in the reports on nutrient dispersal (Zeman et al., 1977).

Consistency of nutrient concentration measurements in the river was determined by the use of two sampling methods, the simultaneous and sequential method. Discharge data were calculated by standard cross-sectional velocity measurements. These measurements are plotted graphically and interpreted by fitting a stage-discharge curve which is the basis for discharge precision estimate of $\pm$ five percent (Water Survey of Canada, personal communication).

Determination of the precision of nutrient concentration measurements and load estimates was one of the major goals of the present study. Concentration and load data were reduced to arithmetic and geometric means on daily, seasonal and annual basis. Standard deviations were calculated to characterize dispersion of individual measurements of nutrient concentrations and loads about the calculated means, and standard errors indicated the variation among observation means. Confidence limits were established around the calculated means of nutrient concentrations and loads.

Consistency of nutrient concentration and load data was assessed by comparison of results obtained by simultaneous and sequential sampling methods. Tables of results were prepared to indicate seasonal and annual arithmetic means of nutrient concentrations and loads for data determined by both sampling methods. Daily geometric means of concentration and loads were used for graphical representation. Confidence limits were determined for daily mean nutrient concentrations obtained by both sampling methods. In terms of daily load determination simultaneous sampling method, involving replicate samples, provided the possibility of establishing confidence limits around the daily nutrient loads. Daily loads determined by sequential method were represented by one number, the sum of loads calculated for six-hour intervals.

5 DATA INTERPRETATION

The procedure of data interpretation involves simple statistical and graphical techniques to illustrate spatial and temporal changes of variables measured during the three-year period. These variables are discharge, concentration of nutrients and their loads determined at the three sampling stations located: (1) below Okanagan Lake dam, (2) near the Penticton airport just upstream of Skaha Lake and (3) at Okanagan Falls, below the Lake.

5.1 Discharge

The acquisition of discharge data for determination of nutrient loads requires a specific approach, depending on the method used for

collection of samples for chemical analysis.

Discharge for the calculation of loads from concentration measurements obtained by simultaneous sampling was determined in situ, during combined hydrometric and chemical measurements. On the other hand, for the calculation of load based on concentration measurements from sequential samples discharge data were obtained from the records of Water Survey of Canada. These records were available for all stations with the exception of the station near the Penticton airport. Discharge at this station, not instrumented with a water level recorder was estimated. In 1976 and 1977, because of the absence of data from tributary streams, discharge for this station was taken from station 08NM050. After instrumentation of tributary creeks, in October 1977, discharge for this station was calculated as the sum of discharges from the station below Okanagan Lake dam, municipal outfall, Shingle and Ellis Creeks. Annual hydrographs are used to illustrate temporal changes of discharge measured and/or estimated at the three sampling stations.

5.2 Concentration

The precision of nutrient concentrations measured by simultaneous and sequential sampling methods are illustrated by plots showing three-year time series records of the daily geometric means and their 95 percent confidence limits. Digital interpretation of concentration data is shown in two sets of tables. The first set of tables shows statistical characteristics of all individual concentration measurements taken in the particular months of sampling during the three-year period. The second set of tables shows statistical characteristics of all individual concentration measurements within the particular years of sampling.

5.3 Load

Two procedures are used in the determination of nutrient loads passing through each of the three sampling stations of Okanagan River. The first procedure utilizes discharge and concentration measurements obtained by simultaneous sampling methods. The second procedure is based

on data obtained by sequential sampling method.

5.3.1 Simultaneous sampling method

In the procedure which is based on simultaneous sampling method the partial load method is used to calculate nutrient loads passing through a channel cross-section. This method was developed during the nutrient dispersion study in the Okanagan River at Penticton (Zeman et al., 1977). An algorithm for the determination of nutrient loads, and their precision, by the partial load method is described by Zeman and Slaymaker (1980a; 1981). In an abbreviated form, this method utilizes instantaneous data on discharge and chemical measurements taken simultaneously in the hydrometric subsections and chemical domains of the investigated channel cross-sections.

On the basis of the three sample replicates and discharge determined in a slice-element (sampling point) the nutrient load is calculated for this smallest sampling unit. Then, the sums of the element loads in each of the four slices give the partial loads of the particular slice. The sum of the partial loads of slices represents the total load in the channel cross-section. In order to determine precision of the load data a number of statistical tests are employed. Variances of the partial loads are calculated and their homogeneity is examined by statistical tests (Welch, 1951; Brown and Forsythe, 1974; Levene, 1960). The procedure proposed by Satterthwaite (1946) is employed for the calculation of degrees of freedom which are used to estimate confidence limits of the partial loads and cross-sectional loads of nutrients.

5.3.2 Sequential sampling method

In the procedure of nutrient load determination, which is based on sequential sampling method, the flow interval method (Zeman and Slaymaker, 1980b) is used for calculation of the daily total loads. In this procedure, the continuous hourly discharge recorded during a day of sampling is divided into the four flow intervals. The time period of the first flow interval is from 0000 to 0600 hours. The hourly discharge during the flow interval is cumulated to produce a volume of discharge for the six-hour period. This discharge, multiplied by nutrient

concentration measured at one point in the channel cross section and in the middle of each flow interval (0300, 0900, 1500 and 2100 hours, respectively) gives nutrient load per six-hour interval. From these four measurements, daily geometric concentration means and their 95 percent confidence limits are calculated and used for graphical representation of a short range temporal heterogeneity of nutrient concentration observed during a particular day of sampling. The sum of the loads determined for each flow interval represents the daily total load of nutrients (kg day). In this procedure, nutrient concentration measured in the middle of a flow interval is assumed to be representative for the particular interval. Missing concentration measurements are replaced by the observations obtained during the nearest sampling period.

6 RESULTS AND DISCUSSION

6.1 General

Data characterizing nutrient transport in the Okanagan River-Skaha Lake system are interpreted in terms of spatial and temporal variation of nutrient concentrations and loads during the period from 1976 to 1978.

Spatial variation of concentrations and loads of total phosphorus (P), total dissolved phosphorus (P), nitrate plus nitrite (N), ammonia (N), organic nitrogen (N) and total nitrogen (N), as well as, dissolved silica are interpreted from measurements taken at stations located below Okanagan Lake dam, near the Penticton airport and at Okanagan Falls.

Temporal variation of nutrient concentration and load during the three-year period is illustrated graphically. Variation of nutrient concentration, measured by simultaneous and sequential sampling methods is shown in the sets of common plots in terms of the daily geometric means and their 95 percent confidence limits. Another set of plots indicates the temporal variation of nutrient loads. Variation of nutrient loads, derived from simultaneous sampling method combined with hydrometric measurements, is indicated by the plots of the cross-sectional loads. The simultaneous sampling method, employing sample replicates, permits the calculation of confidence limits based on concentration error and an assumed discharge error plotted around the

total cross-sectional loads. Data obtained by this method represent instantaneous nutrient loads and are plotted, on the same time scale, as the data derived from sequential sampling method which represent the total daily loads. The total daily loads are calculated as the sum of the loads determined for each of the four flow intervals during the day of sampling and confidence limits of the daily nutrient loads cannot be, therefore, established.

The graphical representation of results, apart from the information on seasonal and year-to-year changes in nutrient behaviour, indicates the degree of precision of nutrient concentration measurements and their consistency in determination of nutrient loads during the three-year period.

Illustration of nutrient concentration and load data in digital form is provided in two sets of tables (Appendices B, C and E). The first set of these tables indicates statistical characteristics of nutrient concentration and load data determined for all observations obtained during individual months of the three-year period. Further reduction of data is shown in the second set of tables, indicating statistical characteristics, nutrient concentrations and loads which are determined for all data obtained during the individual years of sampling. Both tables show the arithmetic means of nutrient concentration and loads for the specified sampling periods and number of samples. The number of samples is a significant criterion in the assessment of precision and representativeness of the results obtained by the two sampling methods.

In the discussion of results, 3-year means of nutrient concentration ratios are used. These 3-year means are determined for two distinct periods in each year of the three-year sampling program. Thus, the first period (spring and summer) includes observations obtained from the beginning of April to the end of September and the second period (fall and winter) includes data obtained from the beginning of October to the end of March. Then, for all the individual observations obtained within the particular period, 3-year concentration means are calculated. Therefore, there are two values of the long-term concentration mean for

each nutrient. The number of observations used for the determination of these long-term means and their 95 percent confidence intervals are used to describe the changes of the individual nutrient forms occurring during these two distinct periods.

In the assessment of nutrient load variation, discharge is the most significant factor. The annual hydrographs are, therefore, provided to illustrate levels and variation of discharge observed at each sampling station during the three-year period.

6.2 Okanagan River below Okanagan Lake Dam

6.2.1 Discharge

At station below Okanagan Lake dam (Water Survey of Canada stream flow recording station 08NM50), the levels and significant changes of discharge maintained by the control dam are illustrated by hydrographs (Appendix A). The flow regulation is obvious from the stepwise characteristics of the hydrographs, from the absence of peaks and the maintenance of the same pattern of flow for an extended period of time. Consequently, the concentration-discharge relationship is not significant but the magnitude of discharge and its changes affect the amount of nutrient loads. Maximum and minimum discharges observed at this station during the three-year period are 76.86 (May 1978) and 0.85 (May 1977) $m^3 s^{-1}$, respectively. The annual discharge means (calculated from the daily means) and their 95 percent confidence intervals vary in the range of 21.63 $\pm$ 1.07, 7.19 $\pm$ 0.36 and 18.5 $\pm$ 1.08 $m^3 s^{-1}$ in 1976, 1977 and 1978, respectively.

6.2.2 Phosphorus

Temporal variation of phosphorus in the Okanagan River below Okanagan Lake dam during the period from 1976 to 1978 is discussed in terms of concentration and load of total phosphorus (P) and total dissolved phosphorus (P).

Seasonal variations of total phosphorus concentration measured by simultaneous and sequential sampling methods is illustrated by the plots of the daily geometric means and their 95 percent confidence limits (Appendix B1). The wide scatter of confidence limits around the

concentration means determined from simultaneous sampling (three sample replicates taken at each of the four slices in the channel cross section) indicate the existence of heterogeneity of cross-sectional means of total phosphorus. Concentration of total phosphorus measured by the sequential method, and illustrated in terms of the daily geometric means, is characterized by very wide spread of the 95 percent confidence limits, because these means were determined on a small number (usually four) samples. The daily means of total phosphorus do not show any long-term trend but they indicate the existence of a seasonal variation over the three-year period. This seasonal variation is characterized by higher concentration of total phosphorus during the three fall-winter seasons than during the three spring-summer seasons.

The seasonal variation of total phosphorus is further illustrated by the arithmetic concentration means and their 95 percent confidence intervals calculated from individual concentration measurements during any given month of sampling (Appendix B2). The seasonal pattern of total phosphorus concentration at station below Okanagan Lake dam is consistent. However, a maximum concentration of total phosphorus, measured by sequential method in August 1978, is 0.1 mg l^{-1} and a minimum concentration of 0.004 mg l^{-1} (sequential measurements) occurs in August 1977; July, August and September 1978. (See the note regarding the results of the concentration data generated from simultaneous and sequential measurements in February 1978, Appendix B).

There is a limited number of observations for determination of annual concentration means, but the arithmetic concentration means and their statistical characteristics, are determined from all individual observations during each year of sampling (Appendix B3). These reduced data indicate that the year-to-year differences of mean annual total phosphorus concentrations determined in Okanagan River below Okanagan Lake dam are not significant.

Loads of total phosphorus, during the three year period, are characterized by different behaviour pattern than concentrations of this phosphorus form. There are pronounced year-to-year differences of total phosphorus loads observed below Okanagan Lake dam. These changes are

associated with hydrological events. The annual hydrographs (Appendix A). show the change from high discharge in 1976 to the significantly lower discharges in the following two years. Also, plots of the daily loads of total phosphorus (Appendix B1 and note in Appendix B) indicate decrease in loads of this phosphorus form during the three-year period, particularly in 1977. However, the plots of daily loads of total phosphorus appear to indicate a return in December, 1978 to the January, 1976 level.

Statistical characteristics of load data are shown in Appendix B2. This appendix shows the arithmetic means and their confidence intervals, of total phosphorus calculated for all individual loads obtained during any given months of sampling. A maximum and a minimum of the monthly means of daily loads of total phosphorus observed during the three-year period are 36.73 $\pm$ 14.75 (May 1978, sequential sampling method) and 2.76 $\pm$ 0.85 (May 1977, sequential sampling method) kg day^{-1}, respectively. The 95 percent confidence intervals around the load means indicate a pronounced variation of total phosphorus daily loads determined at the station below Okanagan Lake dam.

Statistical characteristics of daily load means of total phosphorus are also determined for all individual load data obtained during any particular year of sampling. These means are determined for the number of observations which is different from year to year. In the first year of sampling, for example, the available nutrient data are based on simultaneous sampling in February, then in July, August, September and December 1976. According to the results shown in Appendix B3, the total phosphorus load means and their 95 percent confidence intervals are 23.17 $\pm$ 4.07 (simultaneous method), 5.29 $\pm$ 0.56 and 14.83 $\pm$ 3.14 (sequential method) kg day^{-1}, in 1976, 1977 and 1978, respectively. The information on the load means shown for 1977 and 1978 is based on larger number of observations, which are obtained by sequential sampling method and is, therefore, considered more reliable than information obtained by a limited set of simultaneous samples.

Variation of total dissolved phosphorus, observed at the station below Okanagan Lake dam, is illustrated by the plots of its daily geometric concentration means and their 95 percent confidence limits

(Appendix B4). Similarly, as in the case of total phosphorus, the dissolved form is characterized by a pronounced heterogeneity of the daily concentration measurements and also by seasonal changes during the sampling period. Generally, concentration of total dissolved phosphorus is slightly higher during the fall-winter seasons in comparison to the spring-summer seasons. These seasonal changes are further indicated by the arithmetic means, and their statistical characteristics, determined for all individual concentrations of total dissolved phosphorus measured during any given month of sampling (Appendix B5). A maximum concentration of total phosphorus is 0.02 mg l^{-1} (measured by sequential method in January 1978) and a minimum is 0.002 mg l^{-1} (detection limit of the analytical method), measured by both sampling methods in August 1977 and by sequential method in December 1977, and in the spring and summer months 1978).

Generally, at the station below Okanagan Lake dam, the occurrence of the higher levels of total dissolved phosphorus concentrations during winter and early in spring corresponds to the period characterized by the lake's low phytoplankton growth, while the low concentrations observed in summer can be caused by phytoplankton uptake. In fall, the observed higher concentrations of this nutrient can be ascribed to both, the lower phytoplankton uptaken and phosphorus regeneration in lake water.

Seasonal changes and the year-to-year variation of concentration of total dissolved phosphorus are not significant. Appendix B6 shows the statistical characteristics of all concentration means of total dissolved phosphorus determined for all concentrations measured during the individual years of sampling. These means are of 0.005 $\pm$ 0.0003 (simultaneous method) and 0.004 $\pm$ 0.0002 (sequential method) mg l^{-1} in 1976 to 1978, respectively.

Variation of the daily loads of total dissolved phosphorus derived from the two sampling methods at the station below Okanagan Lake dam is illustrated by plots (Appendix B4). Variation of these loads during the three-year period is associated with changes of the discharge regulated by the dam. The load means of total dissolved phosphorus, calculated for all individual measurements during any given month of the three-year

sampling are shown in Appendix B5.

Total dissolved phosphorus in terms of load means determined for all measurements during individual years (Appendix B6) is 14.98 $\pm$ 7.44 (simultaneous sampling) through 2.46 $\pm$ 0.28 to 5.87 $\pm$ 0.92 (sequential sampling) kg day^{-1} in 1976, 1977 and 1978, respectively.

6.2.3 Nitrogen

Variation of nitrogen in the Okanagan River below Okanagan Lake dam is described in terms of concentrations and loads of nitrate plus nitrite, ammonia, organic nitrogen and total nitrogen.

Variation of nitrate plus nitrite is illustrated by the plots of the daily geometric means and their 95 percent confidence limits during the three-year period (Appendix B7). The significant seasonal variation of nitrate plus nitrite, shown by these plots, is characterized by the higher concentration measurements in the fall-winter seasons in comparison to the spring-summer seasons of the sampling period. Data in Appendix B8, showing variation of nitrate plus nitrite by months, confirm this pattern. A maximum concentration of nitrate plus nitrite is 0.22 mg l^{-1} (simultaneous measurements, July 1976) and a minimum concentration of less than 0.002 mg l^{-1} (representing detection limit of the analytical methods) occurs during several months throughout the three-year period. On the annual basis, the arithmetic means and their 95 percent confidence intervals (Appendix B9) are in the range of 0.02 $\pm$ 0.0032 (simultaneous measurements), 0.011 $\pm$ 0.0019 (sequential measurements) and 0.013 $\pm$ 0.0021 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, rspectively. These reduced data indicate no significant year-to-year variation of nitrate plus nitrite concentrations measured at station below Okanagan Lake dam.

Seasonal variation of the daily loads of nitrate plus nitrite is illustrated by plots (Appendix B7) and by statistical characteristics of the load means determined for any given month during the three-year sampling period (Appendix B8). A maximum and a mimimum load of this nitrogen form are 130.25 (simultaneous measurements, July 1976) and 0.77 (sequential measurements, June 1977) kg day^{-1}, respectively. These

extreme load data are observed during the month characterized by very high and very low discharge measurements. The nitrate plus nitrite load means and their 95 percent confidence intervals determined for all individual measurements during the three years of sampling (Appendix B9) are 65.54 $\pm$ 32.61 (simultaneous measurements), 4.54 $\pm$ 1.08 (sequential measurements) and 23.90 $\pm$ 7.8 (sequential measurements) kg day^{-1}, in 1976, 1977 and 1978, respectively. The low nitrate plus nitrite mean load for 1977 is strongly influenced by low annual discharge.

Ammonia, in the Okanagan River below Okanagan Lake dam, is characterized by a wide range of the 95 percent confidence limits around the daily geometric concentration means (Appendix B10). The pattern of seasonal variation of ammonia concentration is different than that of nitrate plus nitrite. Ammonia concentration, by contrast with nitrate plus ntrite, is higher during the spring-summer seasons than during the fall-winter seasons. Statistical characteristics of concentration means of ammonia calculated for the individual month of sampling (Appendix B11) confirm the pattern of seasonal changes of ammonia concentration. A maximum and a minimum ammonia concentration are 0.35 (sequential measurements, July 1978) and 0.002 (the detection limit of the analytical method) which was observed during several months of the sampling period mg l^{-1}, respectively. On the annual basis, the ammonia concentration means calculated from all measurements obtained during the individual years (Appendix B12) vary in the range of 0.012 $\pm$ 0.002 (simultaneous measurements), 0.035 $\pm$ 0.005 (sequential measurements) and 0.054 $\pm$ 0.008 (sequential measurements) mg l^{-1}, in 1976, 1977 and 1978, respectively.

Loads of ammonia exhibit significant daily and seasonal variation during the three-year period. A wide scatter of confidence limits around the daily loads, illustrated in plots (Appendix B10), are derived from simultaneous sampling method, and reflect the effect of heterogeneity of point concentration measurements. The summer months are characterized by higher loads of ammonia than the winter months (Appendix B11). A maximum and a minimum load, observed during the three-year period, are 358.83 (sequential measurements, May 1978) and 0.35 (simultaneous measurements, March 1978) kg day^{-1}. The mean loads of ammonia calculated for the

individual years (Appendix B12) vary in the range of 30.91 ± 15.00 simultaneous measurements), 24.78 ± 7.26 (sequential measurements) and 70.74 ± 18.47 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively. These changes of ammonia loads are associated with changes of discharge during the three-year period.

Organic nitrogen in the Okanagan River below Okanagan Lake dam is characterized by a wide scatter of confidence limits around its geometric concentration means (Appendix B13). The pattern of seasonal variation of this nitrogen form is similar as that of ammonia. Concentration of organic nitrogen is slightly higher in the spring-summer seasons than in the fall-winter seasons but these changes are not statistically significant. A maximum and a minimum concentration of organic nitrogen (Appendix B14) are 0.278 (simultaneous measurements, September 1976) and 0.069 (sequential measurements, April 1978) mg l^{-1}, respectively. On the annual basis, the arithmetic concentration means, determined for all measurements of organic nitrogen for individual years (Appendix B15), vary in the range of 0.166 ± 0.004 (simultaneous measurements), 0.170 ± 0.012 (sequential measurements) and 0.138 ± 0.003 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of loads of organic nitrogen during the three-year period is illustrated by the plots of its daily loads (Appendix B13). A maximum and minimum of these loads are 560.33 (simultaneous measurements, July 1976) and 23.81 (simultaneous measurements, March 1978) kg day^{-1} (Appendix B14). The magnitude of the organic nitrogen loads is associated with variations of discharge during the sampling period. The loads of organic nitrogen reduced to the annual basis, in terms of the arithmetic means, vary in the range of 431.6 ± 44.9 (simultaneous measurements), 109.9 ± 11.9 (sequential measurements) and 229.25 ± 36.01 (sequential measurements) kg day^{-1}, in 1976, 1977 and 1978, respectively (Appendix B15).

Total nitrogen in the Okanagan River below Okanagan Lake dam exhibits a significant variation, illustrated by its geometric concentration means and their wide 95 percent confidence limits (Appendix B16). Seasonal variation of total nitrogen concentration during the

three-year period is not significant. A maximum and a minimum concentrations of total nitrogen observed during the sampling period are 1.3 (sequential measurements, December 1977) and 0.095 (simultaneous measurements, May 1977) mg l^{-1}, respectively (Appendix B17). The arithmetic means, calculated for all concentration measurements of total nitrogen during the individual years of sampling (Appendix B18) vary in the range of 0.198 $\pm$ 0.005 (simultaneous measurements), 0.216 $\pm$ 0.013 (sequential measurements) and 0.205 $\pm$ 0.008 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of the daily loads of total nitrogen during the three-year period is illustrated in Appendix B16. A maximum and a minimum of total nitrogen loads (Appendix B17) are 1245.3 (sequential measurements, May 1978) and 30.64 (simultaneous measurements, March 1978 and anomalous discharge) kg day^{-1}, respectively. On the annual basis the total nitrogen load means calculated for the individual years of sampling (Appendix B18) vary in the range 528.04 $\pm$ 51.82 (simultaneous measurements), 139.24 $\pm$ 16.29 (sequential measurements) and 323.89 $\pm$ 48.22 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

Variation of silica in the Okanagan River below Okanagan Lake dam during the sampling period is illustrated by the plots of the geometric concentration means and their 95 percent confidence intervals (Appendix B19). Although concentration of silica is slightly higher during the fall-winter seasons (approximately by 6 percent) than in the spring-summer seasons, this variation of silica is not statistically significant. Also, the year-to-year variation of silica concentrations (Appendix B21) measured below Okanagan Lake dam is not significant.

Seasonal variation of silica loads, illustrated by the graphs of its daily loads (Appendix B19) is very significant during the sampling period. A maximum silica load of 29,218 (sequential measurements, May 1978) and a minimum of 866.19 (simultaneous measurement, March 1978) kg day^{-1}, respectively, coincide with the high and low discharges observed during these particular months (Appendix B20). In terms of arithmetic means, calculated for all individual data during the

three-year period (Appendix B21), the silica loads vary in the range of 12.948 ± 1852 (simultaneous measurements), 2,986 ± 297.07 (sequential measurements) and 7,661.4 ± 1260.2 (sequential measurements) kg day^{-1}, in 1976, 1977 and 1978, respectively.

6.2.4 Concentration ratio

The pattern of seasonal changes of nutrient concentrations, measured in water samples collected in Okanagan River below Okanagan Lake dam, is illustrated by variation of nutrient concentration ratios calculated for lumped data obtained during two distinct seasons of the three-year sampling period. The division of data into two periods is based on the examination of scatter-grams of the original observations.

The long-term concentration mean ratio of total dissolved phosphorus to total phosphorus, determined on 378 and 173 observations, varies in the range of 0.53 ± 0.018 and 0.46 ± 0.02 during the first (spring and summer) and the second (fall and winter) period, respectively.

Each of the following long-term concentration mean ratios, describing the seasonal changes of nitrogen forms, is determined on 542 and 242 observations obtained during the two distinctive periods. The long-term mean ratios of nitrate plus nitrite to total nitrogen; ammonia to total nitrogen and organic nitrogen to total nitrogen are 0.03 ± 0.005 and 0.19 ± 0.007; 0.17 ± 0.0012 and 0.05 ± 0.007 and 0.80 ± 0.012 and 0.77 ± 0.009 during the first and the second period, respectively. These concentration ratios indicate significant differences in the composition of total nitrogen observed between the two seasonal periods.

Nitrate plus nitrite content, in total nitrogen, increases very significantly (by 533 percent), in the fall-winter seasons. Ammonia content, on the other hand, is higher (by 240 percent) in the spring-summer than in fall-winter seasons. Further examination of the seasonal changes of these two nitrogen forms is illustrated by the long-term concentration mean ratios of ammonia to nitrate plus nitrite. These ratios, determined on 542 and 242 observations, are 15.5 ± 1.92 to 0.33 ± 0.073 during the spring - summer seasons and the fall - winter seasons, respectively. During the three year period, particularly, June,

July and August show consistently high ratio of ammonia to nitrate plus nitrite ratio. This ratio has an important implication in the assessment of the ammonia pollution loading sources. In water containing oxygen, ammonia is slowly oxidized to nitrite (NO_2^-) and nitrate (NO_3^-). Thus a high ratio of ammonia to nitrate plus nitrite indicates a recent source of ammonia pollution. On the other hand, if this ratio is low, it indicates an older input of ammonia that has subsequently been oxidized or the reduction of the source of ammonia or the mechanism promoting it. The occurrence of the high ammonia to nitrate plus nitrite ratio in water samples taken immediately below the exit of Okanagan Lake during the summer periods implies that a significant source of ammonia pollution exists in the nearshore areas of the Okanagan Lake.

In order to evaluate seasonal changes of both phosphorus and nitrogen in the Okanagan River below Okanagan Lake dam, the concentration ratios of total nitrogen to the individual phosphorus forms are determined. The long-term concentration mean ratios (and their 95 percent confidence limits) of total nitrogen to total phosphorus; and total nitrogen to toal dissolved phosphorus (determined on 464 and 192; 378 and 173 observations, respectively) are 29.9 $\pm$ 1.29 and 21.99 $\pm$ 1.05; 61.63 $\pm$ 2.72 and 50.72 $\pm$ 2.74 during the first period (spring and summer) and the second period (fall and winter), respectively. Because phosphorus is utilized by plankton roughly in an atomic ratio of 1 to 15 with respect to nitrogen, the above data suggest that availability of phosphorus is the limiting factor for aquatic biota in Okanagan Lake water.

6.3 Okanagan River near the Penticton Airport

6.3.1 Discharge

In 1976, data for discharge at the station near the Penticton airport were obtained from the records for station below Okanagan Lake dam (Water Survey of Canada station 08NM050). In the following two years, after the reactivation of the stream gauging stations at the tributary streams, discharge for the station near the airport was calculated as the sum of discharges determined at station 08NM050, 08NM150 (Shingle Creek at the mouth), 08NM135 (Ellis Creek at the mouth)

and the Penticton municipal outfall. A maximum and a minimum discharge observed during the three-year sampling period are 81.85 (May 1978) and 0.92 (May 1977). The annual discharge means and their 95 percent confidence intervals vary in the range of 21.63 $\pm$ 1.07 (data from station 08NM050), 7.32 $\pm$ 0.36 and 19.49 $\pm$ 1.16 $m^3 s^{-1}$ in 1976, 1977 and 1978, respectively. The annual hydrographs, illustrating variation of the discharge at this station during the three-year period are shown in Appendix A.

6.3.2 Phosphorus

Concentrations and loads of total phosphorus and total dissolved phosphorus forms analysed in the Okanagan River near the Penticton airport exhibit different behaviour than that observed below Okanagan Lake dam.

Variation of total phosphorus concentration during the three-year period is illustrated by plots of its geometric means and their 95 percent confidence limits (Appendix C1 and Note Appendix B). The wide scatter of these confidence limits indicates local heterogeneity of point concentration measurements of total phosphorus at this station. High levels of total phosphorus concentration, observed at this station, occur during the year of 1977 which is characterized, in comparison to the other two years, by lower discharge. A maximum concentration measured during the three-year period (Appendix C2) is 0.325 mg l^{-1} (sequential measurements, November 1977) and a minimum is 0.005 mg l^{-1} (simultaneous measurements, July 1976 and sequential measurements, May 1977 and April 1978). However, the seasonal variation of total phosphorus concentration at this station, by contrast to station below Okanagan Lake dam, is not significant.

The arithmetic concentration means, and their 95 percent confidence intervals, determined for all observations during the individual years (Appendix C3) are in the range of 0.011 $\pm$ 0.0005 (simultaneous measurements) 0.021 $\pm$ 0.002 (sequential measurements) and 0.017 $\pm$ 0.0009 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

The time series of total phosphorus concentration, as well as, the arithmetic means calculated for the individual years indicate that there is not any obvious 3 year trend in concentration of this phosphorus form. However, the range in the concentration data for any given month over the sampling period is substantial. This is particularly significant when it is recognized that changes of only several micrograms of total phosphorus concentration can influence the downstream lake behaviour. In order to find a concentration value which would be representative for the three-year sampling period a long-term concentration mean and its 95 percent confidence intervals of total phosphorus are determined. This long-term mean, calculated for 1356 observations which includes all simultaneous and sequential measurements from July 1976 to the end March 1979, is 0.017 $\pm$ 0.001 mg l^{-1}.

Plots of daily loads of total phosphorus, determined at station near the Penticton airport (Appendix C1) indicate that there is a considerable variation of loads of this phosphorus form during the three-year period. A maximum of daily total phosphorus load (Appendix C2) of 129.77 (sequential measurements, May 1978) and a minimum of 3.15 (sequential measurements, May 1977) coincide with the high and low discharges observed during these particular months (Appendix A).

The range of means of total phosphorus loads and their 95 percent confidence intervals, determined for all data during the individual years (Appendix C3) is 28.31 $\pm$ 4.94 (simultaneous measurements), 13.29 $\pm$ 1.55 (sequential measurements) and 29.74 $\pm$ 5.07 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively. These results are based on a limited number of sampling days and months during the three-year period. Thus, in 1976, the sampling period includes data obtained in July, August, September and December. In 1977 the sampling period includes data obtained during nine months, beginning March and in 1978, the load data are determined for all twelve months.

Variation of the daily geometric concentration means of total dissolved phosphorus observed at station near the Penticton airport illustrated by plots (Appendix C4 and Note Appendix B) is characterized by a wide scatter of the 95 percent confidence limits during the

three-year period. These plots indicate that seasonal variation of concentration means of this phosphorus form observed at this station, by contrast to station below Okanagan Lake dam, is not significant. Also, visual examination of these plots suggests that there is a decreasing trend indicated by the geometric concentration means over the data record.

A maximum concentration of total dissolved phosphorus is 0.048 mg l^{-1} (sequential measurements, May 1978) and minimum concentration is 0.002 mg l^{-1} (sequential measurements). This minimum concentration of total dissolved phosphorus, representing the detection limit of the analytical methods, occurs during several months of three-year period (Appendix C5). The arithmetic concentration means, and their 95 percent confidence intervals, calculated for all measurements obtained in the individual year of sampling (Appendix C6) are 0.007 $\pm$ 0.0004 (simultaneous measurements), 0.006 $\pm$ 0.003 (sequential measurements) and 0.004 $\pm$ 0.0002 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

In order to characterize concentration of the dissolved phosphorus forms by one value which can represent the entire sampling period a long-term concentration mean is determined. This long-term arithmetic concentration mean and its 95 percent confidence intervals, determined on 1,161 observations obtained during the period drom July 1976 to the end of March 1979, is 0.005 $\pm$ 0.0002 mg l^{-1}.

Variation of loads of total dissolved phosphorus, during the three-year period, is illustrated by the plots of the daily total loads and shown in Appendix C4. A maximum and a minimum of the daily load of this phosphorus form (Appendix C5) is 19.28 (sequential measurements, May 1978) and 1.05 (sequential measurements, December 1977) kg day^{-1}, respectively. The occurrence of these extreme values of total dissolved phosphorus loads coincide with the period of high and low discharge, indicated by annual hydrographs (Appendix A).

The arithmetic load means and their 95 percent confidence intervals of total dissolved phosphorus determined for all individual data obtained during any given year (Appendix C6) are in the range of 16.98 $\pm$ 4.81 (simultaneous measurements), 3.28 $\pm$ 0.38 (sequential measurements) and 6.72 $\pm$ 0.85 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978,

respectively. These results, as previously mentioned, are based on the limited number of sampling days, particularly in 1976. The year-to-year changes of total dissolved phosphorus loads are associated with annual variation of discharge.

6.3.3 Nitrogen

Variation of nitrogen, in the Okanagan River near the Penticton airport, is interpreted in terms of concentration and loads of nitrate plus nitrite, ammonia, organic nitrogen and total nitrogen observed during the three-year period.

Concentration of nitrate plus nitrite, shown by the plots of the daily geometric means and their 95 percent confidence limits (Appendix C7) is characterized by a significant seasonal variation. This variation is illustrated by a long-term concentration means and their 95 percent confidence intervals, calculated on lumped concentration data obtained during the two distinct seasons of the sampling period. These long-term concentration means, determined on 1,078 and 574 observations vary in the range of 0.024 $\pm$ 0.002 and 0.06 $\pm$ 0.014 mg l^{-1} during the three spring-summer and the three fall-winter seasons, respectively.

A maximum concentration of nitrate plus nitrite, measured in December 1977 (sequential measurements), is 0.8 mg l^{-1} (Appendix C8). A minimum concentration of 0.002 mg l^{-1}, measured in August (simultaneous measurements), October 1977, June and September 1978 (sequential measurements), is at the detection limit of the analytical method.

The arithmetic concentration means and their 95 percent confidence intervals, determined for all data obtained during the individual years (Appendix C9), are 0.021 $\pm$ 0.002 (simultaneous measurements), 0.054 $\pm$ 0.009 (sequential measurements) and 0.034 $\pm$ 0.003 (sequential measurements) mg l^{-1}, in 1976, 1977 and 1978, respectively.

Variation of the daily loads of nitrate plus nitrite determined at station near the Penticton airport is illustrated by plots in Appendix C7. A maximum and a minimum of the daily loads of this nitrogen form observed during the three-year period is 159.95 (simultaneous measurements, July

1977) and 3.49 (sequential measurements, June 1978) kg day^{-1}, respectively (Appendix C8). These extreme values of nitrate plus nitrite loads coincide with the periods of high and low discharge. The load means and their 95 percent confidence intervals of this nitrogen form calculated for all individual data of any given year (Appendix C9) are 75.41 $\pm$ 42 (simultaneous measurements), 26.69 $\pm$ 5.41 (sequential measurements) and 50.96 $\pm$ 7.54 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

Variation of ammonia concentration, measured at station near the Penticton airport, is illustrated by the plots of the daily geometric means and their 95 percent confidence limits (Appendix C10). Significant seasonal variation of ammonia, observed at this station (by contrast to stations below Okanagan Lake dam) is characterized by higher concentrations in the fall-winter seasons rather than in the spring-summer seasons. The long-term ammonia concentration means and their 95 percent confidence limits, determined on 1,078 and 574 observations (simultaneous and sequential) vary from 0.145 $\pm$ 0.007 to 0.205 $\pm$ 0.015 mg l^{-1} during the three spring-summer and the three fall-winter seasons, respectively. A maximum ammonia concentration is 0.97 mg l^{-1} (sequential measurements, December 1977) and a minimum of 0.002 mg l^{-1} (sequential measurements), representing the detection limit of the analytical method, occurs during several months of the fall seasons (Appendix C11). The arithmetic concentration means and their 95 percent confidence intervals calculated for all measurements obtained during the individual year of sampling (Appendix C12) are 0.086 $\pm$ 0.004 (simultaneous measurements), 0.277 $\pm$ 0.016 (sequential measurements) and 0.096 $\pm$ 0.008 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of ammonia loads observed at station near the Penticton airport is illustrated by plots of its daily total loads (Appendix C10). These plots indicate decreasing year-to-year trend in ammonia loads during the three-year period. A maximum and a minimum load of ammonia is 413.46 (simultaneous measurements, July 1976) and 3.49 (sequential measurements, June 1976) kg day^{-1}. These extreme loads of ammonia

coincide with the high and low discharge illustrated by the annual hydrographs. The ammonia load means and their 95 percent confidence intervals determined for all data obtained during the individual years of sampling (Appendix C12) are 253.73 ± 68.89 (simultaneous measurements), 149.1 ± 12.76 (sequential measurements) and 111.59 ± 12.9 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

Variation of concentration data (obtained by calculation) on organic nitrogen is illustrated by plots of the daily geometric means and their 95 percent confidence limits (Appendix C13). The long-term concentration means, and their 95 percent confidence intervals, of organic nitrogen determined on 1,078 and 574 observation (simultaneous and sequential measurements) vary from 0.189 ± 0.003 to 0.199 ± 0.015 mg l^{-1} during the three spring-summer and fall-winter seasons, respectively. A maximum and a minimum concentration of this nitrogen form is 2.166 (sequential measurements, December 1977) and 0.012 (sequential measurements, June 1977) mg l^{-1}, respectively (Appendix C14). The arithmetic means, and their 95 percent confidence intervals, calculated for all concentration data of organic nitrogen obtained in any given year of sampling are in the range of 0.174 ± 0.004 (simultaneous measurements), 0.245 ± 0.017 (sequential measurements) and 0.167 ± 0.005 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively (Appendix C15).

Variation of organic nitrogen loads during the three-year period is illustrated by plots of its daily total loads (Appendix C13). A maximum load of this nitrogen form is 1437.5 kg day^{-1} (sequential measurements, May 1978) and a minimum concentration is 30.92 kg day^{-1} (sequential method, March 1977) (Appendix C14). The arithmetic load means, and their 95 percent confidence intevals, determined for all data of organic nitrogen obtained during the individual years of sampling (Appendix C15) are 447.25 ± 47.67 (simultaneous measurements), 146.98 ± 13.58 (sequential measurements) and 285.96 ± 43.31 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

Total nitrogen is characterized by a wide scatter of 95 percent confidence limits around the daily geometric concentration means and by a

significant seasonal variation (Appendix C16). The long-term concentration means, and their 95 percent confidence intervals, of total nitrogen determined on 1,078 and 574 observations (simultaneous and sequential measurements) vary in the range of 0.358 $\pm$ 0.009 and 0.464 $\pm$ 0.026 mg l^{-1} during the three spring-summer and fall-winter seasons, respectively. A maximum of total nitrogen concentration, observed during the sampling period is 2.4 mg l^{-1} (sequential measurements, December 1977) and minimum is 0.1 mg l^{-1} (sequential measurements, August 1978) (Appendix C17). The arithmetic concentration means and their precision calculated for all concentration measurements of total nitrogen during the individual years (Appendix C18) are in the range of 0.282 $\pm$ 0.007 (simultaneous measurements), 0.576 $\pm$ 0.027 (sequential measurements) and 0.297 $\pm$ 0.012 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of total nitrogen loads during the three-year period is illustrated by the plots of its daily total loads (Appendix C16). A maximum and a minimum of total nitrogen load (Appendix C17) is 1,534 (sequential measurements, May 1978) and 134.83 (simultaneous measurements, December 1977) kg day^{-1}, respectively. The arithmetic means and their 95 percent confidence intervals determined for all data of total nitrogen loads during the three-year period (Appendix C18) vary in the range of 776.39 $\pm$ 144.2 (simultaneous measurements), 322.77 $\pm$ 21.18 (sequential measurements) and 448.51 $\pm$ 43.84 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

Variation of silica concentration observed at station near the Penticton airport is illustrated by the plots of its geometric concentration means and their 95 percent confidence limits (Appendix C19). The wide scatter of confidence intervals around the concentration means derived from sequential measurements indicate significant heterogeneity of the daily mean concentration measurements of silica at this station. Seasonal variation of silica concentration is significant. The peak of silica concentration observed in spring 1978 coincides with peak discharge from the tributaries Shingle and Ellis Creeks. The long-term concentration means and their 95 percent confidence interval determined

on 706 and 568 observations (simultaneous and sequential) vary in the range of 5.715 ± 0.09 and 5.372 ± 0.047 mg l^{-1} during the three spring-summer and fall-winter seasons, respectively. A maximum silica concentration is 9.4 mg l^{-1} (sequential measurements, May 1977) and a minimum is 1.7 mg l^{-1} (sequential measurements, July 1977), (Appendix C20). This maximum concentration of silica is associated with the very low discharge measured in May 1977, while minimum occurs during the month July 1977 which is characterized, approximately, by an average discharge. The arithmetic concentration means, and their 95 percent confidence intervals, of silica determined for all measurements taken during the individual years of sampling (Appendix C21) are in the range of 5.031 ± 0.009 (simultaneous measurements), 5.807 ± 0.104 (sequential measurements) and 5.328 ± 0.071 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of the daily total loads of silica during the three-year period are shown by plots in Appendix C19. A maximum load of silica (Appendix C20) of 39,271 kg day^{-1} (sequential measurements), is observed during very high discharge in May 1978 and a minimum load of 1,684 kg day^{-1} (sequential measurements) is associated with low discharge in December 1977. The arithmetic means and their 95 percent confidence limits, determined for all load data of silica obtained at any given year (Appendix C21) are 12,404 ± 213.31 (simultaneous measurements), 3,473.7 ± 211.76 (sequential measurements) and 9,478 ± 1,423.6 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

6.3.4 Concentration Ratio

The pattern of temporal variation of nutrient concentration observed in Okanagan River near the Penticton airport is further illustrated on variation of the long-term concentration mean ratios of individual nutrients. These ratios are calculated from concentration data lumped for the three spring-summer (April - September) and three fall-winter seasons (October - March) of the study period.

The long-term concentration mean ratio of total dissolved

phosphorus to total phosphorus, is determined on 645 and 466 observations and varies in the range of 0.33 ± 0.013 and 0.37 ± 0.017 during the spring-summer and fall-winter seasons, respectively. Therefore, from the calculation of this ratio it is evident that the dissolved phosphorus form, at this station accounts for approximately 33 percent of total phosphorus in the spring-summer seasons and about 37 percent in the fall-winter seasons. This pattern of seasonal differences is in opposite to that observed at station below Okanagan Lake dam. Also, this long-term mean ratio indicates that there is a significant downstream decrease of the dissolved phosphorus content in total phosphorus, by approximately 37 and 20 percent, in the spring-summer and fall-winter seasons, respectively.

The long-term concentration mean ratios describing the pattern of seasonal changes of each of the three following nitrogen forms are determined on 1,078 and 574 observation obtained during the two distinct seasons. Thus, the mean ratios of nitrate plus nitrite to total nitrogen; ammonia to totoal nitrogen; and organic nitrogen to total nitrogen vary from 0.064 ± 0.004 (spring-summer seasons) to 0.134 ± 0.007 (fall-winter seasons); from 0.353 ± 0.01 (spring-summer seasons) to 0.389 ± 0.017 (fall-winter seasons); and from 0.583 ± 0.01 (spring-summer seasons) to 0.476 ± 0.015 (fall-winter seasons).

These data indicate that composition of total nitrogen, at this station by contrast to station below Okanagan Lake dam, is characterized by higher content of inorganic and by lower content of organic nitrogen forms. At this station, the content of ammonia in total nitrogen is higher during both distinct seasons, during the spring-summer, approximately by 106 percent, and during the fall-winter seasons by approximately 786 percent. The content of nitrate plus nitrite is higher here during the spring-summer (by approximately 110 percent) but lower, approximately by 30 percent, during the fall-winter seasons. The content of organic nitrogen in total nitrogen decreases, by approximately 28 and 38 percent, during the spring-summer and the fall-winter seasons, respectively.

The long-term means of ammonia to nitrate plus nitrite ratios, and

their 95 percent confidence intervals, determined on 1,078 and 574 observationsd are 8.02 ± 0.33 (spring-summer seasons) and 4.29 ± 0.29 (fall-winter seasons). The magnitude of these ratios indicates a significant effect of ammonia pollution sources along the investigated Okanagan River reach such as effluent from the Penticton waste treatment plant, run-off from urban area via Ellis Creek and from agricultural land via Shingle Creek.

Seasonal changes of phosphorus and nitrogen occurring at station near the Penticton airport are shown by the means of the concentration ratios, and their 95 percent confidence intervals, of total nitrogen to total dissolved phosphorus and by the ratio of total nitrogen to total phosphorus. The long-term concentration mean ratios of total nitrogen to total dissolved phosphorus, determined on 694 and 467 observations are 80.7 ± 2.8 (spring-summer seasons) and 97.9 ± 5.5 (fall-winter seasons). The long-term mean ratios of total nitrogen to total phosphorus are 25.6 ± 0.96 (spring-summer seasons) and 31.51 ± 1.69 (fall-winter seasons). These results indicate different seasonal pattern of the nitrogen to phosphorus ratios at this station in comparison to station below Okanagan Lake dam. At station near the airport the ratios of total nitrogen to total dissolved phosphorus show consistent increase, by approximately 81 and 98 percent during the spring-summer and fall-winter seasons. On the other hand, the ratio of total nitrogen to total phosphorus decreases here, (by approximately 14 percent) during the spring-summer and increases (by approximately 44 percent) during the fall-winter seasons.

6.4 Okanagan River at Okanagan Falls

6.4.1 Discharge

Variation of discharge, measured in Okanagan River at Okanagan Falls (Water Survey of Canada station 08NM002) during 1976 to 1978, is illustrated by the annual hydrographs (Appendix D). A maximum daily mean discharge, observed during the three-year period, is 51.45 $m^3 s^{-1}$ (May 1978) and a minimum is 3.99 $m^3 s^{-1}$ (December 1977). The annual dishcarge means and their 95 percent confidence intervals are 23.05 ± 1.0, 7.99 ± 0.25 and 19.53 ± 1.01 $m^3 s^{-1}$ in 1976, 1977 and 1978,

respectively.

6.4.2 Phosphorus

Total phosphorus, in Okanagan River at Okanagan Falls, is characterized by a wide scatter of the 95 percent confidence limits around the geometric concentration means (Appendix E1) and very significant seasonal variation during the sampling period. This variation is illustrated by the long-term concentration means, and their associated confidence intervals. These means, determined on 370 and 248 simultaneous and sequential measurements of total phosphorus concentration are 0.015 $\pm$ 0.001 and 0.031 $\pm$ 0.002 mg l^{-1} during the three spring-summer and fall-winter seasons, respectively. On the monthly basis, the statistical characteristics of total phosphorus concentrations are shown in Appendix E2. A maximum concentration of total phosphorus is 0.019 mg l^{-1} (simultaneous measurements, July 1976) and a minimum is 0.004 mg l^{-1} (sequential measurements, May 1977). On the annual basis (Appendix E3) the arithmetic concentration means and their 95 percent confidence intervals are in the range of 0.01 $\pm$ 0.001 (simultaneous measurements in 1976, data were obtained in July only), 0.02 $\pm$ 0.01 (sequential measurements) and 0.023 $\pm$ 0.002 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively.

Variation of the daily loads of total phosphorus, during the three-year period, is illustrated by graphs in Appendix E1. A maximum load of total phosphorus is 111.14 (sequential measurements, November 1977) and a minimum is 2.32 (sequential measurements, May 1977) kg day^{-1} (Appendix E2). The load means, and their 95 percent confidence intervals, determined for all load data of total phosphorus and any given year (Appendix E3) are 31.64 $\pm$ 6.77 (simultaneous measurements in 1976, data in July only), 28.34 $\pm$ 0.98 (sequential measurements) and 41.96 $\pm$ 6.73 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively.

The pattern of the concentration data of total phosphorus, observed at this station, is disturbed in terms of low load data in 1977, because of a very low discharge during that particular year.

Total dissolved phosphorus is characterized by a pronounced variation of concentration measurements, illustrated by the plots of the geometric concentration means and a wide spread of 95 percent confidence limits (Appendix E4). Seasonal variation of this phosphorus form is highly significant. The long-term concentration means and their 95 percent confidence intervals determined on 347 and 239 simultaneous and sequential measurements vary in the range of 0.006 $\pm$ 0.0002 and 0.014 $\pm$ 0.001 mg l^{-1} during the three-year spring-summer and fall-winter seasons. A maximum concentration of total dissolved phosphorus is 0.038 (sequential measurements, February 1978) and minimum is 0.002 (sequential measurements, October 1977) mg l^{-1} (Appendix E5). The arithmetic concentration means and their 95 percent confidence intervals determined for concentration measurements of total dissolved phosphorus during the individual years (Appendix E6) are in the range of 0.028 $\pm$ 0.0009 (sequential measurements) and 0.038 $\pm$ 0.0007 (sequential measurements) mg l^{-1} in 1977 and 1978, respectively. These data indicate during these two years, that there is a slight increase in concentration of total dissolved phosphorus in discharge from Skaha Lake.

Variation of the daily loads of total dissolved phosphorus during the two-year period is plotted in Appendix E4. A maximum load of this phosphorus form is 85.23 (sequential measurements) and minimum is 2.05 (sequential measurements, May 1977) kg day^{-1} (Appendix E5). The load means and their 95 percent confidence intervals determined for all load data during any given year (Appendix E6) are in the range of 5.83 $\pm$ 0.69 (sequential measurements) and 13.69 $\pm$ 3.25 (sequential measurements) kg day^{-1} in 1977 and 1978, respectively. These 2 year data indicate an increasing output of total dissolved phosphorus from Skaha Lake.

6.4.3 Nitrogen

Variation of nitrate plus nitrite, in terms of the daily geometric concentration means and their 95 percent confidence limits, during the three-year period is illustrated in Appendix E7. At this station, nitrate plus nitrite is characterized by pronounced short range temporal heterogeneity of point concentration measurements and by highly

significant seasonal variation. The long-term arithmetic concentration means and their 95 percent confidence intervals, determined on 417 and 260 simultaneous and sequential measurements, are in the range of 0.005 $\pm$ 0.002 and 0.041 $\pm$ 0.005 mg l^{-1} during the three-year spring-summer and fall-winter seasons, respectively. Although, the long-term concentration means of nitrate plus nitrite is high during the fall and winter seasons. A maximum concentration of 0.37 mg l^{-1} of this nitrogen form occurs in August 1978 (sequential measurements). But, during the spring and summer seasons most of minimum concentrations (0.002 mg l^{-1}) are at the detection limit of the analytic method (Appendix E8). The arithmetic concentration means and their 95 percent confidence intervals determined for all concentration measurements of nitrate plus nitrite during any given year are 0.013 $\pm$ 0.014 (simultaneous measurements based on measurements in July 1976 only), 0.016 $\pm$ 0.004 (sequential measurements) and 0.018 $\pm$ 0.005 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively (Appendix E9). These data indicate that there is a slight year-to-year increase in concentration of nitrate plus nitrite. (Note that the 1976 data are for a very short period).

Also, the daily loads of nitrate plus nitrite are characterized by a pronounced variation during the three-year period (Appendix E7). A maximum daily load of nitrate plus nitrite is 220.02 kg day^{-1} (sequential measurements, November 1978) and a minimum is 0.95 kg day^{-1} (sequential and simultaneous measurements in March and May 1977, respectively), (Appendix E8). The load means and their 95 percent confidence intervals determined for all observations obtained during the individual years of sampling are 37.16 $\pm$ 71.07 (simultaneous measurements) 8.53 $\pm$ 3.0 (sequential measurements) and 35.97 $\pm$ 13.74 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978. The extreme variation of loads of nitrate plus nitrite determined for July 1976 is caused by sudden discharge changes, shown by the hydrograph, during period of sampling (Appendix E9).

Ammonia, in Okanagan River at Okanagan Falls, is charaterized by a very pronounced short range temporal heterogeneity of point concentration measurements, shown by the plots of the daily geometric means and their

95 percent confidence limits (Appendix E10). Seasonal variation of ammonia concentration is very siginficant. The long-term concentration means, and their 95 percent confidence intervals, determined for 417 and 260 simultaneous and sequential measurements, vary in the range of 0.039 $\pm$ 0.007 and 0.129 $\pm$ 0.041 mg l^{-1} during the three-year spring-summer and fall-winter seasons, respectively.

A maximum concentration of ammonia observed at this station is 4.1 mg l^{-1} (sequential measurements, February 1977). A minimum of 0.002 mg l^{-1} (a detection limit of the analytical method) occurs during several months of the three-year period (Appendix E11). Data shown in this Appendix indicate that, in winter 1977-1978, there are more measurements of ammonia concentrations exceeding a permissible limit of 0.5 mg l^{-1}, established for drinking water (EPA, 1972).

On the annual basis, the arithmetic concentration means and their 95 percent confidence intervals, determined from all concentration measurements of ammonia are in the range of 0.009 $\pm$ 0.0039 (simultaneous measurements in July 1976, only), 0.02 $\pm$ 0.0073 (sequential measurements) and 0.177 $\pm$ 0.044 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978 (Appendix E12). The data indicate an increase in ammonia concentration during the sampling period.

Variation of the daily loads of ammonia is illustrated in Appendix E10. A maximum ammonia load is 7,889 (sequential measurements, February 1978) and a minimum is 0.76 (sequential measurements, March 1977) kg day^{-1} (Appendix E11). This maximum load is caused by the occurrence of an extreme ammonia concentration measured in February 1978 while a minimum load obaserved in March 1977 is associated with the low discharge in this particular month.

The ammonia load means, and their 95 percent confidence intervals, determined for all data obtained during the individual years of sampling (Appendix E12) are 28.54 $\pm$ 41.27 (simultaneous measurements in July, only) 14.44 $\pm$ 6.45 (sequential measurements) and 364.03 $\pm$ 229.56 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively. The very high variation of ammonia load for 1976 is caused by the high variability of discharge in summer of this particular year.

High levels of ammonia concentration, also high discharge resulted in very high ammonia load in 1978.

Variation of organic nitrogen, in terms of the daily geometric concentration means and their 95 percent confidence limits are illustrated by the plots in Appendix E13. The high concentration values of organic nitrogen occur particularly during the fall-winter seasons in 1977 to 1978. Thus, the long-term concentration means and their 95 percent confidence intervals, determined on 417 and 260 data, derived from simultaneous and sequential measurements, vary from 0.454 $\pm$ 0.135 to 0.546 $\pm$ 0.077 mg l^{-1} during the three-year spring-summer and fall-winter seasons, respectively. A maximum concentration of organic nitrogen is 17.95 (sequential measurements, April 1978), (Appendix E14) and a minimum is 0.086 (sequential measurements) mg l^{-1}.

The arithmetic concentrations means and their 95 percent confidence intervals, determined for all data on organic nitrogen during any given year (Appendix E15) are in the range of 0.165 $\pm$ 0.008 (simultaneous measurements), 0.396 $\pm$ 0.067 (sequential measurements) and 0.824 $\pm$ 0.234 (sequential measurements) mg l^{-1} in 1976, 1977 and 1978, respectively. These arithmetic means indicate an increase in concentration of organic nitrogen observed during this sampling period at this station located below Skaha Lake.

Variation of organic nitrogen loads, observed during the three-year period, is illustrated by plots in Appendix E13. A maximum daily load of organic nitrogen is 10,824.1 (sequential method, April 1978) and minimum is 81.8 (sequential measurements, November 1977) kg day^{-1} (Appendix E14). This maximum load of organic nitrogen is associated with the high concentration data obtained for April 1978, rather than with high discharge, but a minimum load in November 1977, occurs during a period of very low discharge. The organic nitrogen load means and their 95 percent confidence intervals, determined for all data obtained during the individual years (Appendix E15) are 519.88 $\pm$ 73.35 (simultaneous measurements), 206.34 $\pm$ 38.69 (sequential measurements) and 1,516.1 $\pm$ 533.61 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively. Because of the low discharge in 1977, there is no obvious

year-to-year trend in organic nitrogen load at this sampling station.

Total nitrogen, in Okanagan River at Okanagan Falls, is characterized by a pronounced short range temporal heterogeneity of concentration measurements (Appendix E16) and by a significant seasonal variation during the three-year period. The long-term concentration means and their 95 percent confidence limits, derived from 417 and 260 simultaneous and sequential measurements of total nitrogen are ranging from 0.498 $\pm$ 0.139 to 0.716 $\pm$ 0.094 mg l^{-1} during the three-year spring-summer and fall-winter seasons, respectively. A maximum concentration of total nitrogen is 18.0 mg l^{-1} (sequential measurements, April 1978) and a minimum is 0.15 mg l^{-1} (simultaneous measurements, July 1976) (Appendix E17). The arithmetic concentration means and their 95 percent confidence intervals, determined for all measurements of total nitrogen during the individual years of sampling (Appendix E18) are 0.187 $\pm$ 0.017 (simultaneous measurements), 0.432 $\pm$ 0.07 (sequential measurements) and 1.02 $\pm$ 0.24 (sequential measurements) kg day^{-1} in 1976, 1977 and 1978, respectively. These means indicate an increase in concentration of total nitrogen at this station.

Time series of the daily geometric concentration mean, and their 95 percent confidence limits, of silica observed in Okanagan River at Okanagan Falls is plotted in Appendix E19. Seasonal variation of silica concentration is very significant at this station, by contrast to station below Okanagan Lake dam. The long-term means and their 95 percent confidence intervals, derived from 390 and 236 simultaneous and sequential measurements of silica concentration vary from 1.08 $\pm$ 0.076 to 2.13 $\pm$ 0.162 mg l^{-1} during the three-year spring-summer and fall-winter seasons, respectively. Maxima of silica concentration of 5.0 mg l^{-1}, (sequential measurements), (Appendix E20) occur in October and January in 1977 and 1978, respectively; while minima of 0.2 mg l^{-1}, reaching the detection limit of the analytical method, are observed during the early spring seasons (sequential measurements, March and April 1977 and 1978).

The occurrence of minimum concentration of silica during the spring-summer seasons observed in discharge from Skaha Lake indicates that silica limitation may be significant in controlling peak levels of

diatoms in spring. The seasonal changes of silica concentration observed in discharge at this station can provide important information on diatom growth in the lake. Diatoms have a special requirement for silicon that most other algal groups do not share. Silica, in the form available to algae (measured as soluble, reactive silica) is required by diatoms so that they can form siliceous cell walls. If available silicon levels fall too low, 0.1-0.2 mg SiO_2 (Schelske and Stoermer 1972) the diatoms can no longer meet this requirement, and they are replaced by other forms, usually green and blue-green algae, that do not require silicon. According to Schelske and Stoermer (op. cit.) the problem associated with silica depletion is the reverse of that of phosphorus. Thus, increasing concentrations of phosphorus allow increased algal growth and shifts to less desirable types. On the other hand, decreasing concentrations of silica cause shifts away from desirable types. The implication for water management is that there is no necessity to limit silicon input. But, the proposed phosphorus objectives should reduce algal growth and thus eliminate silicon deficiencies.

On the annual basis, the arithmetic means and their 95 percent confidence intervals determined for all concentration measurements of silica during the individual years of sampling are 1.53 $\pm$ 0.149 and 1.23 $\pm$ 0.115 mg l^{-1} in 1977 and 1978, respectively (Appendix E21).

Variation of the daily loads of silica, observed in Okanagan River at Okanagan Falls during 1977 and 1978, is illustrated by plots in Appendix E19. a maximum of silica load is 7,711.9 kg day^{-1} (sequential measurements, November 1978), (Appendix E20), and a minimum is 93.66 kg day^{-1} (sequential measurements, April 1977). The arithmetic load means and their 95 percent confidence intervals (Appendix E21) determined for all load data obtained during the individual year of sampling are 1,137.3 $\pm$ 244.8 (sequential method) and 2,061 $\pm$ 380.4 (sequential method) kg day^{-1} in 1977 and 1978, respectively.

6.4.4 Concentration Ratio

The pattern of seasonal changes of nutrient concentration, measured by simultaneous and sequential methods in Okanagan River at

Okanagan Falls, is further shown on variation of the long-term concentration mean ratios determined for the individual nutrient forms. All concentration data obtained in 1976 through March 1979 are lumped for the two distinct seasons, the spring-summer (April - September) and the fall-winter (October - March) seasons.

The long-term concentration mean ratios of total dissolved phosphorus to total phosphorus determined on 323 and 238 observations are 0.399 ± 0.018 and 0.455 ± 0.029 during the three-year spring-summer and fall-winter seasons, respectively. These ratios indicate that the pattern of the seasonal changes of the two phosphorus forms, observed at this station, is similar to that at station near the Penticton ariport. However, there is a substantial increase in the percentage content of the dissolved phosphorus form in total phosphorus.

The long-term concentration mean ratios, indicating the pattern of seasonal changes of each of the three following nitrogen forms, are derived from 417 and 260 observations obtained during the two periods. Thus, the mean ratios, and their 95 percent confidence intervals, of nitrate plus nitrite to total nitrogen; ammonia to total nitrogen; and organic nitrogen to total nitrogen vary from 0.017 ± 0.004 (spring-summer seasons) to 0.106 ± 0.02 (fall-winter seasons); 0.098 ± 0.011 (spring-summer seasons) to 0.116 ± 0.02 (fall-winter seasons); and 0.886 ± 0.012 (spring-summer seasons) to 0.778 ± 0.02 (fall-winter seasons). These data indicate that there is a substantial decrease in the percentage content of inorganic nitrogen forms and increase in the content of organic forms in total nitrogen at this sampling station, in comparison to station near the Penticton airport.

The long-term concentration mean ratios of ammonia to nitrate plus nitrite and their 95 percent confidence intervals, determined on 417 and 260 observations are 12.611 ± 2.08 and 14.83 ± 5.479 during the spring-summer and fall-winter seasons, respectively. These ratios observed at this station, by contrast to that near the Penticton airport, are significantly higher indicating an increasing effect of the ammonia pollution in discharge from Skaha Lake.

The long-term concentration means ratio, and their 95 percent

confidence intervals, of total nitrogen to total dissolved phosphorus, determined on 346 and 239 observations, are 93.58 ± 22.85 (spring-summer seasons) and 79.45 ± 11.30 (fall-winter seasons). The ratios of total nitrogen to total phosphorus, determined on 369 and 247 observations are 31.9 ± 7.29 (spring-summer seasons) and 25.35 ± 2.99 (fall-winter seasons). These ratios, observed at this station, by contrast to station near the Penticton airport, show increase during the spring-summer and decrease during fall-winter seasons.

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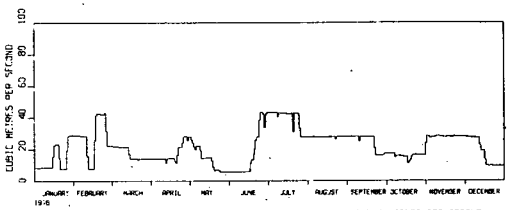
APPENDIX A

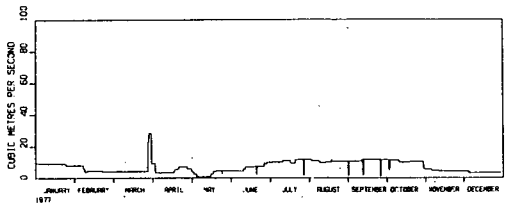
Annual hydrographics illustrating hourly discharge ($m^3 s^{-1}$) determined during the period from 1976 to 1978 at:

1. Okanagan River below Okanagan Lake dam (Water Survey of Canada station 08NM050).
2. Penticton municipal outfall
3. Shingle Creek at the mouth (Water Survey of Canada station 08NM150).
4. Ellis Creek at the mouth (Water Survey of Canada station 08NM135), and
5. Okanagan River near the Penticton airport.



STATION 06
OKANAGAN RIVER AT PENTICTON

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM050



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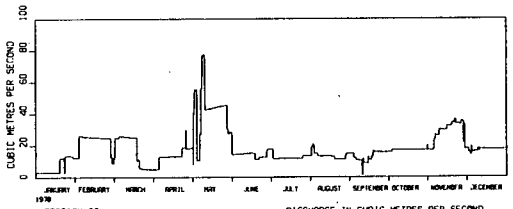
OKANAGAN RIVER AT PENTICTON

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM050



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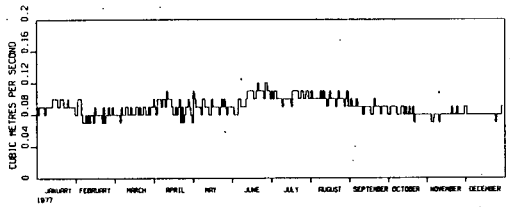
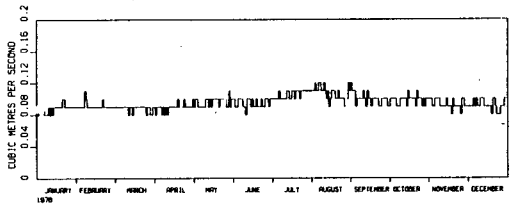
OKANAGAN RIVER AT PENTICTON

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM050



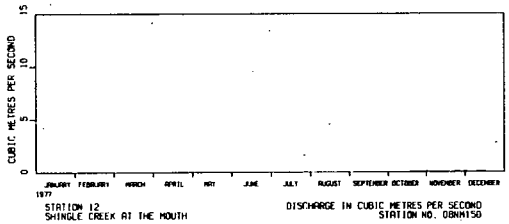
STATION 11
PENTICTON OUTFALL

DISCHARGE IN CUBIC METRES PER SECOND



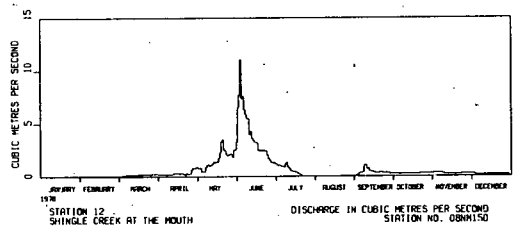
STATION 11
PENTICTON OUTFALL

DISCHARGE IN CUBIC METRES PER SECOND



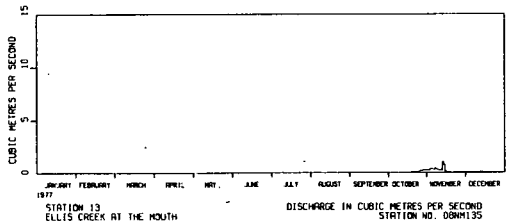
STATION 12
SHINGLE CREEK AT THE MOUTH

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM150



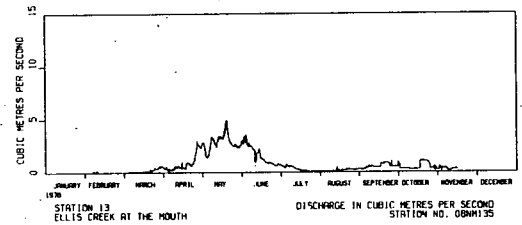
STATION 12
SHINGLE CREEK AT THE MOUTH

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM150



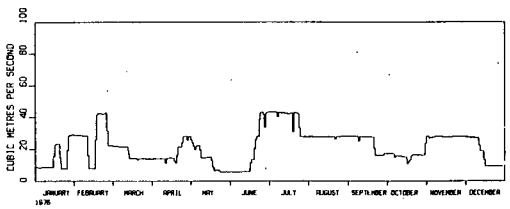
STATION 13
ELLIS CREEK AT THE MOUTH

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM135



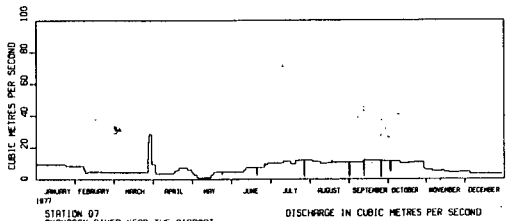
STATION 13
ELLIS CREEK AT THE MOUTH

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 08NM135



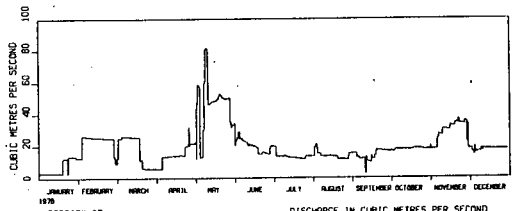
STATION 07
OKANAGAN RIVER NEAR THE AIRPORT

DISCHARGE IN CUBIC METRES PER SECOND



STATION 07
OKANAGAN RIVER NEAR THE AIRPORT

DISCHARGE IN CUBIC METRES PER SECOND



STATION 07
OKANAGAN RIVER NEAR THE AIRPORT

DISCHARGE IN CUBIC METRES PER SECOND

A

APPENDIX B

Okanagan River below Okanagan Lake dam, 1976 to 1978

Concentrations and loads derived from simultaneous and sequential measurements are shown in (1) graphs and (2) tables.

1. Graphs

   Graphs illustrate time series of

   (a) the daily geometric concentration means (mg l^{-1}) and their 95 percent confidence limits, and

   (b) the daily total loads (kg day^{-1}) of nutrients during the three-year period with confidence limits for data generated using concentration from simultaneous samples.

2. Tables

   Tables show statistical characteristics of nutrient concentrations and loads, reduced to the (a) monthly and (b) annual basis, in terms of

   (a_i) the arithmetic concentration means (mg l^{-1}), and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given month of sampling,

   (a_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given month of sampling.

   (b_i) the arithemetic concentration means (mg l^{-1}) and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given year of sampling,

   (b_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given year of sampling.

NOTE

Note regarding the concentration and load data generated from simultaneous and sequential measurements in February 1978.

According to the sampling procedure designed for this study

simultaneous samples should be collected in four slices across the channel. In February 1978, however, samples employing this method were collected in one slice only, close to the sampling point where, on the same day, sequential samples were taken. As a result in February 1978 the nutrient concentration data obtained by these two sampling methods are identical (see lines 1978 02 in Tables B2, B5, B8, B11, B14, B17 and B20).

Nutrient loads for February, 1978, based on simultaneous measurements, were calculated for one slice and do not, therefore, represent the cross-sectional load. On the other hand, loads derived from sequential measurements represent the load passing through the channel cross-section.

B1 Time series of total phosphorus (P) concentration and loads, 1976 to 1978

B2 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual months of sampling

B3 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual year of sampling

B4 Time series of total dissolved phosphorus (P) concentration and loads, 1976 to 1978

B5 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual months of sampling

B6 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual year of sampling

B7 Time series of nitrate plus nitrite (N) concentration and loads, 1976 to 1978

B8 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual months of sampling

B9 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual year of sampling

B10 Time series of ammonia (N) concentration and loads, 1976 to 1978

B11 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual months of sampling

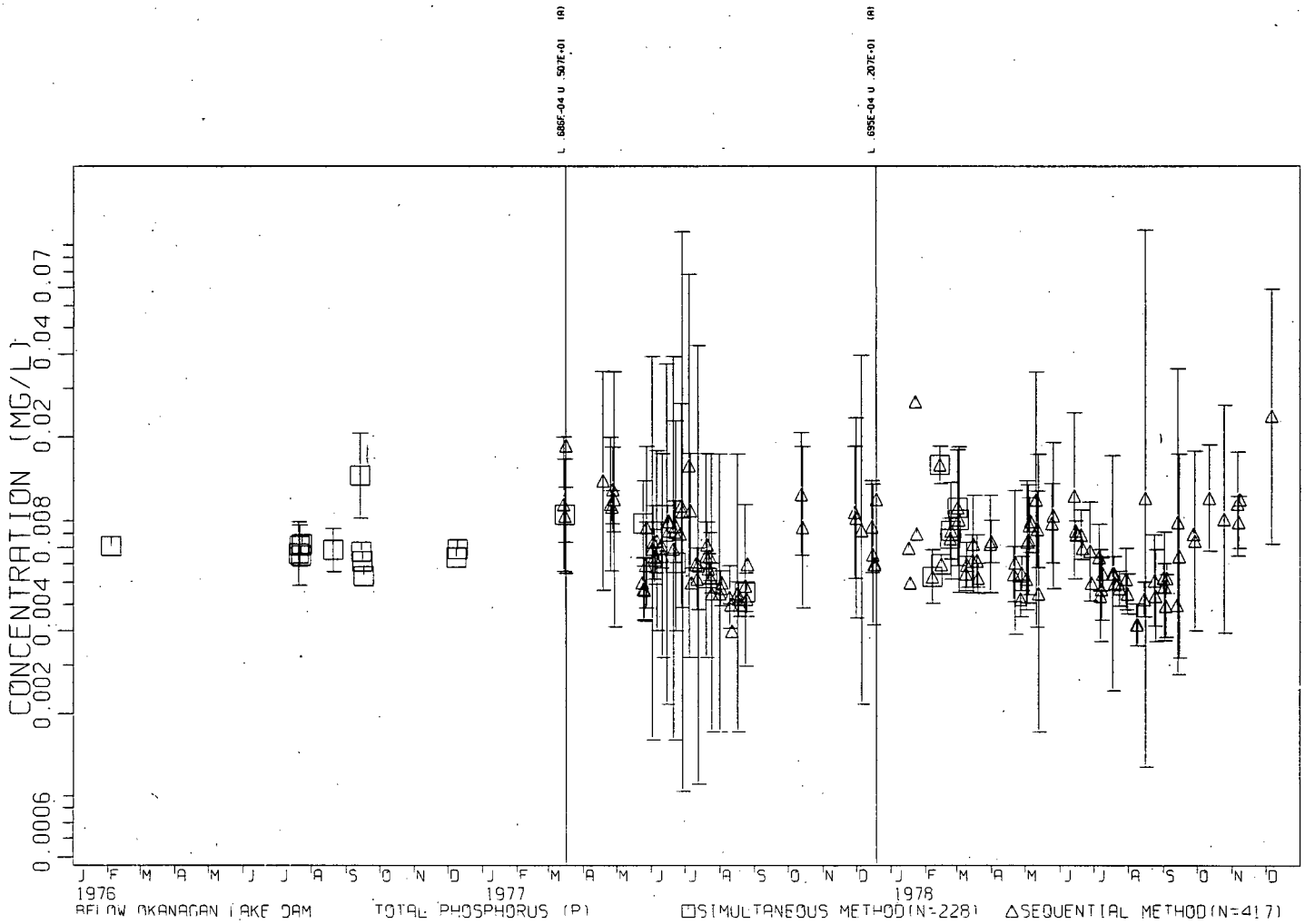
B12 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual year of sampling

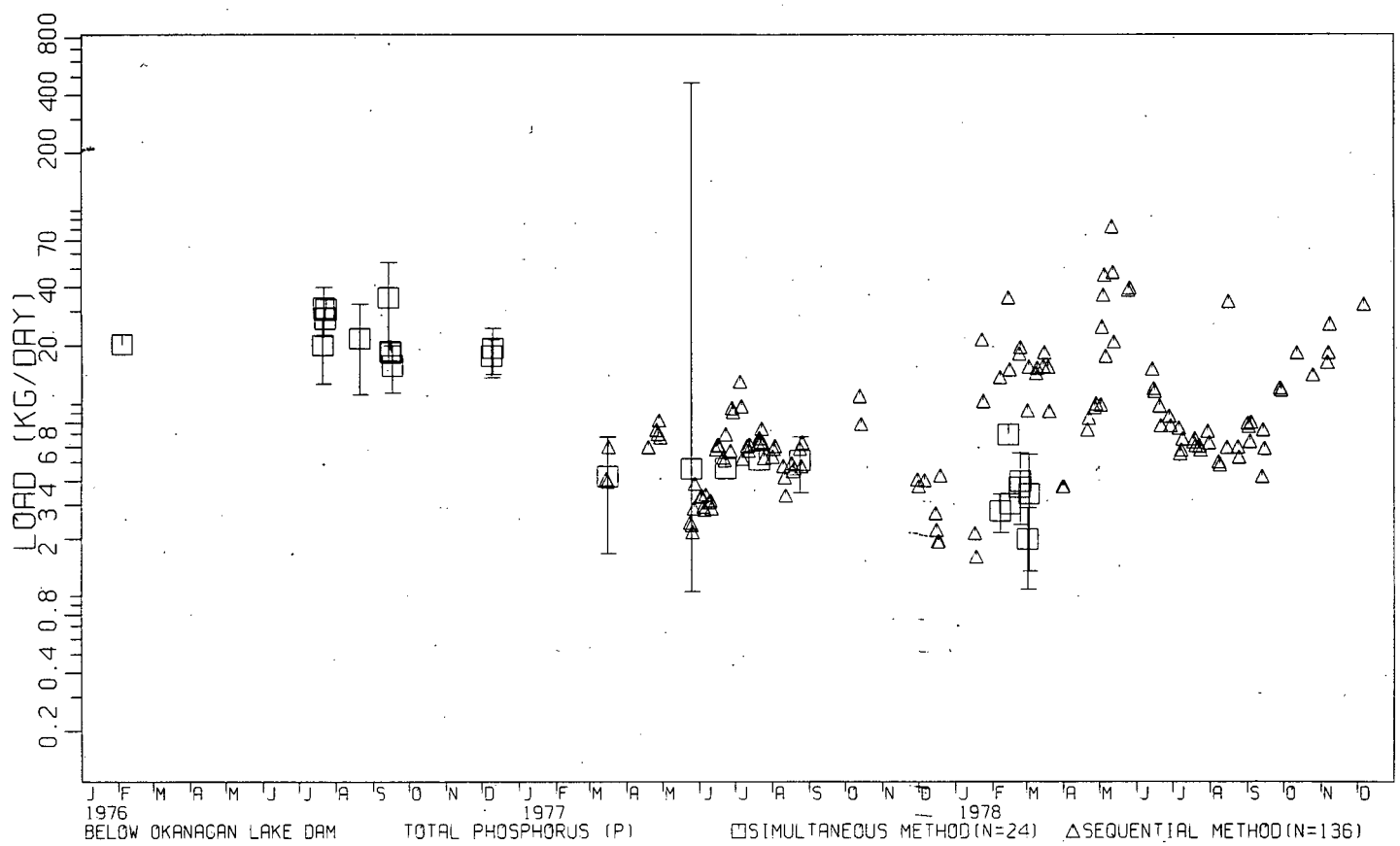
B13 Time series of organic nitrogen (N) concentration and loads, 1976 to 1978

B14 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual months of sampling

B15 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual year of sampling

B16 Time series of total nitrogen (N) concentration and loads, 1976 to 1978


L .685E-04 U .50TE+01 (A)
L .695E-04 U .20TE+01 (A)
CONCENTRATION (MG/L)
0.0006
0.002
0.004
0.008
0.02
0.04
0.07
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
TOTAL PHOSPHORUS (P)
□SIMULTANEOUS METHOD(N=228)
△SEQUENTIAL METHOD(N=417)

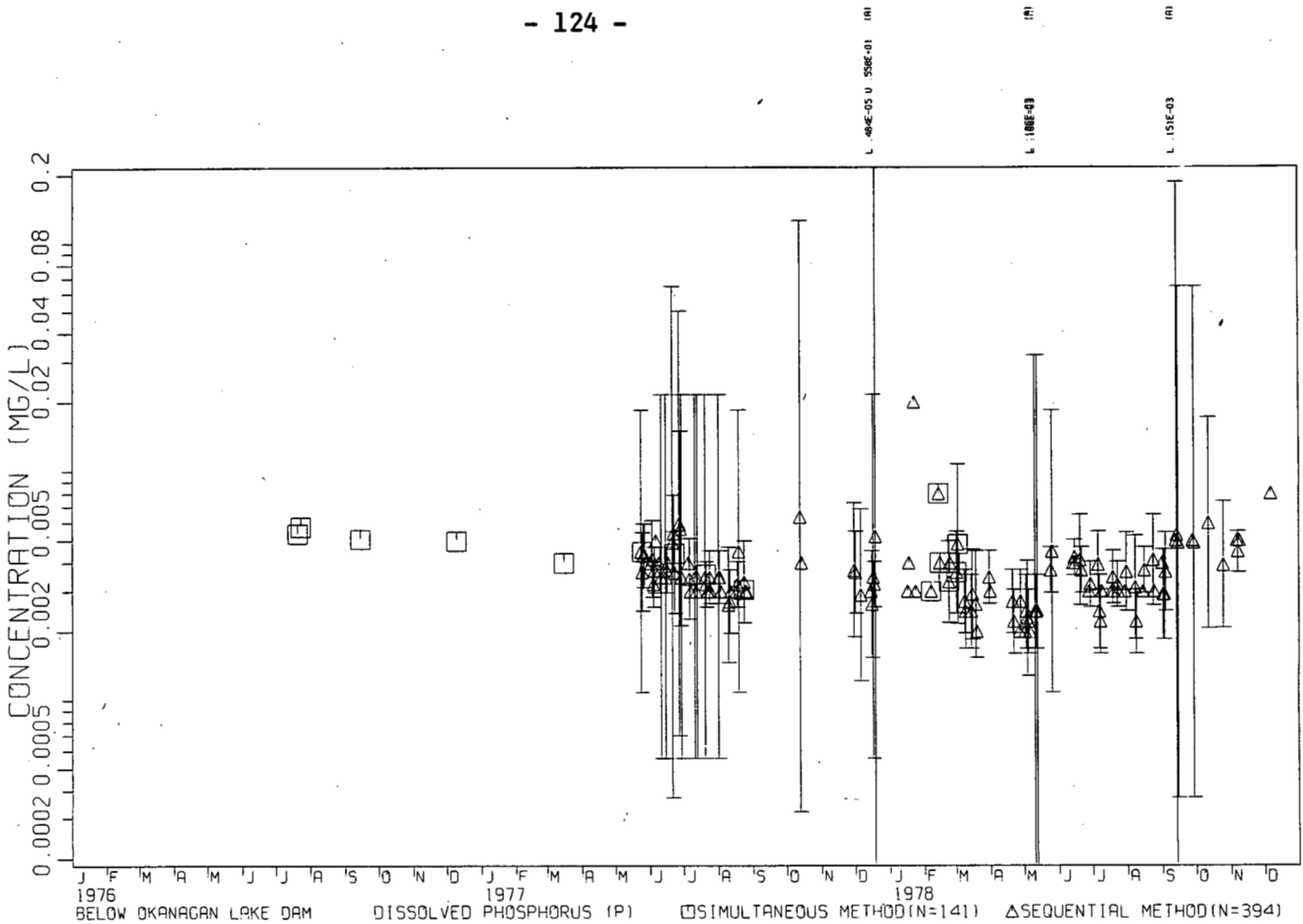

LOAD (KG/DAY)
0.2
0.4
0.8
2
3
4
6
8
20
40
70
200
400
800
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
TOTAL PHOSPHORUS (P)
□SIMULTANEOUS METHOD(N=24)
△SEQUENTIAL METHOD(N=136)

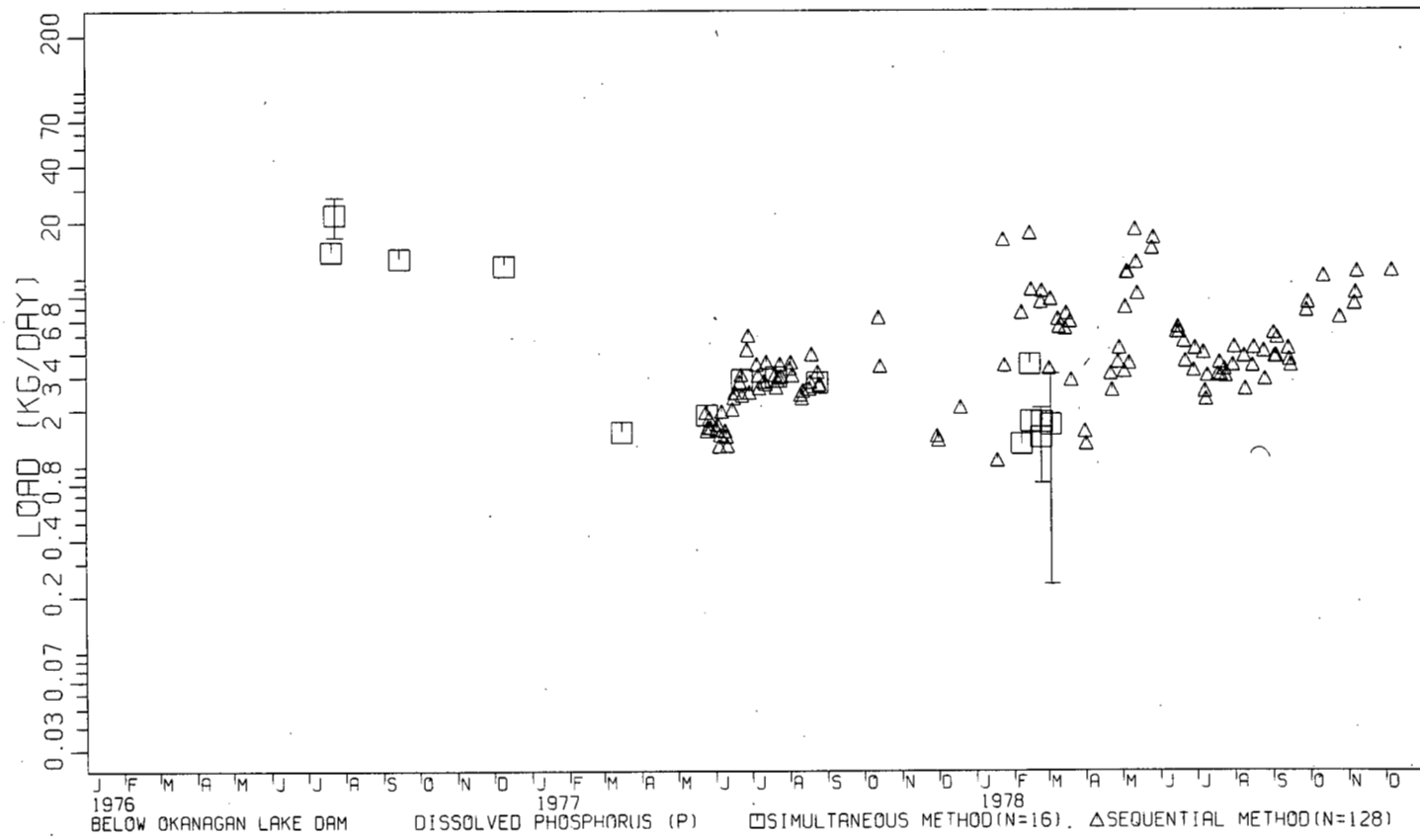
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL PHOSPHORUS(P)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 02	6	0.007	0.010	0.008	0.0012	0.0005	±0.0012							
1976 07	36	0.006	0.017	0.008	0.0021	0.0004	±0.0007							
1976 08	18	0.006	0.028	0.009	0.0051	0.0012	±0.0025							
1976 09	54	0.005	0.040	0.009	0.0054	0.0007	±0.0015							
1976 12	33	0.006	0.019	0.008	0.0032	0.0006	±0.0011							
1977 03	12	0.008	0.032	0.011	0.0065	0.0019	±0.0041	9	0.007	0.029	0.013	0.0063	0.0021	±0.0049
1977 04								14	0.010	0.018	0.012	0.0020	0.0005	±0.0012
1977 05	12	0.005	0.050	0.012	0.0121	0.0035	±0.0077	14	0.005	0.010	0.007	0.0015	0.0004	±0.0009
1977 06	12	0.005	0.009	0.007	0.0012	0.0003	±0.0008	49	0.006	0.024	0.009	0.0027	0.0004	±0.0008
1977 07	12	0.005	0.009	0.006	0.0012	0.0003	±0.0007	36	0.005	0.018	0.008	0.0028	0.0005	±0.0009
1977 08	12	0.005	0.012	0.006	0.0020	0.0006	±0.0013	32	0.004	0.008	0.005	0.0008	0.0001	±0.0003
1977 10								4	0.009	0.013	0.011	0.0018	0.0009	±0.0029
1977 11								4	0.008	0.015	0.011	0.0038	0.0019	±0.0060
1977 12								22	0.005	0.018	0.009	0.0035	0.0008	±0.0016
1978 01								4	0.006	0.027	0.012	0.0097	0.0049	±0.0155
1978 02	15	0.006	0.017	0.010	0.0036	0.0009	±0.0020	15	0.006	0.017	0.010	0.0036	0.0009	±0.0020
1978 03	6	0.008	0.013	0.011	0.0021	0.0009	±0.0022	34	0.006	0.013	0.008	0.0021	0.0004	±0.0007
1978 04								20	0.005	0.012	0.007	0.0018	0.0004	±0.0008
1978 05								30	0.005	0.013	0.009	0.0023	0.0004	±0.0008
1978 06								24	0.006	0.015	0.009	0.0023	0.0005	±0.0010
1978 07								40	0.004	0.009	0.006	0.0009	0.0001	±0.0003
1978 08								24	0.004	0.100	0.009	0.0194	0.0040	±0.0082
1978 09								25	0.004	0.011	0.007	0.0017	0.0003	±0.0007
1978 10								7	0.007	0.018	0.012	0.0037	0.0014	±0.0034
1978 11								8	0.009	0.014	0.011	0.0017	0.0006	±0.0014
1978 12								2	0.022	0.026	0.024	0.0028	0.0020	±0.0254
						LOAD (KG/DAY)								
1976 02	1	20.38	20.38	20.38										
1976 07	4	20.23	31.30	27.51	5.11	2.55	±8.12							
1976 08	1	21.93	21.93	21.93										
1976 09	4	15.78	35.40	22.11	8.96	4.48	±14.26							
1976 12	2	17.76	19.51	18.63	1.24	0.88	±11.13							
1977 03	1	4.23	4.23	4.23				3	4.01	6.03	4.72	1.14	0.66	±2.83
1977 04								5	6.04	8.29	7.11	0.82	0.37	±1.02
1977 05	1	4.65	4.65	4.65				5	2.18	3.89	2.76	0.69	0.31	±0.85
1977 06	1	4.68	4.68	4.68				17	2.85	9.60	5.02	2.16	0.53	±1.11
1977 07	1	5.18	5.18	5.18				12	5.24	13.09	7.05	2.24	0.65	±1.43
1977 08	1	5.13	5.13	5.13				12	3.38	6.36	5.08	0.87	0.25	±0.56
1977 10								2	7.91	10.96	9.43	2.16	1.53	±19.41
1977 11								1	4.09	4.09	4.09			
1977 12								7	1.94	4.29	2.99	1.02	0.39	±0.94
1978 01								4	1.62	21.72	8.98	9.40	4.70	±14.96
1978 02	5	2.80	6.98	4.11	1.68	0.75	±2.08	5	13.80	35.45	20.52	8.68	3.88	±10.78
1978 03	2	2.00	3.45	2.73	1.02	0.72	±9.19	9	3.77	18.59	13.13	4.68	1.56	±3.60
1978 04								5	3.76	10.13	7.90	2.54	1.14	±3.16
1978 05								10	10.02	82.99	36.73	20.61	6.52	±14.75
1978 06								7	7.80	15.32	10.48	2.75	1.04	±2.54
1978 07								11	5.58	7.59	6.41	0.61	0.18	±0.41
1978 08								6	4.88	33.85	10.21	11.59	4.73	±12.17
1978 09								9	4.26	12.23	8.02	2.60	0.87	±2.00
1978 10								2	14.34	18.47	16.40	2.92	2.07	±26.24
1978 11								3	16.55	26.21	20.45	5.09	2.94	±12.64
1978 12								1	32.84	32.84	32.84			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	147	0.005	0.040	0.008	0.0041	0.0003	±0.0007							
1977	60	0.005	0.050	0.008	0.0066	0.0009	±0.0017	184	0.004	0.029	0.009	0.0035	0.0003	±0.0005
1978	21	0.006	0.017	0.010	0.0033	0.0007	±0.0015	233	0.004	0.100	0.008	0.0068	0.0004	±0.0009
						LOAD (KG/DAY)								
1976	12	15.78	35.40	23.17	6.40	1.85	±4.07							
1977	5	4.23	5.18	4.77	0.39	0.17	±0.48	64	1.94	13.09	5.29	2.25	0.28	±0.56
1978	7	2.00	6.98	3.72	1.58	0.60	±1.46	72	1.62	82.99	14.83	13.36	1.57	±3.14


CONCENTRATION (MG/L)
0.0002 0.0005 0.002 0.005 0.02 0.04 0.08 0.2
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM DISSOLVED PHOSPHORUS (P) □SIMULTANEOUS METHOD(N=141) △SEQUENTIAL METHOD(N=394)

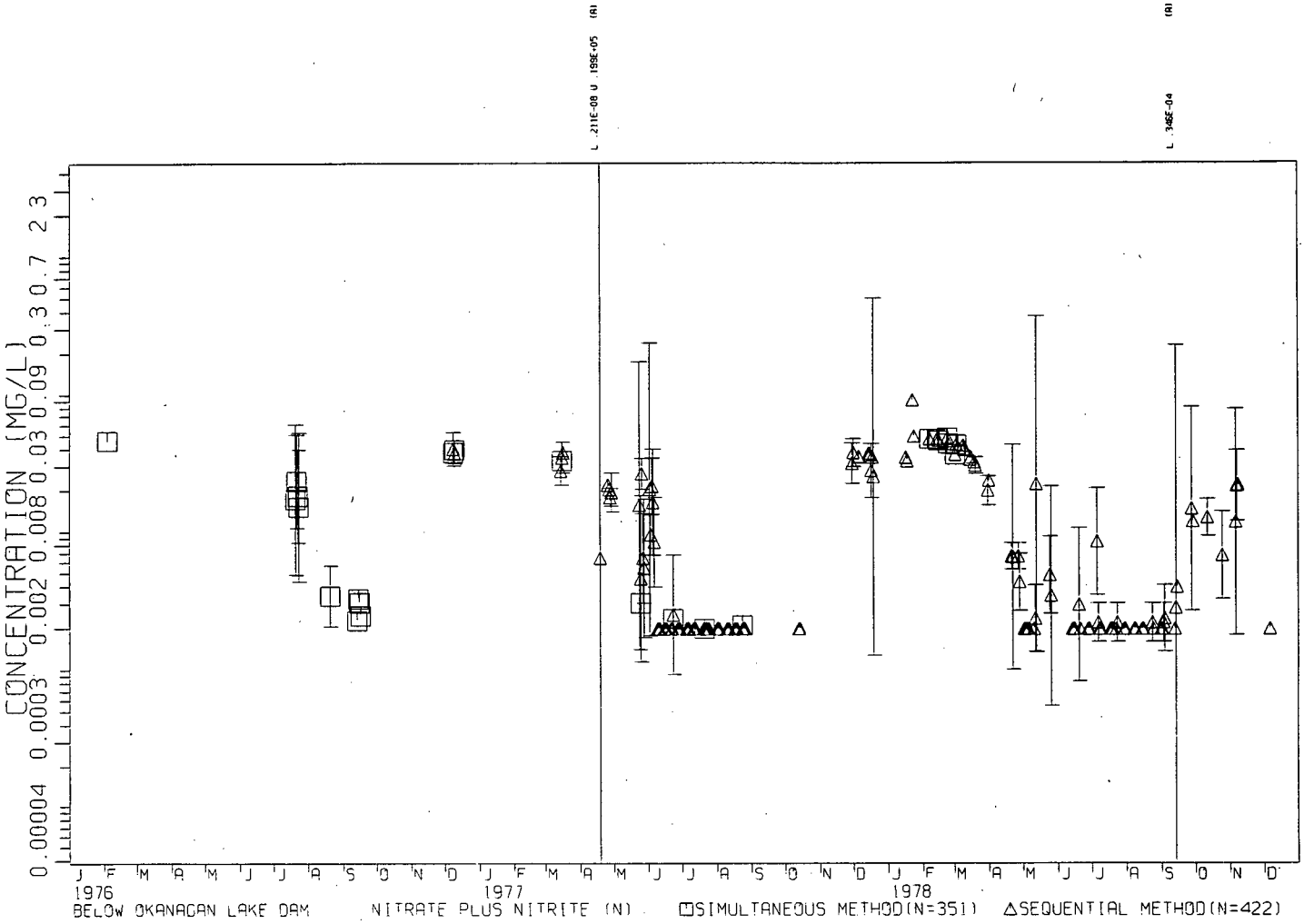

LOAD (KG/DAY)
0.03 0.07 0.2 0.4 0.8 2 3 4 6 8 20 40 70 200
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM DISSOLVED PHOSPHORUS (P) □SIMULTANEOUS METHOD(N=16). △SEQUENTIAL METHOD(N=128)

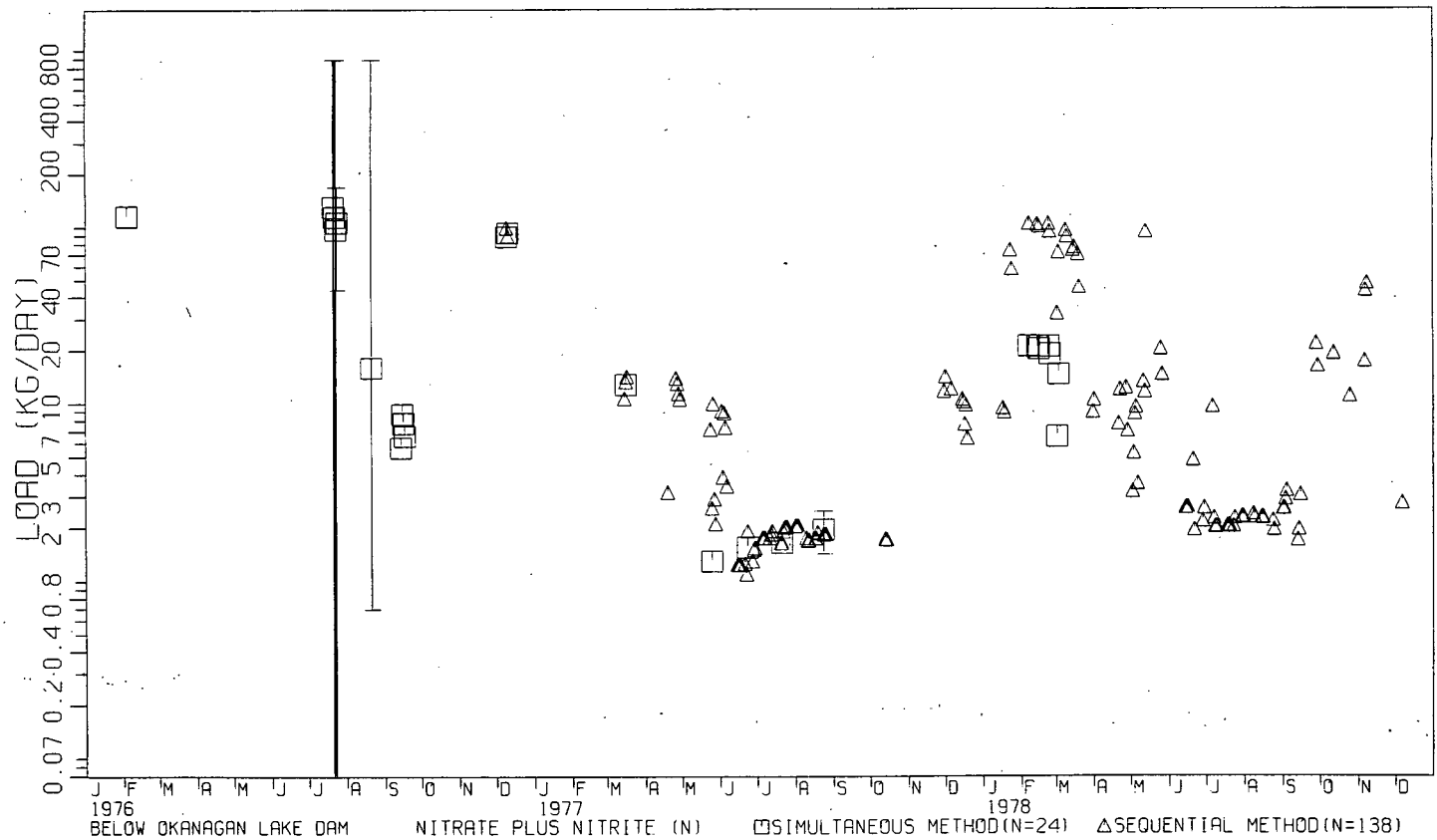
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 07	18	0.004	0.007	0.006	0.0009	0.0002	±0.0005							
1976 09	18	0.004	0.009	0.005	0.0014	0.0003	±0.0007							
1976 12	24	0.004	0.007	0.005	0.0009	0.0002	±0.0004							
1977 03	12	0.004	0.004	0.004	0.0	0.0	±0.0							
1977 05	12	0.003	0.007	0.005	0.0011	0.0003	±0.0007	14	0.003	0.005	0.004	0.0007	0.0002	±0.0004
1977 06	12	0.003	0.007	0.005	0.0014	0.0004	±0.0009	49	0.003	0.012	0.004	0.0015	0.0002	±0.0004
1977 07	12	0.003	0.006	0.004	0.0010	0.0003	±0.0006	36	0.003	0.005	0.003	0.0005	0.0001	±0.0002
1977 08	12	0.002	0.004	0.003	0.0005	0.0001	±0.0003	32	0.002	0.005	0.003	0.0006	0.0001	±0.0002
1977 10								4	0.004	0.008	0.005	0.0019	0.0009	±0.0030
1977 11								4	0.003	0.007	0.004	0.0020	0.0010	±0.0032
1977 12								22	0.002	0.009	0.003	0.0014	0.0003	±0.0006
1978 01								4	0.003	0.020	0.008	0.0083	0.0042	±0.0133
1978 02	15	0.003	0.008	0.005	0.0019	0.0005	±0.0010	15	0.003	0.008	0.005	0.0019	0.0005	±0.0010
1978 03	6	0.003	0.007	0.004	0.0014	0.0006	±0.0014	34	0.002	0.007	0.003	0.0010	0.0002	±0.0004
1978 04								20	0.002	0.003	0.002	0.0005	0.0001	±0.0002
1978 05								30	0.002	0.005	0.003	0.0008	0.0002	±0.0003
1978 06								24	0.003	0.006	0.004	0.0007	0.0002	±0.0003
1978 07								40	0.002	0.005	0.003	0.0007	0.0001	±0.0002
1978 08								24	0.002	0.006	0.003	0.0009	0.0002	±0.0004
1978 09								25	0.002	0.007	0.004	0.0012	0.0002	±0.0005
1978 10								7	0.003	0.013	0.006	0.0036	0.0014	±0.0034
1978 11								8	0.004	0.005	0.005	0.0005	0.0002	±0.0004
1978 12								2	0.008	0.008	0.008	0.0	0.0	±0.0
LOAD (KG/DAY)														
1976 07	2	13.78	21.86	17.82	5.71	4.04	±51.32							
1976 09	1	12.69	12.69	12.69										
1976 12	1	11.58	11.58	11.58										
1977 03	1	1.52	1.52	1.52										
1977 05	1	1.87	1.87	1.87				5	1.55	1.93	1.70	0.16	0.07	±0.20
1977 06	1	2.88	2.88	2.88				17	1.28	4.98	2.29	1.02	0.25	±0.53
1977 07	1	2.99	2.99	2.99				12	2.62	3.58	3.03	0.33	0.10	±0.21
1977 08	1	2.79	2.79	2.79				12	2.31	3.96	2.93	0.50	0.14	±0.32
1977 10								2	3.42	6.23	4.83	1.99	1.41	±17.89
1977 11								1	1.46	1.46	1.46			
1977 12								7	0.77	2.07	1.12	0.46	0.18	±0.43
1978 01								4	0.81	16.09	5.36	7.25	3.63	±11.54
1978 02	5	1.32	3.49	1.94	0.88	0.40	±1.10	5	6.62	17.45	9.78	4.37	1.96	±5.43
1978 03	2	0.65	1.67	1.16	0.72	0.51	±6.49	9	1.55	7.78	5.02	2.00	0.67	±1.54
1978 04								5	1.33	4.28	2.99	1.12	0.50	±1.39
1978 05								10	3.21	18.25	10.52	5.10	1.61	±3.64
1978 06								7	3.27	5.55	4.55	0.86	0.32	±0.79
1978 07								11	2.29	4.34	3.26	0.60	0.18	±0.40
1978 08								6	2.59	4.30	3.54	0.68	0.28	±0.72
1978 09								9	3.46	7.49	4.83	1.43	0.48	±1.10
1978 10								2	6.25	10.34	8.30	2.89	2.05	±26.00
1978 11								3	7.36	10.92	8.89	1.83	1.06	±4.55
1978 12								1	10.99	10.99	10.99			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	60	0.004	0.009	0.005	0.0011	0.0001	±0.0003							
1977	60	0.002	0.007	0.004	0.0011	0.0001	±0.0003	161	0.002	0.012	0.004	0.0012	0.0001	±0.0002
1978	21	0.003	0.008	0.004	0.0017	0.0004	±0.0008	233	0.002	0.020	0.004	0.0018	0.0001	±0.0002
						LOAD (KG/DAY)								
1976	4	11.58	21.86	14.98	4.67	2.34	±7.44							
1977	5	1.52	2.99	2.41	0.67	0.30	±0.83	56	0.77	6.23	2.46	1.05	0.14	±0.28
1978	7	0.65	3.49	1.72	0.87	0.33	±0.80	72	0.81	18.25	5.87	3.90	0.46	±0.92


L .211E-08 U .195E-05 (R)
L .345E-04 (R)
CONCENTRATION (MG/L)
0.00004 0.0003 0.002 0.008 0.03 0.09 0.3 0.7 2 3
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
NITRATE PLUS NITRITE (N)
SIMULTANEOUS METHOD(N=351)
SEQUENTIAL METHOD(N=422)

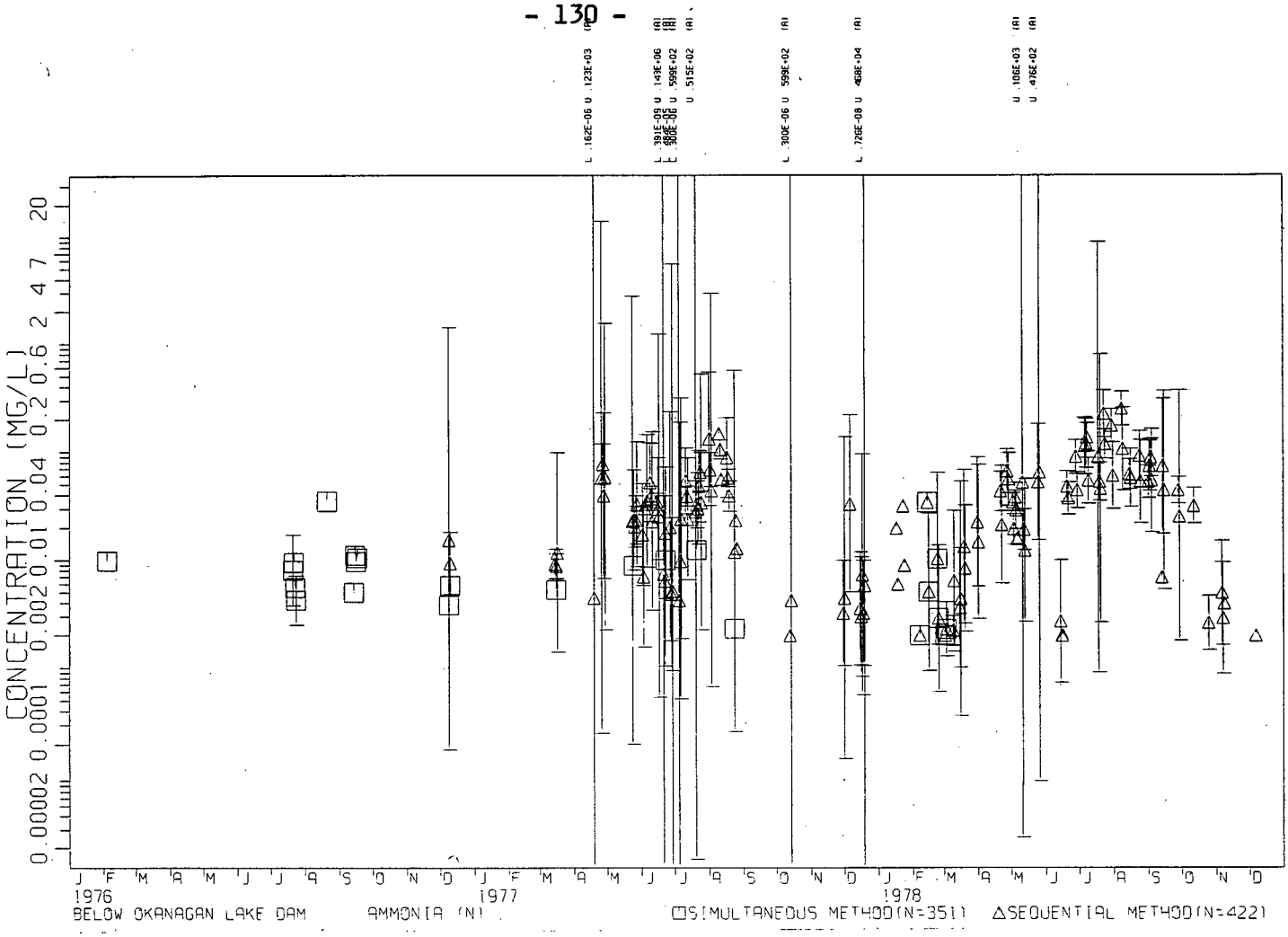

LOAD (KG/DAY)
0.07 0.2 0.4 0.8 2 3 5 7 10 20 40 70 200 400 800
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
NITRATE PLUS NITRITE (N)
SIMULTANEOUS METHOD(N=24)
SEQUENTIAL METHOD(N=138)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
NITRATE PLUS NITRITE(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 02	6	0.043	0.051	0.046	0.0033	0.0013	±0.0034							
1976 07	36	0.002	0.220	0.036	0.0435	0.0073	±0.0147							
1976 08	18	0.002	0.062	0.008	0.0159	0.0037	0.0079							
1976 09	108	0.002	0.008	0.003	0.0013	0.0001	±0.0003							
1976 12	66	0.036	0.041	0.039	0.0012	0.0001	±0.0003	5	0.037	0.046	0.039	0.0038	0.0017	±0.0047
1977 03	24	0.027	0.036	0.033	0.0019	0.0004	±0.0008	9	0.025	0.041	0.033	0.0056	0.0019	±0.0043
1977 04								14	0.002	0.022	0.019	0.0051	0.0014	±0.0029
1977 05	24	0.002	0.004	0.003	0.0007	0.0001	±0.0003	14	0.002	0.030	0.012	0.0093	0.0025	±0.0054
1977 06	24	0.002	0.004	0.002	0.0006	0.0001	±0.0002	49	0.002	0.030	0.007	0.0081	0.0012	±0.0023
1977 07	12	0.002	0.002	0.002	0.0	0.0	±0.0	36	0.002	0.002	0.002	0.0	0.0	±0.0
1977 08	12	0.002	0.004	0.002	0.0006	0.0002	±0.0004	32	0.002	0.002	0.002	0.0	0.0	±0.0
1977 10								4	0.002	0.002	0.002	0.0	0.0	±0.0
1977 11								4	0.025	0.039	0.032	0.0068	0.0034	±0.0108
1977 12								22	0.020	0.040	0.035	0.0046	0.0010	±0.0021
1978 01								4	0.033	0.092	0.052	0.0274	0.0137	±0.0436
1978 02	15	0.044	0.049	0.047	0.0017	0.0004	±0.0010	15	0.044	0.049	0.047	0.0017	0.0004	±0.0010
1978 03	6	0.036	0.044	0.040	0.0037	0.0015	±0.0039	34	0.016	0.044	0.035	0.0070	0.0012	±0.0024
1978 04								20	0.002	0.025	0.010	0.0082	0.0018	±0.0038
1978 05								30	0.002	0.028	0.004	0.0055	0.0010	±0.0021
1978 06								24	0.002	0.010	0.002	0.0016	0.0003	±0.0007
1978 07								40	0.002	0.014	0.003	0.0026	0.0004	±0.0008
1978 08								24	0.002	0.003	0.002	0.0002	0.0	±0.0001
1978 09								25	0.002	0.017	0.004	0.0043	0.0009	±0.0018
1978 10								7	0.005	0.017	0.010	0.0039	0.0015	±0.0036
1978 11								8	0.005	0.036	0.019	0.0087	0.0031	±0.0073
1978 12								2	0.002	0.002	0.002	0.0	0.0	±0.0
						LOAD (KG/DAY)								
1976 02	1	115.61	115.61	115.61										
1976 07	4	96.36	130.25	111.72	14.31	7.16	±22.77							
1976 08	1	15.82	15.82	15.82										
1976 09	4	5.60	8.64	7.11	1.33	0.67	±2.12							
1976 12	2	87.56	92.15	89.86	3.25	2.30	±29.18	2	88.49	98.85	93.67	7.33	5.18	±65.83
1977 03	1	12.67	12.67	12.67				3	10.64	14.10	12.63	1.78	1.03	±4.43
1977 04								5	3.16	13.81	10.32	4.21	1.88	±5.22
1977 05	1	1.29	1.29	1.29				5	2.10	9.91	4.92	3.44	1.54	±4.27
1977 06	1	1.54	1.54	1.54				17	0.77	9.03	2.76	2.82	0.68	±1.45
1977 07	1	1.63	1.63	1.63				12	1.63	2.01	1.82	0.14	0.04	±0.09
1977 08	1	1.94	1.94	1.94				12	1.68	2.04	1.83	0.14	0.04	±0.09
1977 10								2	1.71	1.72	1.71	0.01	0.01	±0.06
1977 11								1	11.74	11.74	11.74			
1977 12								7	6.36	14.12	10.07	2.58	0.98	±2.39
1978 01								4	8.90	74.02	37.56	33.45	16.73	±53.23
1978 02	5	18.87	21.05	20.36	0.90	0.40	±1.11	5	94.37	104.87	101.78	4.48	2.00	±5.56
1978 03	2	6.48	14.47	10.47	5.65	3.99	±50.73	9	8.98	96.02	62.83	28.18	9.39	±21.66
1978 04								5	7.01	12.30	9.90	2.44	1.09	±3.02
1978 05								10	3.21	94.19	18.45	27.14	8.58	±19.41
1978 06								7	1.95	4.82	2.77	0.94	0.36	±0.87
1978 07								11	2.03	9.61	2.83	2.25	0.68	±1.51
1978 08								6	1.95	2.39	2.24	0.16	0.06	±0.16
1978 09								9	1.70	21.75	6.24	7.40	2.47	±5.69
1978 10								2	11.03	19.21	15.12	5.78	4.09	±51.95
1978 11								3	17.28	48.04	36.35	16.65	9.61	±41.37
1978 12								1	2.75	2.75	2.75			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
NITRATE PLUS NITRITE(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	234	0.002	0.220	0.020	0.0247	0.0016	±0.0032	5	0.037	0.046	0.039	0.0038	0.0017	±0.0047
1977	96	0.002	0.036	0.010	0.0134	0.0014	±0.0027	184	0.002	0.041	0.011	0.0132	0.0010	±0.0019
1978	21	0.036	0.049	0.045	0.0039	0.0009	±0.0018	233	0.002	0.092	0.013	0.0163	0.0011	±0.0021
LOAD (KG/DAY)														
1976	12	5.60	130.25	65.54	51.33	14.82	±32.61	2	88.49	98.85	93.67	7.33	5.18	±65.83
1977	5	1.29	12.67	3.81	4.96	2.22	±6.15	64	0.77	14.12	4.54	4.31	0.54	±1.08
1978	7	6.48	21.05	17.54	5.40	2.04	±4.99	72	1.70	104.87	23.90	33.19	3.91	±7.80


CONCENTRATION (MG/L)
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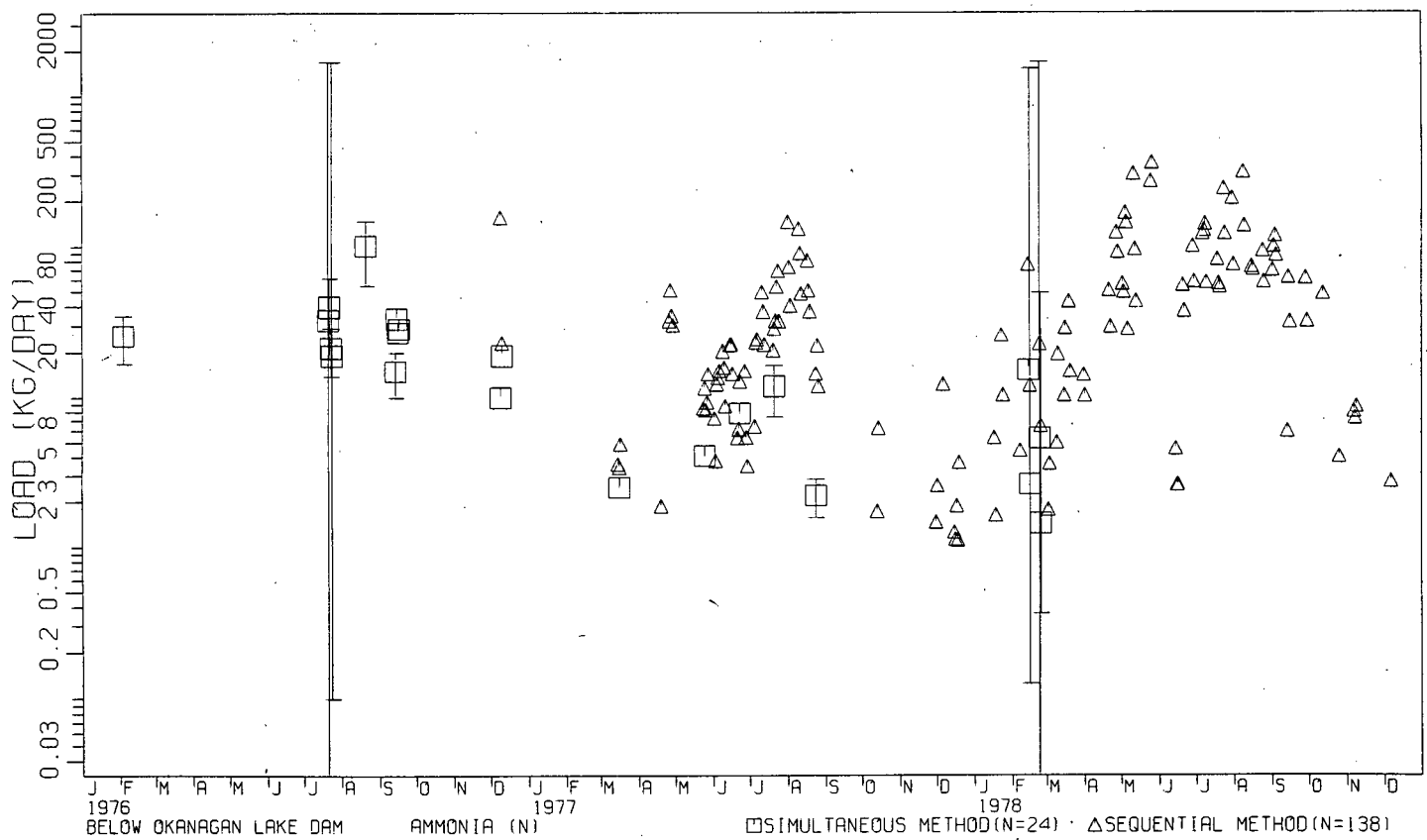
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
AMMONIA (N)
SIMULTANEOUS METHOD(N=351)
SEQUENTIAL METHOD(N=422)

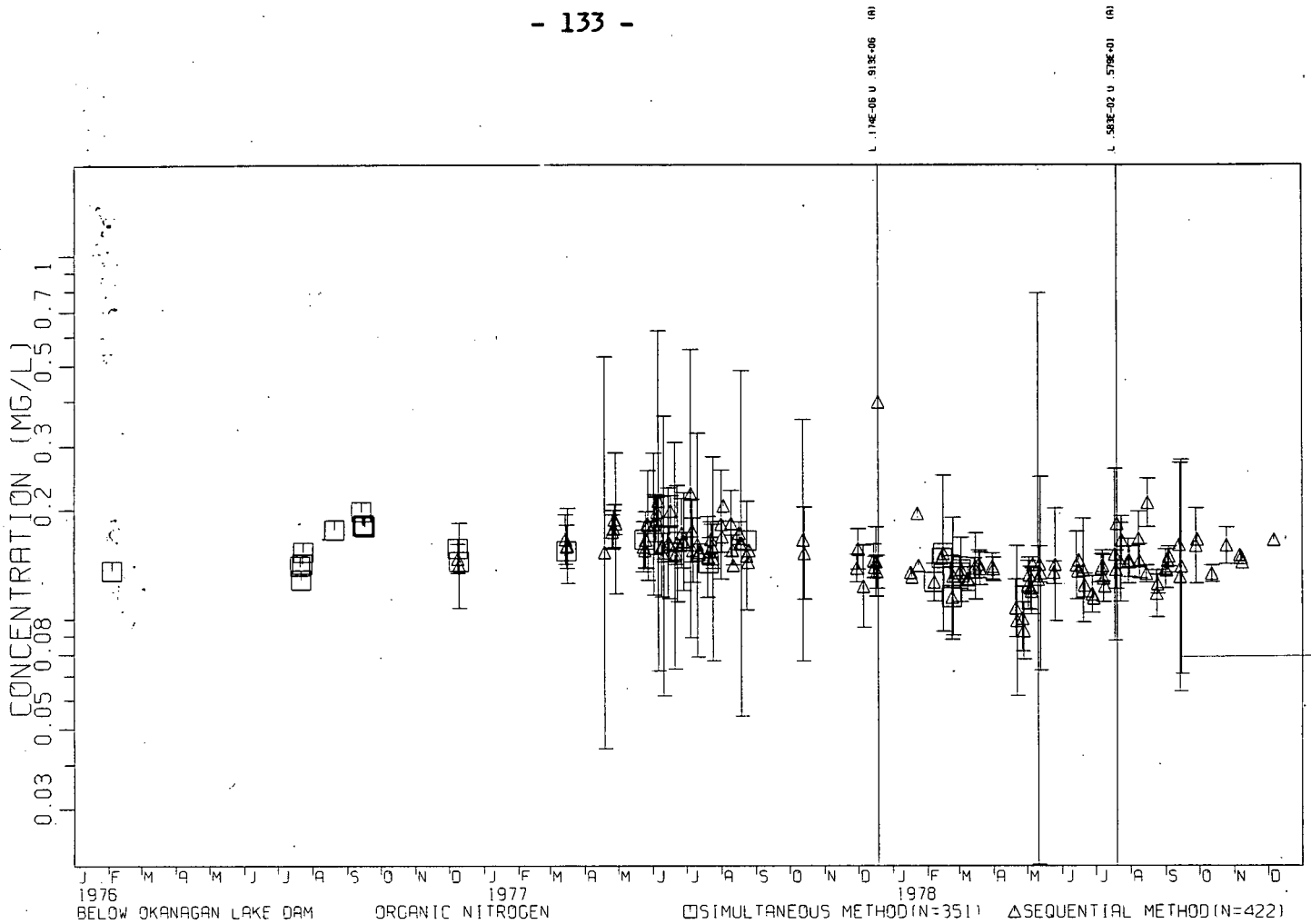

LOAD (KG/DAY)
0.03 0.2 0.5 2 3 5 8 20 40 80 200 500 2000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
AMMONIA (N)
SIMULTANEOUS METHOD(N=24)
SEQUENTIAL METHOD(N=138)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
AMMONIA(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 02	6	0.006	0.014	0.010	0.0034	0.0014	±0.0036							
1976 07	36	0.002	0.076	0.009	0.0122	0.0020	±0.0041							
1976 08	18	0.012	0.132	0.045	0.0339	0.0080	±0.0168							
1976 09	108	0.002	0.031	0.011	0.0065	0.0006	±0.0012							
1976 12	66	0.002	0.042	0.007	0.0064	0.0008	±0.0016	5	0.005	0.127	0.031	0.0535	0.0239	±0.0664
1977 03	24	0.002	0.018	0.006	0.0035	0.0007	±0.0015	9	0.007	0.014	0.010	0.0019	0.0006	±0.0015
1977 04								14	0.002	0.109	0.058	0.0339	0.0091	±0.0195
1977 05	24	0.005	0.017	0.009	0.0031	0.0006	±0.0013	14	0.010	0.046	0.026	0.0097	0.0026	±0.0056
1977 06	24	0.002	0.028	0.012	0.0067	0.0014	±0.0028	49	0.002	0.060	0.025	0.0153	0.0022	±0.0044
1977 07	12	0.007	0.029	0.014	0.0061	0.0018	±0.0039	36	0.002	0.094	0.038	0.0220	0.0037	±0.0075
1977 08	12	0.002	0.005	0.002	0.0009	0.0003	±0.0006	32	0.002	0.160	0.070	0.0439	0.0078	±0.0158
1977 10								4	0.002	0.009	0.004	0.0035	0.0017	±0.0056
1977 11								4	0.002	0.009	0.004	0.0034	0.0017	±0.0054
1977 12								22	0.002	0.076	0.010	0.0165	0.0035	±0.0073
1978 01								4	0.006	0.032	0.017	0.0118	0.0059	±0.0188
1978 02	15	0.002	0.035	0.012	0.0130	0.0034	±0.0072	15	0.002	0.035	0.012	0.0130	0.0034	±0.0072
1978 03	6	0.002	0.003	0.002	0.0004	0.0002	±0.0004	34	0.002	0.082	0.011	0.0170	0.0029	±0.0059
1978 04								20	0.006	0.100	0.045	0.0256	0.0057	±0.0120
1978 05								30	0.011	0.170	0.038	0.0328	0.0060	±0.0122
1978 06								24	0.002	0.110	0.038	0.0330	0.0067	±0.0139
1978 07								40	0.033	0.350	0.118	0.0669	0.0106	±0.0214
1978 08								24	0.025	0.330	0.110	0.0799	0.0163	±0.0337
1978 09								25	0.007	0.150	0.063	0.0327	0.0065	±0.0135
1978 10								7	0.002	0.039	0.020	0.0170	0.0064	±0.0157
1978 11								8	0.002	0.009	0.004	0.0027	0.0009	±0.0022
1978 12								2	0.002	0.002	0.002	0.0	0.0	±0.0
						LOAD (KG/DAY)								
1976 02	1	25.78	25.78	25.78										
1976 07	4	18.78	39.67	28.03	9.77	4.89	±15.55							
1976 08	1	101.02	101.02	101.02										
1976 09	4	14.80	33.17	25.82	7.81	3.91	±12.43							
1976 12	2	9.90	18.84	14.37	6.32	4.47	±56.81	2	22.85	155.92	89.39	94.09	66.53	±845.38
1977 03	1	2.47	2.47	2.47				3	3.36	4.82	3.91	0.80	0.46	±1.98
1977 04								5	1.85	50.76	29.87	17.68	7.91	±21.95
1977 05	1	4.03	4.03	4.03				5	8.12	14.07	10.23	2.51	1.12	±3.12
1977 06	1	7.76	7.76	7.76				17	3.44	22.09	11.85	6.15	1.49	±3.16
1977 07	1	11.74	11.74	11.74				12	6.32	68.40	33.00	16.93	4.89	±10.76
1977 08	1	2.19	2.19	2.19				12	11.81	145.34	61.92	43.41	12.53	±27.58
1977 10								2	1.72	6.19	3.96	3.16	2.24	±28.42
1977 11								1	1.46	1.46	1.46			
1977 12								7	1.11	12.18	3.39	3.99	1.51	±3.69
1978 01								4	1.62	25.75	10.79	10.60	5.30	±16.87
1978 02	5	0.88	15.13	5.07	5.87	2.63	±7.29	5	4.42	75.81	24.24	29.68	13.27	±36.84
1978 03	2	0.35	0.78	0.57	0.30	0.21	±2.70	9	1.77	43.25	15.72	13.39	4.46	±10.29
1978 04								5	10.30	124.21	61.53	46.43	20.77	±57.65
1978 05								10	28.54	358.83	152.05	120.21	38.01	±85.98
1978 06								7	2.61	101.25	37.53	37.32	14.10	±34.51
1978 07								11	54.06	241.86	117.75	62.34	18.80	±41.88
1978 08								6	58.42	313.28	124.77	96.51	39.40	±101.29
1978 09								9	5.97	119.31	63.68	36.14	12.05	±27.78
1978 10								2	4.04	48.76	26.40	31.62	22.36	±284.05
1978 11								3	7.26	8.74	8.03	0.74	0.43	±1.84
1978 12								1	2.75	2.75	2.75			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
AMMONIA(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	234	0.002	0.132	0.012	0.0152	0.0010	±0.0020	5	0.005	0.127	0.031	0.0535	0.0239	±0.0664
1977	96	0.002	0.029	0.009	0.0058	0.0006	±0.0012	184	0.002	0.160	0.035	0.0323	0.0024	±0.0047
1978	21	0.002	0.035	0.009	0.0118	0.0026	±0.0054	233	0.002	0.350	0.054	0.0592	0.0039	±0.0076
						LOAD (KG/DAY)								
1976	12	9.90	101.02	30.91	23.62	6.82	±15.00	2	22.85	155.92	89.39	94.09	66.53	±845.38
1977	5	2.19	11.74	5.64	4.07	1.82	±5.05	64	1.11	145.34	24.78	29.05	3.63	±7.26
1978	7	0.35	15.13	3.78	5.28	1.99	±4.88	72	1.62	358.83	70.74	78.59	9.26	±18.47


L .174E-06 U .913E-06 (A)
L .583E-02 U .579E-01 (A)
CONCENTRATION (MG/L)
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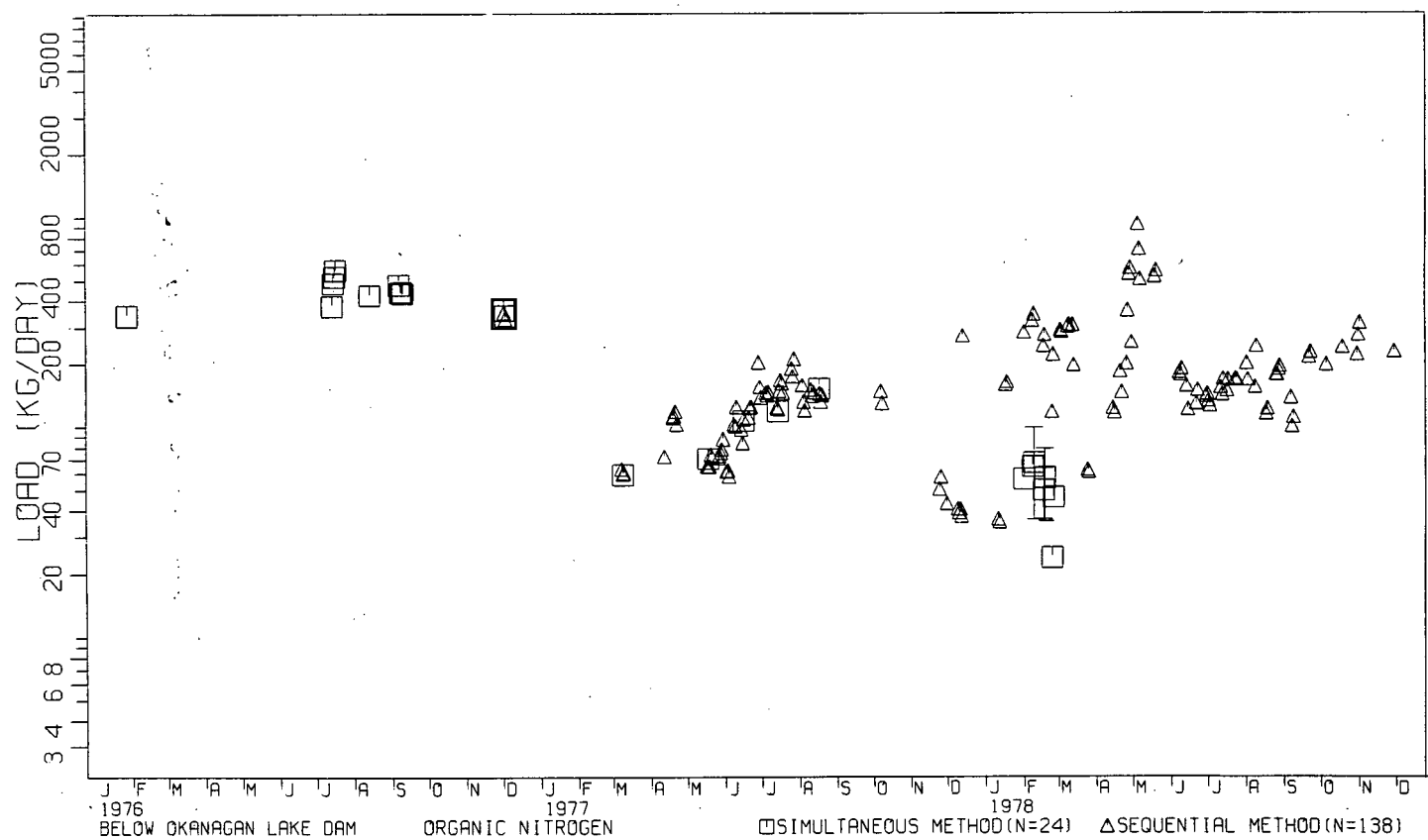
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
ORGANIC NITROGEN
SIMULTANEOUS METHOD(N=351)
SEQUENTIAL METHOD(N=422)

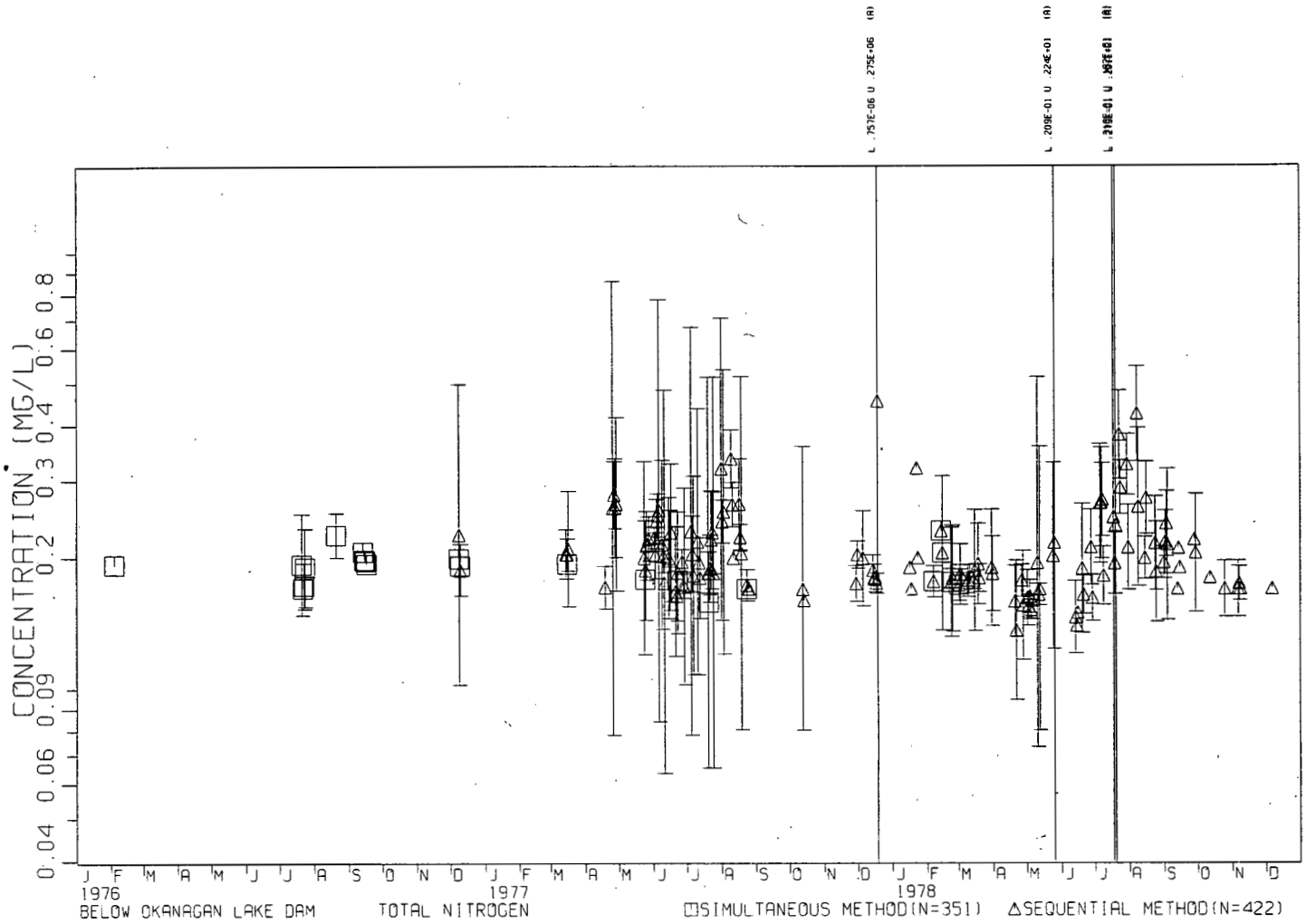

LOAD (KG/DAY)
3 4 6 8 20 40 70 200 400 800 2000 5000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
ORGANIC NITROGEN
SIMULTANEOUS METHOD(N=24)
SEQUENTIAL METHOD(N=138)

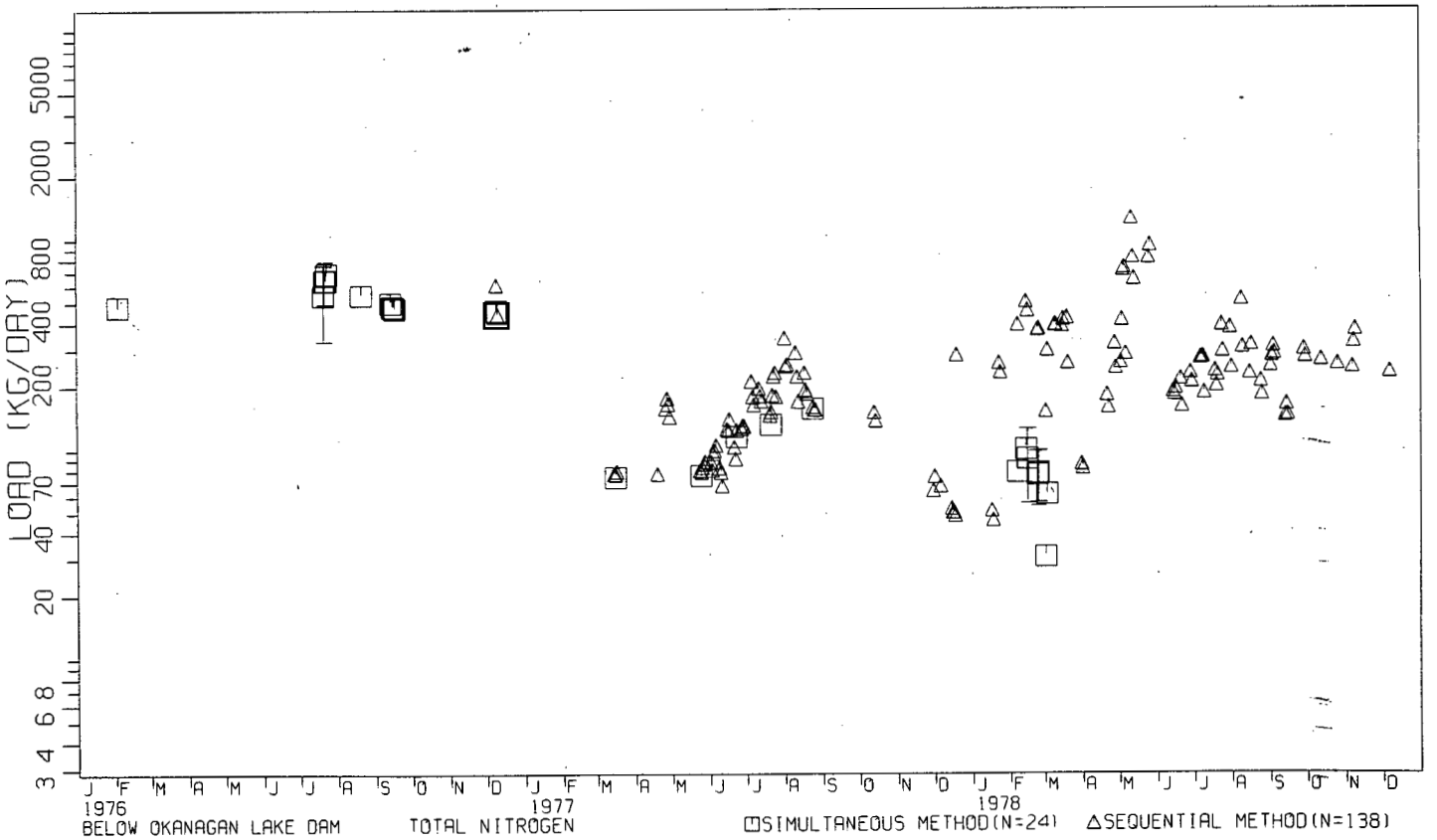
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
ORGANIC NITROGEN

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 02	6	0.131	0.142	0.136	0.0038	0.0016	±0.0040							
1976 07	36	0.115	0.184	0.142	0.0156	0.0026	±0.0053							
1976 08	18	0.146	0.231	0.178	0.0231	0.0054	±0.0115							
1976 09	108	0.147	0.278	0.185	0.0225	0.0022	±0.0043							
1976 12	66	0.114	0.190	0.149	0.0154	0.0019	±0.0038	5	0.138	0.153	0.145	0.0056	0.0025	±0.0070
1977 03	24	0.137	0.182	0.155	0.0124	0.0025	±0.0053	9	0.152	0.181	0.162	0.0109	0.0036	±0.0084
1977 04								14	0.139	0.197	0.178	0.0157	0.0042	±0.0090
1977 05	24	0.086	0.201	0.168	0.0213	0.0043	±0.0090	14	0.143	0.187	0.168	0.0142	0.0038	±0.0082
1977 06	24	0.139	0.183	0.164	0.0115	0.0024	±0.0049	49	0.140	0.231	0.172	0.0210	0.0030	±0.0060
1977 07	12	0.129	0.169	0.144	0.0135	0.0039	±0.0086	36	0.140	0.239	0.162	0.0201	0.0034	±0.0068
1977 08	12	0.126	0.213	0.167	0.0259	0.0075	±0.0165	32	0.137	0.206	0.165	0.0191	0.0034	±0.0069
1977 10								4	0.149	0.176	0.159	0.0116	0.0058	±0.0185
1977 11								4	0.133	0.150	0.139	0.0078	0.0039	±0.0124
1977 12								22	0.110	1.263	0.191	0.2397	0.0511	±0.1063
1978 01								4	0.131	0.196	0.151	0.0304	0.0152	±0.0484
1978 02	15	0.106	0.172	0.136	0.0204	0.0053	±0.0113	15	0.106	0.172	0.136	0.0204	0.0053	±0.0113
1978 03	6	0.125	0.145	0.136	0.0080	0.0032	±0.0084	34	0.122	0.167	0.137	0.0095	0.0016	±0.0033
1978 04								20	0.069	0.147	0.109	0.0216	0.0048	±0.0101
1978 05								30	0.108	0.155	0.132	0.0120	0.0022	±0.0045
1978 06								24	0.107	0.186	0.129	0.0167	0.0034	±0.0071
1978 07								40	0.118	0.241	0.145	0.0218	0.0034	±0.0070
1978 08								24	0.110	0.233	0.150	0.0341	0.0070	±0.0144
1978 09								25	0.124	0.167	0.146	0.0120	0.0024	±0.0049
1978 10								7	0.129	0.168	0.145	0.0151	0.0057	±0.0139
1978 11								8	0.144	0.152	0.149	0.0034	0.0012	±0.0029
1978 12								2	0.166	0.166	0.166	0.0	0.0	±0.0
						LOAD (KG/DAY)								
1976 02	1	339.35	339.35	339.35										
1976 07	4	375.85	560.33	484.90	79.29	39.65	±126.15							
1976 08	1	423.79	423.79	423.79										
1976 09	4	431.07	475.34	445.06	20.40	10.20	±32.45							
1976 12	2	336.63	359.55	348.09	16.21	11.46	±145.60	2	326.99	350.09	338.54	16.33	11.55	±146.73
1977 03	1	58.68	58.68	58.68				3	59.47	62.55	60.64	1.67	0.96	±4.14
1977 04								5	71.79	118.23	102.81	18.25	8.16	±22.65
1977 05	1	69.94	69.94	69.94				5	64.08	73.21	67.51	4.52	2.02	±5.61
1977 06	1	106.01	106.01	106.01				17	57.82	123.80	90.20	22.62	5.49	±11.63
1977 07	1	117.75	117.75	117.75				12	120.61	201.51	148.73	21.25	6.13	±13.50
1977 08	1	151.43	151.43	151.43				12	119.06	209.78	152.33	26.25	7.58	±16.68
1977 10								2	128.83	147.01	137.92	12.85	9.09	±115.49
1977 11								1	50.48	50.48	50.48			
1977 12								7	37.53	270.60	75.53	86.28	32.61	±79.80
1978 01								4	35.34	163.32	98.16	72.03	36.02	±114.60
1978 02	5	49.71	67.23	58.87	7.01	3.13	±8.70	5	243.33	344.69	293.38	40.05	17.91	±49.72
1978 03	2	23.81	45.96	34.88	15.67	11.08	±140.75	9	62.27	309.48	232.61	90.92	30.31	±69.89
1978 04								5	61.12	183.69	126.20	44.80	20.03	±55.62
1978 05								10	200.75	927.76	515.49	212.36	67.15	±151.90
1978 06								7	121.44	190.43	157.84	26.76	10.11	±24.75
1978 07								11	126.39	169.44	150.88	15.67	4.72	±10.52
1978 08								6	115.18	241.88	166.83	48.17	19.67	±50.56
1978 09								9	99.96	227.03	169.73	44.49	14.83	±34.20
1978 10								2	197.98	238.59	218.29	28.72	20.31	±258.03
1978 11								3	221.09	314.47	269.90	46.83	27.04	±116.35
1978 12								1	227.98	227.98	227.98			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
ORGANIC NITROGEN

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	234	0.114	0.278	0.166	0.0276	0.0018	±0.0036	5	0.138	0.153	0.145	0.0056	0.0025	±0.0070
1977	96	0.086	0.213	0.160	0.0186	0.0019	±0.0038	184	0.110	1.263	0.170	0.0836	0.0062	±0.0122
1978	21	0.106	0.172	0.136	0.0175	0.0038	±0.0080	233	0.069	0.241	0.138	0.0219	0.0014	±0.0028
LOAD (KG/DAY)														
1976	12	336.63	560.33	431.60	70.70	20.41	±44.92	2	326.99	350.09	338.54	16.33	11.55	±146.73
1977	5	58.68	151.43	100.76	37.43	16.74	±46.47	64	37.53	270.60	109.92	47.67	5.96	±11.91
1978	7	23.81	67.23	52.02	14.51	5.49	±13.42	72	35.34	927.76	229.25	153.23	18.06	±36.01


CONCENTRATION (MG/L)
0.04 0.06 0.09 0.2 0.3 0.4 0.6 0.8
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
TOTAL NITROGEN
SIMULTANEOUS METHOD(N=351)
SEQUENTIAL METHOD(N=422)

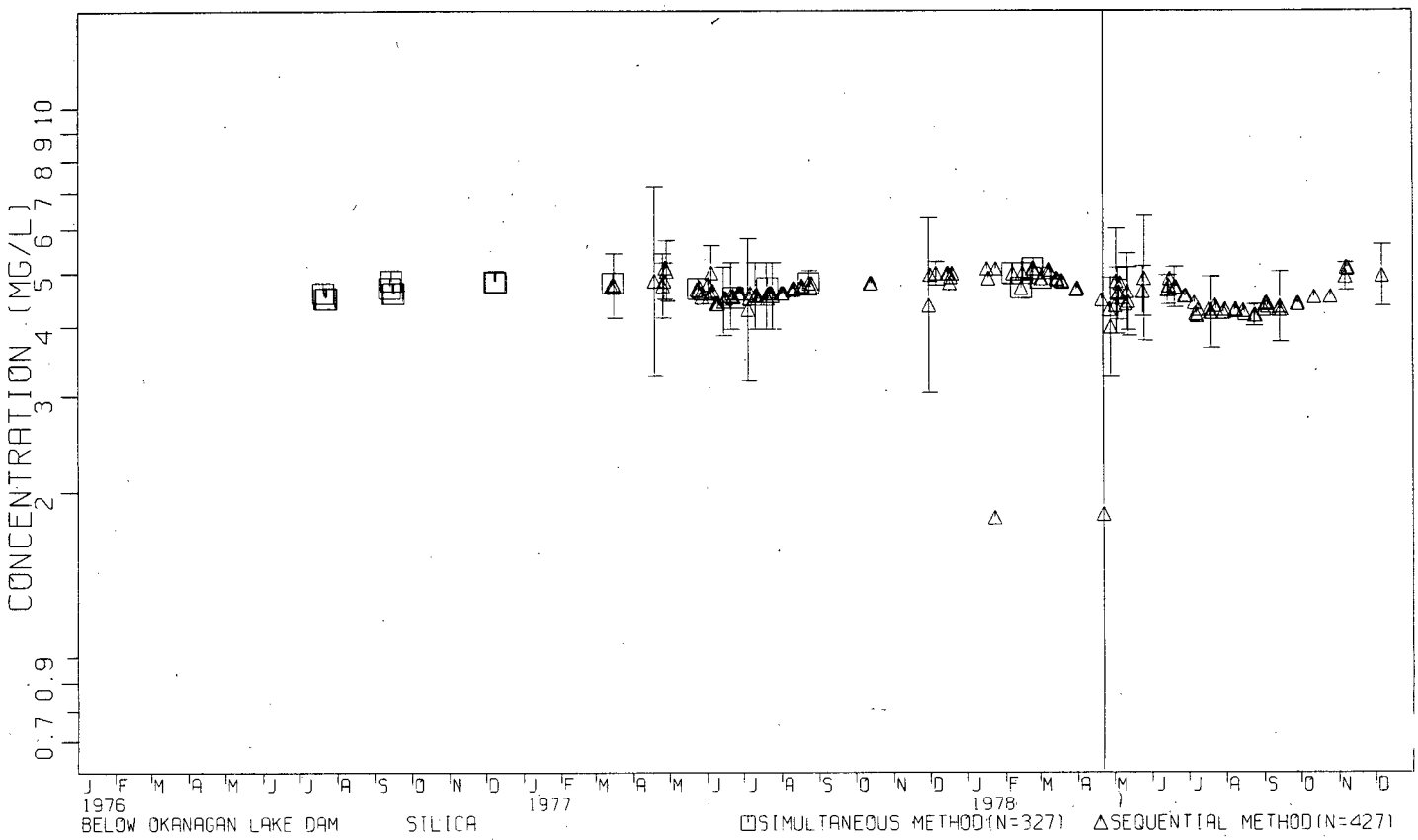

LOAD (KG/DAY)
3 4 6 8 20 40 70 200 400 800 2000 5000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM
TOTAL NITROGEN
SIMULTANEOUS METHOD(N=24)
SEQUENTIAL METHOD(N=138)

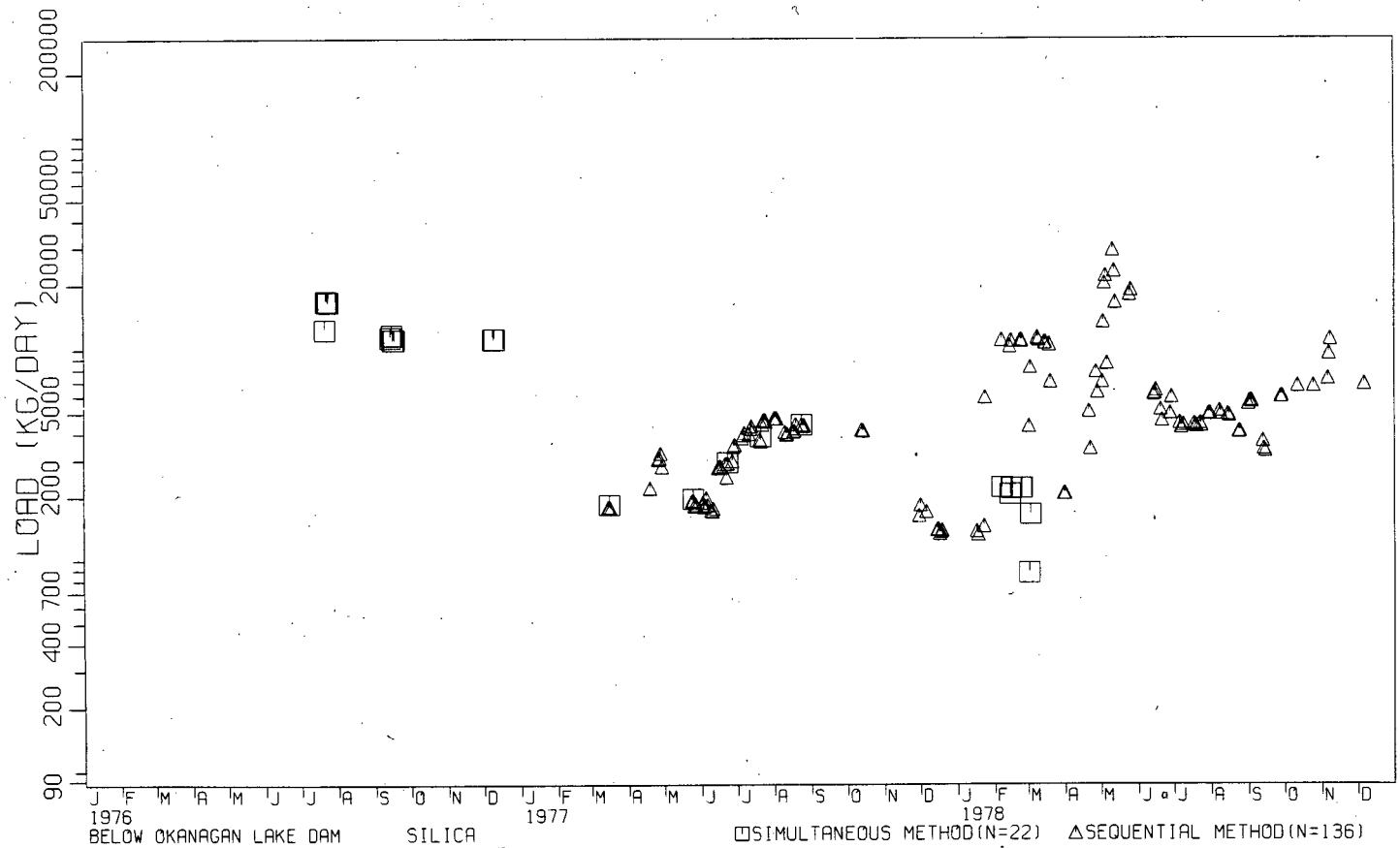
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL NITROGEN(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 02	6	0.190	0.195	0.193	0.0021	0.0008	±0.0022							
1976 07	36	0.138	0.425	0.187	0.0553	0.0092	±0.0187							
1976 08	18	0.160	0.350	0.231	0.0560	0.0132	±0.0278							
1976 09	108	0.152	0.305	0.200	0.0263	0.0025	±0.0050							
1976 12	66	0.170	0.257	0.195	0.0181	0.0022	±0.0045	5	0.185	0.326	0.216	0.0618	0.0276	±0.0767
1977 03	24	0.174	0.230	0.194	0.0152	0.0031	±0.0064	9	0.192	0.220	0.205	0.0093	0.0031	±0.0072
1977 04								14	0.170	0.325	0.255	0.0453	0.0121	±0.0262
1977 05	24	0.095	0.215	0.180	0.0224	0.0046	±0.0095	14	0.156	0.230	0.206	0.0207	0.0055	±0.0120
1977 06	24	0.145	0.204	0.178	0.0160	0.0033	±0.0068	49	0.155	0.280	0.203	0.0323	0.0046	±0.0093
1977 07	12	0.140	0.200	0.159	0.0188	0.0054	±0.0120	36	0.170	0.280	0.202	0.0270	0.0045	±0.0091
1977 08	12	0.130	0.220	0.172	0.0266	0.0077	±0.0169	32	0.170	0.360	0.237	0.0547	0.0097	±0.0197
1977 10								4	0.160	0.180	0.165	0.0100	0.0050	±0.0159
1977 11								4	0.160	0.180	0.175	0.0100	0.0050	±0.0159
1977 12								22	0.160	1.300	0.236	0.2380	0.0507	±0.1055
1978 01								4	0.170	0.320	0.220	0.0678	0.0339	±0.1079
1978 02	15	0.160	0.230	0.194	0.0275	0.0071	±0.0152	15	0.160	0.230	0.194	0.0275	0.0071	±0.0152
1978 03	6	0.170	0.190	0.178	0.0098	0.0040	±0.0103	34	0.160	0.250	0.183	0.0211	0.0036	±0.0074
1978 04								20	0.097	0.220	0.164	0.0260	0.0058	±0.0122
1978 05								30	0.150	0.320	0.173	0.0353	0.0064	±0.0132
1978 06								24	0.140	0.260	0.170	0.0326	0.0066	±0.0138
1978 07								40	0.160	0.470	0.265	0.0685	0.0108	±0.0219
1978 08								24	0.150	0.490	0.263	0.0921	0.0188	±0.0389
1978 09								25	0.170	0.310	0.212	0.0307	0.0061	±0.0127
1978 10								7	0.160	0.180	0.176	0.0079	0.0030	±0.0073
1978 11								8	0.160	0.190	0.173	0.0089	0.0031	±0.0074
1978 12								2	0.170	0.170	0.170	0.0	0.0	±0.0
						LOAD (KG/DAY)								
1976 02	1	480.75	480.75	480.75										
1976 07	4	538.55	685.32	624.65	61.70	30.85	±98.16							
1976 08	1	540.63	540.63	540.63										
1976 09	4	465.93	495.74	477.98	12.76	6.38	±20.31							
1976 12	2	447.63	457.01	452.32	6.63	4.69	±59.61	2	438.33	604.86	521.60	117.75	83.26	±1057.90
1977 03	1	73.82	73.82	73.82				3	75.98	78.82	77.18	1.47	0.85	±3.66
1977 04								5	76.79	175.34	143.01	38.88	17.39	±48.26
1977 05	1	75.25	75.25	75.25				5	78.09	87.82	82.67	3.96	1.77	±4.91
1977 06	1	115.31	115.31	115.31				17	67.26	138.96	104.81	22.13	5.37	±11.38
1977 07	1	131.12	131.12	131.12				12	144.80	230.52	183.56	26.58	7.67	±16.89
1977 08	1	155.56	155.56	155.56				12	154.46	336.59	216.09	58.05	16.76	±36.89
1977 10								2	136.74	150.45	143.59	9.70	6.86	±87.14
1977 11								1	63.67	63.67	63.67			
1977 12								7	48.38	280.63	88.99	85.09	32.16	±78.70
1978 01								4	45.86	257.46	146.51	113.73	56.86	±180.94
1978 02	5	75.92	100.35	84.30	10.62	4.75	±13.18	5	370.63	501.79	419.40	57.69	25.80	±71.62
1978 03	2	30.64	61.21	45.92	21.61	15.28	±194.18	9	85.32	421.61	311.16	123.15	41.05	±94.66
1978 04								5	81.94	320.20	197.63	90.07	40.28	±111.82
1978 05								10	260.45	1245.30	685.99	303.25	95.90	±216.92
1978 06								7	160.95	231.94	198.14	23.59	8.91	±21.81
1978 07								11	186.36	392.05	271.46	65.68	19.80	±44.12
1978 08								6	182.57	516.40	293.84	121.19	49.48	±127.21
1978 09								9	144.90	310.38	239.65	68.15	22.72	±52.39
1978 10								2	253.67	265.94	259.80	8.68	6.14	±77.97
1978 11								3	246.47	371.25	314.28	63.09	36.43	±156.74
1978 12									233.48	233.48	233.48			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
TOTAL NITROGEN(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	234	0.138	0.425	0.198	0.0347	0.0023	±0.0045	5	0.185	0.326	0.216	0.0618	0.0276	±0.0767
1977	96	0.095	0.230	0.180	0.0218	0.0022	±0.0044	184	0.155	1.300	0.216	0.0896	0.0066	±0.0130
1978	21	0.160	0.230	0.189	0.0246	0.0054	±0.0112	233	0.097	0.490	0.205	0.0612	0.0040	±0.0079
						LOAD (KG/DAY)								
1976	12	447.63	685.32	528.04	81.56	23.54	±51.82	2	438.33	604.86	521.60	117.75	83.26	±1057.90
1977	5	73.82	155.56	110.21	35.59	15.92	±44.19	64	48.38	336.59	139.24	65.22	8.15	±16.29
1978	7	30.64	100.35	73.34	22.44	8.48	±20.76	72	45.86	1245.30	323.89	205.19	24.18	±48.22


CONCENTRATION (MG/L)
0.7 0.9 2 3 4 5 6 7 8 9 10
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM SILICA
SIMULTANEOUS METHOD(N=327) SEQUENTIAL METHOD(N=427)


LOAD (KG/DAY)
90 200 400 700 2000 5000 20000 50000 200000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
BELOW OKANAGAN LAKE DAM SILICA
SIMULTANEOUS METHOD(N=22) SEQUENTIAL METHOD(N=136)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
DISSOLVED SILICA

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 07	36	4.500	4.600	4.525	0.0439	0.0073	±0.0149							
1976 09	108	4.600	5.000	4.700	0.1421	0.0137	±0.0271							
1976 12	66	4.800	4.900	4.818	0.0389	0.0048	±0.0096							
1977 03	24	4.800	4.800	4.800	0.0	0.0	±0.0	9	4.700	4.800	4.756	0.0527	0.0176	±0.0405
1977 04								14	4.700	5.200	4.943	0.1989	0.0532	±0.1148
1977 05	24	4.600	5.900	4.696	0.2612	0.0533	±0.1103	20	4.500	4.800	4.635	0.0875	0.0196	±0.0410
1977 06	24	4.500	4.600	4.512	0.0338	0.0069	±0.0143	53	4.400	5.500	4.585	0.1854	0.0255	±0.0511
1977 07	12	4.700	4.700	4.700	0.0	0.0	±0.0	36	4.200	4.600	4.544	0.0843	0.0141	±0.0285
1977 08	12	4.800	4.800	4.800	0.0	0.0	±0.0	32	4.600	4.900	4.691	0.0818	0.0145	±0.0295
1977 10								4	4.800	4.800	4.800	0.0	0.0	±0.0
1977 11								4	3.100	4.900	4.450	0.9000	0.4500	±1.4319
1977 12								22	4.800	5.100	4.964	0.0790	0.0168	±0.0350
1978 01								4	1.800	5.100	4.225	1.6194	0.8097	±2.5765
1978 02	15	4.700	5.100	4.980	0.1521	0.0393	±0.0843	15	4.700	5.100	4.980	0.1521	0.0393	±0.0843
1978 03	6	4.900	4.900	4.900	0.0	0.0	±0.0	34	4.600	5.100	4.891	0.1190	0.0204	±0.0415
1978 04								20	0.200	4.700	4.095	1.0272	0.2297	±0.4808
1978 05								30	4.200	5.500	4.627	0.3383	0.0618	±0.1263
1978 06								24	4.400	5.000	4.671	0.1517	0.0310	±0.0641
1978 07								40	4.200	4.500	4.290	0.0810	0.0128	±0.0259
1978 08								24	4.100	4.400	4.246	0.0779	0.0159	±0.0329
1978 09								25	4.300	4.500	4.364	0.0638	0.0128	±0.0263
1978 10								7	4.500	4.600	4.529	0.0488	0.0184	±0.0451
1978 11								8	4.800	5.200	5.050	0.1195	0.0423	±0.0999
1978 12								2	4.900	5.000	4.950	0.0707	0.0500	±0.6353
LOAD (KG/DAY)														
1976 07	4	12269.00	16734.00	15563.00	2196.80	1098.40	±3495.10							
1976 09	4	11029.00	11628.00	11242.00	283.76	141.88	±451.46							
1976 12	2	11118.00	11142.00	11130.00	16.93	11.97	±152.12							
1977 03	1	1820.60	1820.60	1820.60				3	1752.70	1780.80	1769.10	14.61	8.44	±36.30
1977 04								5	2193.90	3205.90	2841.60	393.95	176.18	±489.07
1977 05	1	1954.70	1954.70	1954.70				5	1796.00	1919.40	1851.90	56.21	25.14	±69.78
1977 06	1	2902.00	2902.00	2902.00				17	1695.50	3515.40	2401.90	632.78	153.47	±325.36
1977 07	1	3837.50	3837.50	3837.50				12	3661.00	4610.30	4140.20	341.92	98.70	±217.25
1977 08	1	4367.00	4367.00	4367.00				12	3924.40	4701.60	4302.80	285.10	82.30	±181.14
1977 10								2	4102.10	4126.50	4114.30	17.23	12.18	±154.79
1977 11								1	1619.00	1619.00	1619.00			
1977 12								7	1332.30	1824.70	1483.50	193.17	73.01	±178.65
1978 01								4	1321.90	5907.30	2512.00	2264.20	1132.10	±3602.30
1978 02	5	2050.70	2207.50	2163.10	63.72	28.50	±79.10	5	10254.00	11038.00	10816.00	318.81	142.57	±395.79
1978 03	2	866.19	1635.90	1251.00	544.24	384.83	±4889.70	9	2072.10	11334.00	8432.10	3343.00	1114.40	±2569.70
1978 04								5	2081.70	7793.10	4925.50	2263.40	1012.20	±2809.90
1978 05								10	7013.20	29218.00	17740.00	6747.40	2133.70	±4826.50
1978 06								7	4609.00	6391.10	5628.30	698.30	263.93	±645.84
1978 07								11	4269.70	4975.30	4480.70	243.98	73.56	±163.90
1978 08								6	4082.30	5114.20	4664.40	456.74	186.46	±479.39
1978 09								9	3304.40	5990.50	4987.80	1166.10	388.69	±896.33
1978 10								2	6685.40	6690.90	6688.20	3.88	2.74	±34.86
1978 11								3	7210.30	11137.00	9282.40	1972.50	1138.90	±4900.50
1978 12								1	6795.30	6795.30	6795.30			

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER BELOW OKANAGAN LAKE DAM
DISSOLVED SILICA

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	210	4.500	5.000	4.707	0.1441	0.0099	±0.0196							
1977	96	4.500	5.900	4.690	0.1714	0.0175	±0.0347	194	3.100	5.500	4.678	0.2245	0.0161	±0.0318
1978	21	4.700	5.100	4.957	0.1326	0.0289	±0.0603	233	0.200	5.500	4.529	0.4780	0.0313	±0.0617
						LOAD (KG/DAY)								
1976	10	11029.00	16734.00	12948.00	2589.10	818.76	±1852.00							
1977	5	1820.60	4367.00	2976.40	1124.80	503.01	±1396.40	64	1332.30	4701.60	2986.80	1149.40	143.68	±287.07
1978	7	866.19	2207.50	1902.50	500.13	189.03	±462.56	72	1321.90	29218.00	7661.40	5362.80	632.01	±1260.20

APPENDIX C

Okanagan River near the Penticton airport, 1976 to 1978

Concentrations and loads derived from simultaneous and sequential measurements are shown in (1) graphs and (2) tables.

1. Graphs

   Graphs illustrate time series of

   (a) the daily geometric concentration means (mg l^{-1}) and their 95 percent confidence limits, and

   (b) the daily total loads (kg day^{-1}) of nutrients during the three-year period.

2. Tables

   Tables show statistical characteristics of nutrient concentrations and loads, reduced to the (a) monthly and (b) annual basis, in terms of

   (a_i) the arithmetic concentration means (mg l^{-1}), and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given month of sampling,

   (a_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given month of sampling.

   (b_i) the arithemetic concentration means (mg l^{-1}) and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given year of sampling,

   (b_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given year of sampling.

C1 Time series of total phosphorus (P) concentration and loads, 1976 to 1978

C2 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual months of sampling

C3 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual year of sampling

C4 Time series of total dissolved phosphorus (P) concentration and loads, 1976 to 1978

C5 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual months of sampling

C6 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual year of sampling

C7 Time series of nitrate plus nitrite (N) concentration and loads, 1976 to 1978

C8 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual months of sampling

C9 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual year of sampling

C10 Time series of ammonia (N) concentration and loads, 1976 to 1978

C11 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual months of sampling

C12 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual year of sampling

C13 Time series of organic nitrogen (N) concentration and loads, 1976 to 1978

C14 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual months of sampling

C15 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual year of sampling

C16 Time series of total nitrogen (N) concentration and loads, 1976 to 1978

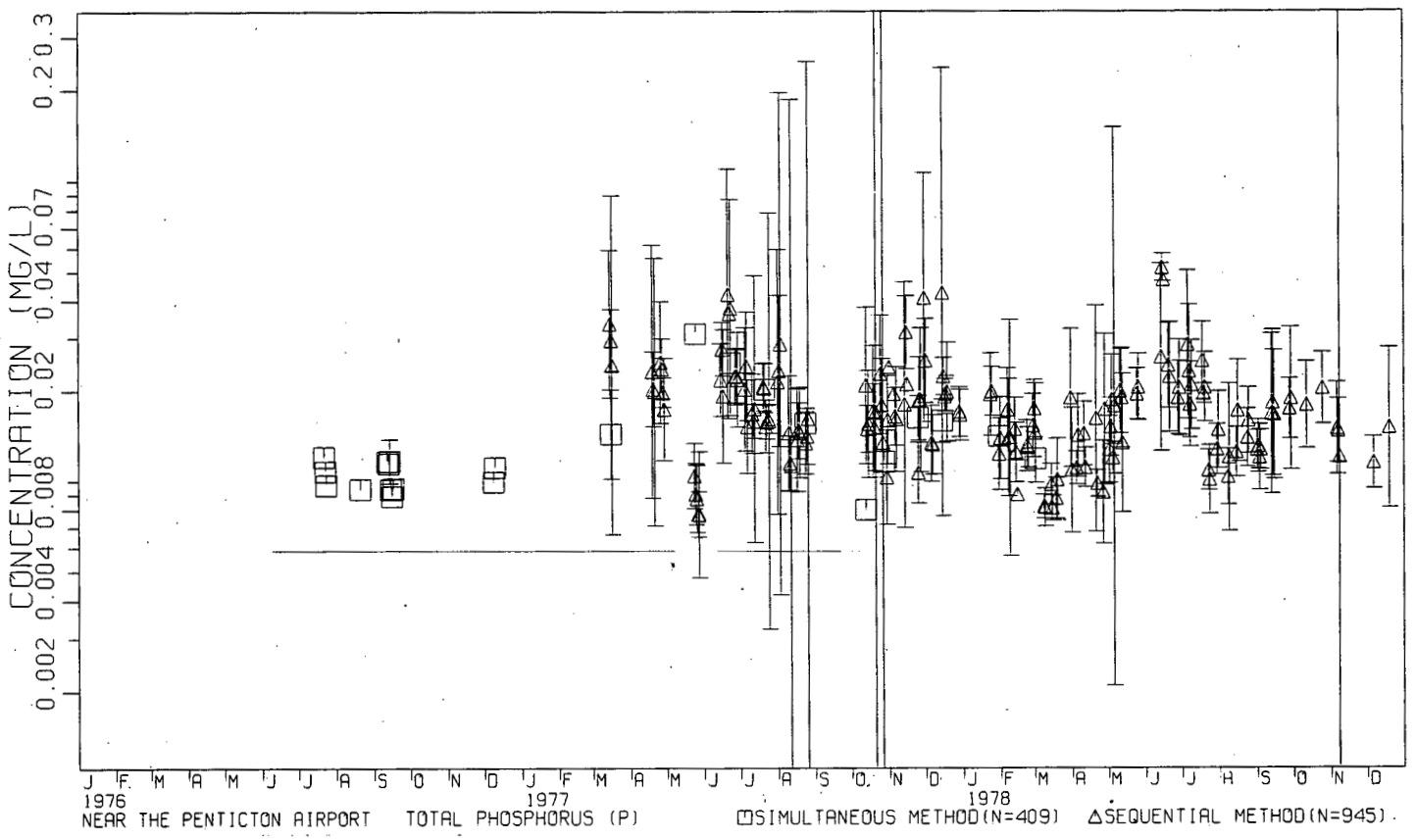
C17 Statistical characteristics of concentration and load data of total nitrogen (N) determined for the individual months of sampling

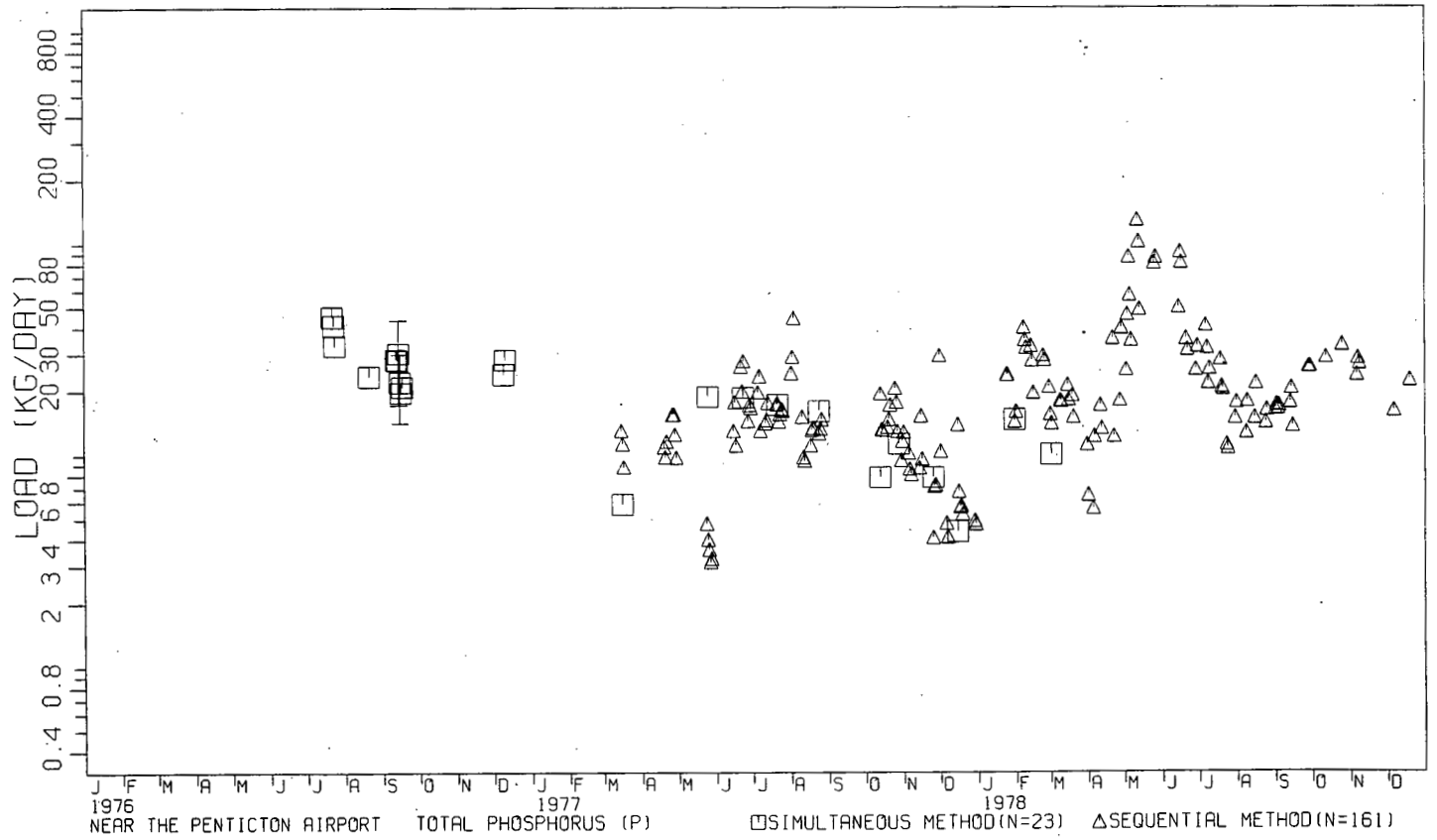
C18 Statistical characteristics of concentration and load data of total nitrogen (N) determined for the individual year of sampling

C19 Time series of dissolved silica concentration and loads, 1976 to 1978

C20 Statistical characteristics of concentration and load data of dissolved silica determined for the individual months of sampling

C21 Statistical characteristics of concentration and load data of dissolved silica determined for the individual year of sampling


CONCENTRATION (MG/L)
0.002 0.004 0.008 0.02 0.04 0.07 0.2 0.3
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT TOTAL PHOSPHORUS (P)
SIMULTANEOUS METHOD(N=409)
SEQUENTIAL METHOD(N=945)

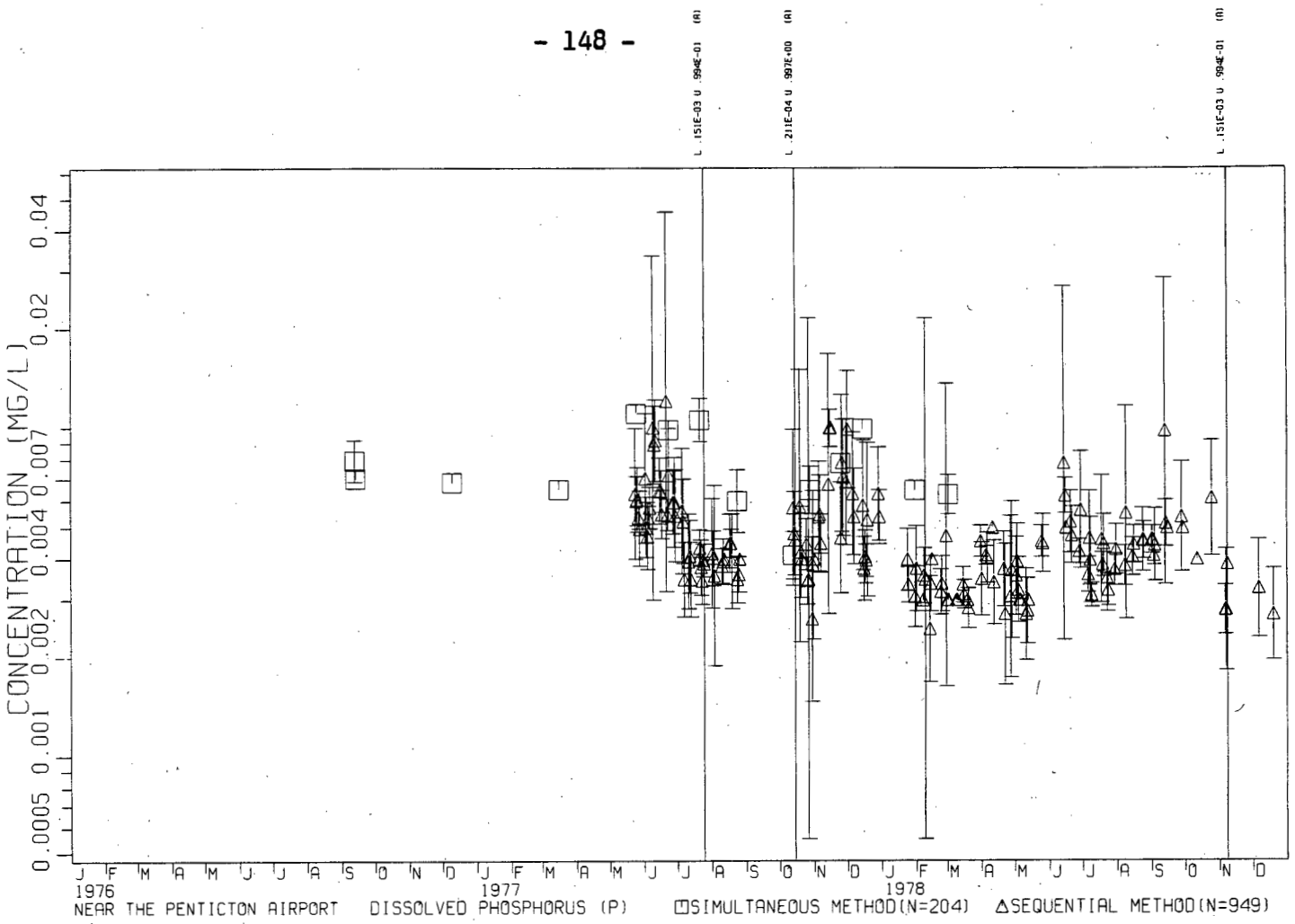

LOAD (KG/DAY)
0.4 0.8 2 3 4 6 8 20 30 50 80 200 400 800
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT TOTAL PHOSPHORUS (P)
SIMULTANEOUS METHOD(N=23)
SEQUENTIAL METHOD(N=161)

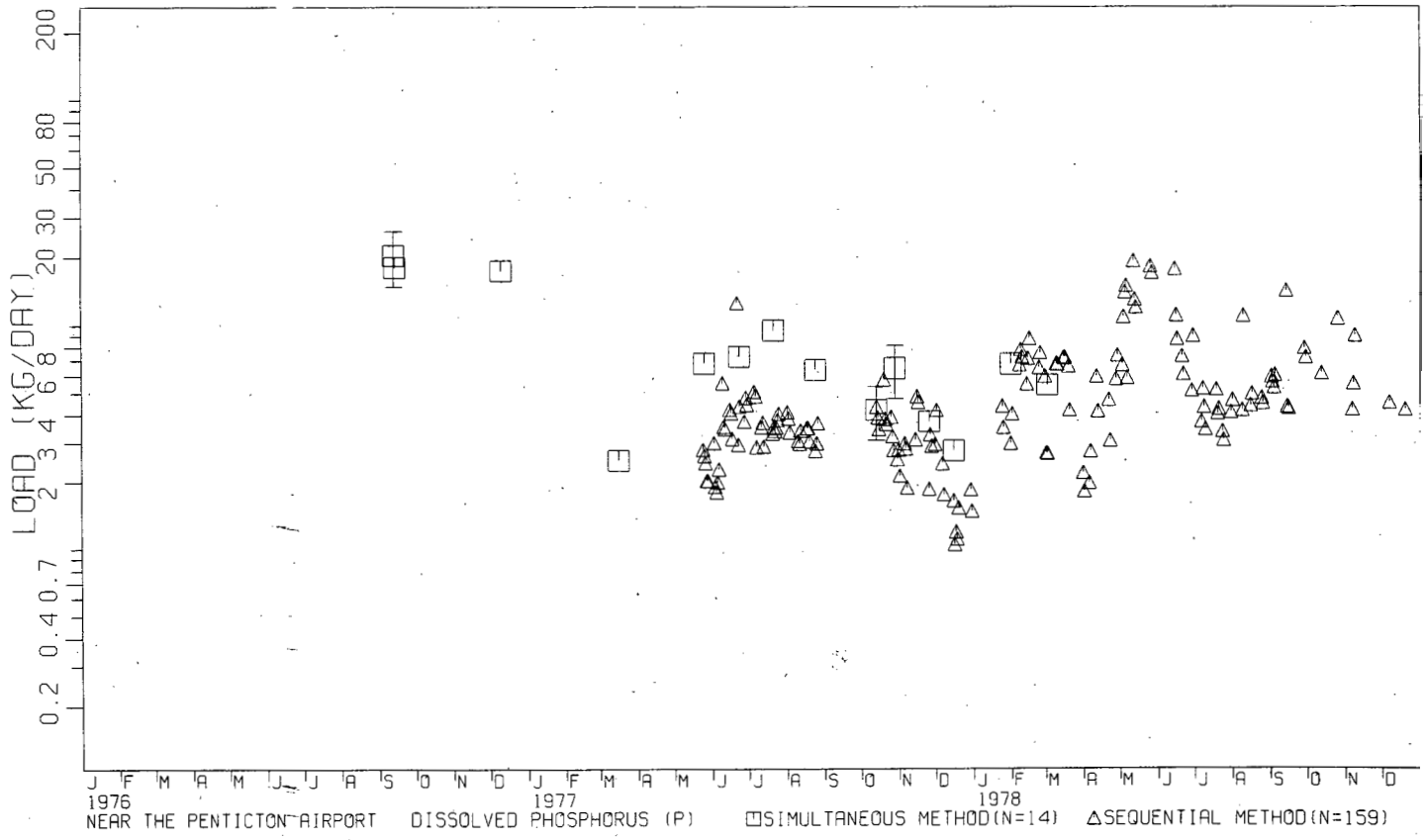
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 07	63	0.005	0.018	0.011	0.0026	0.0003	±0.0007							
1976 08	24	0.007	0.021	0.010	0.0042	0.0009	±0.0018							
1976 09	129	0.007	0.064	0.011	0.0054	0.0005	±0.0009							
1976 12	48	0.006	0.017	0.011	0.0021	0.0003	±0.0006							
1977 03	12	0.006	0.023	0.016	0.0065	0.0019	±0.0041	8	0.022	0.036	0.029	0.0048	0.0017	±0.0040
1977 04								38	0.009	0.040	0.022	0.0071	0.0012	±0.0023
1977 05	12	0.026	0.050	0.032	0.0068	0.0020	±0.0043	32	0.005	0.016	0.009	0.0025	0.0004	±0.0009
1977 06	12	0.020	0.031	0.025	0.0036	0.0010	±0.0023	50	0.014	0.141	0.031	0.0208	0.0029	±0.0059
1977 07	12	0.015	0.027	0.021	0.0040	0.0012	±0.0025	72	0.010	0.053	0.019	0.0072	0.0008	±0.0017
1977 08	12	0.012	0.022	0.016	0.0036	0.0010	±0.0023	63	0.008	0.087	0.019	0.0146	0.0018	±0.0037
1977 10	24	0.006	0.016	0.010	0.0028	0.0006	±0.0012	50	0.009	0.043	0.018	0.0078	0.0011	±0.0022
1977 11	12	0.013	0.030	0.017	0.0053	0.0015	±0.0034	53	0.007	0.325	0.028	0.0459	0.0063	±0.0126
1977 12	12	0.012	0.028	0.016	0.0049	0.0014	±0.0031	71	0.008	0.187	0.022	0.0210	0.0025	±0.0050
1978 01	12	0.011	0.017	0.014	0.0023	0.0007	±0.0015	23	0.007	0.031	0.018	0.0063	0.0013	±0.0027
1978 02								42	0.008	0.026	0.014	0.0037	0.0006	±0.0012
1978 03	12	0.009	0.015	0.012	0.0022	0.0006	±0.0014	62	0.006	0.040	0.011	0.0061	0.0008	±0.0016
1978 04								60	0.005	0.082	0.014	0.0118	0.0015	±0.0030
1978 05								53	0.008	0.041	0.017	0.0057	0.0008	±0.0016
1978 06								41	0.011	0.057	0.027	0.0129	0.0020	±0.0041
1978 07								80	0.006	0.088	0.020	0.0137	0.0015	±0.0030
1978 08								48	0.006	0.057	0.015	0.0084	0.0012	±0.0025
1978 09								56	0.009	0.091	0.016	0.0111	0.0015	±0.0030
1978 10								16	0.012	0.041	0.020	0.0082	0.0021	±0.0044
1978 11								16	0.009	0.023	0.015	0.0046	0.0011	±0.0024
1978 12								11	0.008	0.020	0.013	0.0034	0.0010	±0.0023
LOAD (KG/DAY)														
1976 07	3	32.98	41.57	37.18	4.30	2.48	±10.68							
1976 08	1	23.47	23.47	23.47										
1976 09	4	20.91	28.26	23.95	3.65	1.82	±5.80							
1976 12	2	24.12	28.15	26.13	2.85	2.02	±25.62							
1977 03	1	5.85	5.85	5.85				3	8.80	13.06	11.06	2.14	1.24	±5.32
1977 04								7	9.75	15.55	12.23	2.47	0.93	±2.28
1977 05	1	18.81	18.81	18.81				5	3.15	4.77	3.76	0.66	0.29	±0.82
1977 06	1	18.57	18.57	18.57				9	11.12	27.77	18.24	5.62	1.87	±4.32
1977 07	1	17.18	17.18	17.18				12	13.02	23.52	16.66	2.85	0.82	±1.81
1977 08	1	16.00	16.00	16.00				12	9.39	44.46	17.55	10.30	2.97	±6.54
1977 10	2	7.79	11.16	9.47	2.38	1.69	±21.42	11	9.43	20.71	14.86	3.48	1.05	±2.34
1977 11	1	7.81	7.81	7.81				11	4.08	29.60	11.02	6.84	2.06	±4.60
1977 12	1	4.33	4.33	4.33				10	4.12	13.90	6.62	3.10	0.98	±2.22
1978 01	1	14.62	14.62	14.62				3	14.43	24.02	20.81	5.53	3.19	±13.73
1978 02								10	15.99	40.15	28.31	7.49	2.37	±5.36
1978 03	1	10.03	10.03	10.03				9	11.18	21.53	16.78	3.09	1.03	±2.38
1978 04								9	5.60	40.14	17.95	12.17	4.06	±9.35
1978 05								10	25.40	129.77	70.26	32.90	10.40	±23.53
1978 06								7	25.43	91.91	49.99	26.52	10.02	±24.53
1978 07								11	10.81	41.22	22.39	9.17	2.77	±6.16
1978 08								6	12.80	21.94	16.40	3.24	1.32	±3.40
1978 09								9	13.72	26.27	19.14	4.42	1.47	±3.40
1978 10								2	29.07	33.37	31.22	3.04	2.15	±27.28
1978 11								3	23.86	28.83	26.59	2.52	1.46	±6.26
1978 12								2	16.24	22.55	19.40	4.46	3.16	±40.09

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	264	0.005	0.064	0.011	0.0043	0.0003	±0.0005							
1977	108	0.006	0.050	0.018	0.0079	0.0008	±0.0015	437	0.005	0.325	0.021	0.0213	0.0010	±0.0020
1978	24	0.009	0.017	0.013	0.0025	0.0005	±0.0011	508	0.005	0.091	0.017	0.0104	0.0005	±0.0009
						LOAD (KG/DAY)								
1976	10	20.91	41.57	28.31	6.91	2.19	±4.94							
1977	9	4.33	18.81	11.95	5.76	1.92	±4.42	80	3.15	44.46	13.29	6.95	0.78	±1.55
1978	2	10.03	14.62	12.32	3.24	2.29	±29.14	81	5.60	129.77	29.74	22.94	2.55	±5.07


L .151E-03 U .994E-01 (A)
L .211E-04 U .997E+00 (A)
L .151E-03 U .994E-01 (A)
CONCENTRATION (MG/L)
0.0005 0.001 0.002 0.004 0.007 0.02 0.04
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
NEAR THE PENTICTON AIRPORT DISSOLVED PHOSPHORUS (P) ⊡SIMULTANEOUS METHOD(N=204) ΔSEQUENTIAL METHOD(N=949)

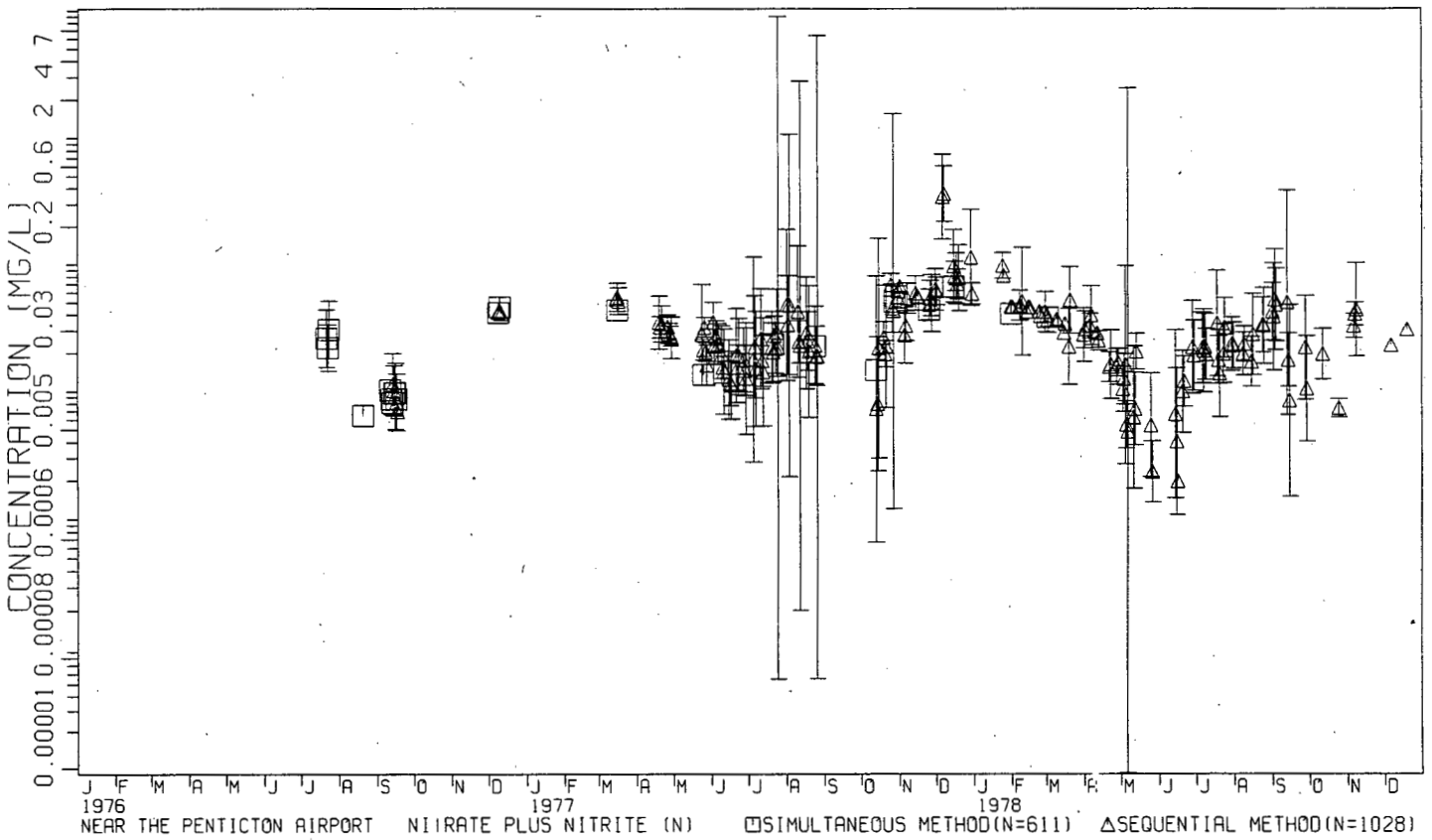

LOAD (KG/DAY)
0.2 0.4 0.7 2 3 4 6 8 20 30 50 80 200
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
NEAR THE PENTICTON AIRPORT DISSOLVED PHOSPHORUS (P) ⊡SIMULTANEOUS METHOD(N=14) ΔSEQUENTIAL METHOD(N=159)

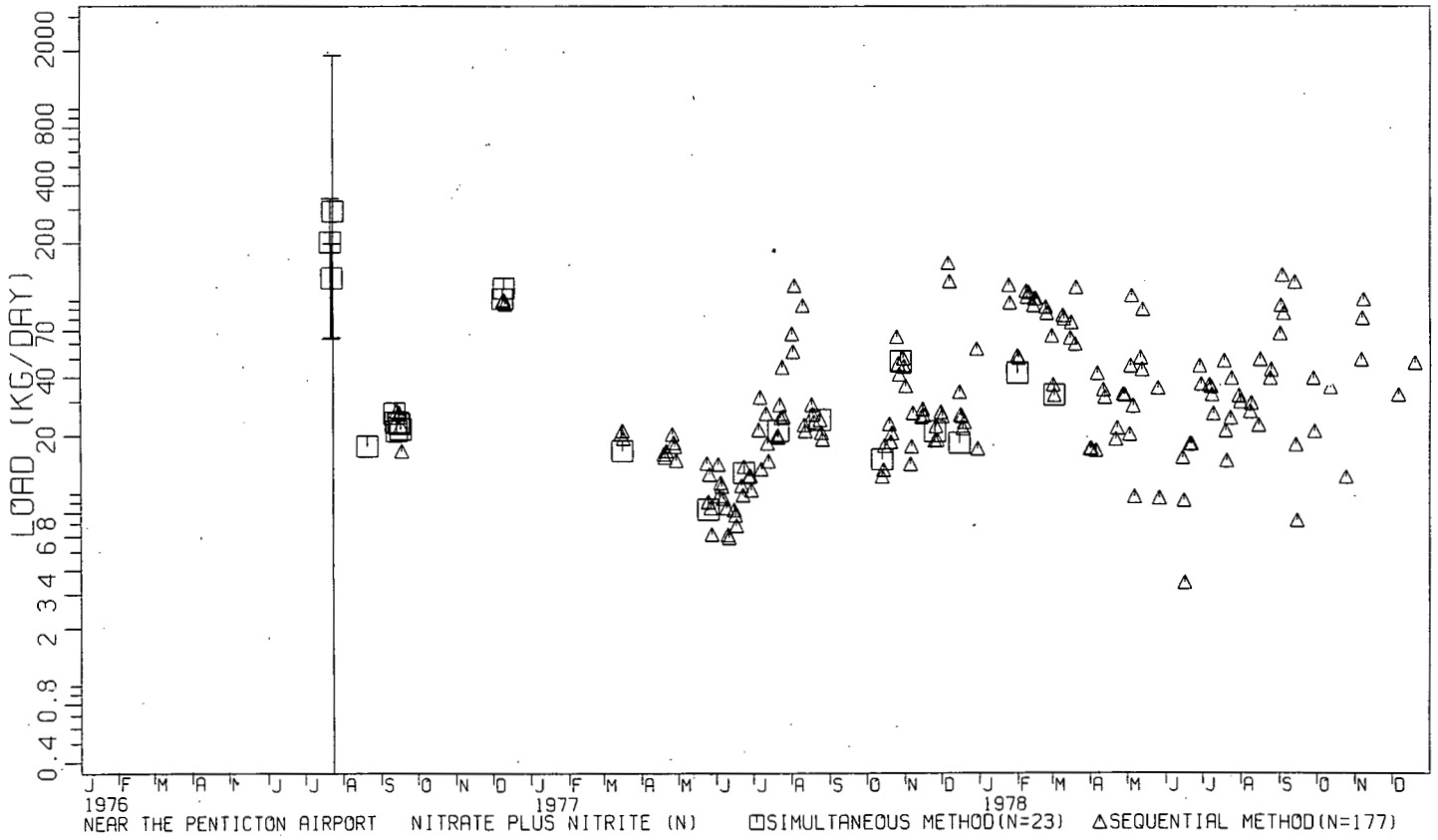
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 09	42	0.005	0.013	0.007	0.0018	0.0003	±0.0005							
1976 12	24	0.005	0.011	0.007	0.0016	0.0003	±0.0007							
1977 03	12	0.005	0.008	0.007	0.0011	0.0003	±0.0007							
1977 05	12	0.010	0.014	0.011	0.0012	0.0003	±0.0007	32	0.004	0.009	0.006	0.0013	0.0002	±0.0005
1977 06	12	0.008	0.012	0.010	0.0013	0.0004	±0.0008	98	0.003	0.040	0.007	0.0044	0.0004	±0.0009
1977 07	12	0.008	0.015	0.011	0.0026	0.0007	±0.0016	72	0.003	0.009	0.004	0.0012	0.0001	±0.0003
1977 08	12	0.004	0.010	0.006	0.0021	0.0006	±0.0013	64	0.002	0.006	0.004	0.0007	0.0001	±0.0002
1977 10	24	0.003	0.009	0.005	0.0018	0.0004	±0.0008	50	0.002	0.014	0.005	0.0020	0.0003	±0.0006
1977 11	12	0.007	0.009	0.008	0.0007	0.0002	±0.0005	53	0.003	0.016	0.007	0.0031	0.0004	±0.0009
1977 12	12	0.009	0.011	0.010	0.0005	0.0001	±0.0003	71	0.003	0.019	0.006	0.0030	0.0004	±0.0007
1978 01	12	0.005	0.009	0.007	0.0012	0.0004	±0.0008	23	0.002	0.007	0.004	0.0009	0.0002	±0.0004
1978 02								42	0.002	0.008	0.004	0.0011	0.0002	±0.0003
1978 03	12	0.005	0.009	0.006	0.0014	0.0004	±0.0009	62	0.002	0.005	0.003	0.0006	0.0001	±0.0001
1978 04								60	0.002	0.007	0.004	0.0013	0.0002	±0.0003
1978 05								53	0.002	0.006	0.004	0.0010	0.0001	±0.0003
1978 06								41	0.004	0.025	0.006	0.0037	0.0006	±0.0012
1978 07								80	0.002	0.010	0.004	0.0012	0.0001	±0.0003
1978 08								48	0.003	0.048	0.005	0.0064	0.0009	±0.0018
1978 09								56	0.003	0.027	0.005	0.0031	0.0004	±0.0008
1978 10								16	0.004	0.014	0.005	0.0030	0.0008	±0.0016
1978 11								16	0.002	0.009	0.003	0.0017	0.0004	±0.0009
1978 12								12	0.002	0.005	0.003	0.0011	0.0003	±0.0007
						LOAD (KG/DAY)								
1976 09	1	16.60	16.60	16.60										
1976 12	1	17.36	17.36	17.36										
1977 03	1	2.50	2.50	2.50										
1977 05	1	6.77	6.77	6.77				5	2.03	2.80	2.39	0.35	0.16	±0.43
1977 06	1	7.25	7.25	7.25				17	1.80	12.52	3.99	2.44	0.59	±1.26
1977 07	1	9.48	9.48	9.48				12	2.87	5.07	3.70	0.67	0.19	±0.43
1977 08	1	6.32	6.32	6.32				12	2.76	4.11	3.35	0.40	0.12	±0.26
1977 10	2	4.20	6.43	5.31	1.58	1.12	±14.19	11	2.53	5.75	3.64	0.90	0.27	±0.60
1977 11	1	3.74	3.74	3.74				11	1.86	4.83	3.02	0.96	0.29	±0.65
1977 12	1	2.76	2.76	2.76				10	1.05	4.20	1.83	0.93	0.29	±0.66
1978 01	1	6.72	6.72	6.72				3	2.99	4.39	3.63	0.71	0.41	±1.76
1978 02								10	4.06	8.77	6.72	1.32	0.42	±0.94
1978 03	1	5.43	5.43	5.43				9	2.21	7.20	5.14	2.15	0.72	±1.65
1978 04								9	1.82	7.37	4.18	1.93	0.64	±1.48
1978 05								10	5.87	19.28	13.22	4.53	1.43	±3.24
1978 06								7	5.15	17.83	9.32	4.24	1.60	±3.92
1978 07								11	3.09	5.25	4.15	0.71	0.21	±0.47
1978 08								6	4.22	11.03	5.66	2.64	1.08	±2.78
1978 09								9	4.29	14.20	6.77	3.03	1.01	±2.33
1978 10								2	6.12	10.72	8.42	3.25	2.30	±29.23
1978 11								3	4.23	9.03	6.26	2.48	1.43	±6.17
1978 12								2	4.21	4.53	4.37	0.23	0.16	±2.08

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	66	0.005	0.013	0.007	0.0017	0.0002	±0.0004							
1977	108	0.003	0.015	0.008	0.0027	0.0003	±0.0005	440	0.002	0.040	0.006	0.0030	0.0001	±0.0003
1978	24	0.005	0.009	0.006	0.0013	0.0003	±0.0005	509	0.002	0.048	0.004	0.0028	0.0001	±0.0002
LOAD (KG/DAY)														
1976	2	16.60	17.36	16.98	0.54	0.38	±4.81							
1977	9	2.50	9.48	5.49	2.33	0.78	±1.79	78	1.05	12.52	3.28	1.47	0.17	±0.33
1978	2	5.43	6.72	6.07	0.91	0.64	±8.19	81	1.82	19.28	6.72	3.85	0.43	±0.85


CONCENTRATION (MG/L)
0.00001 0.00008 0.0006 0.005 0.03 0.2 0.6 2 4 7
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT NITRATE PLUS NITRITE (N) □SIMULTANEOUS METHOD(N=611) △SEQUENTIAL METHOD(N=1028)

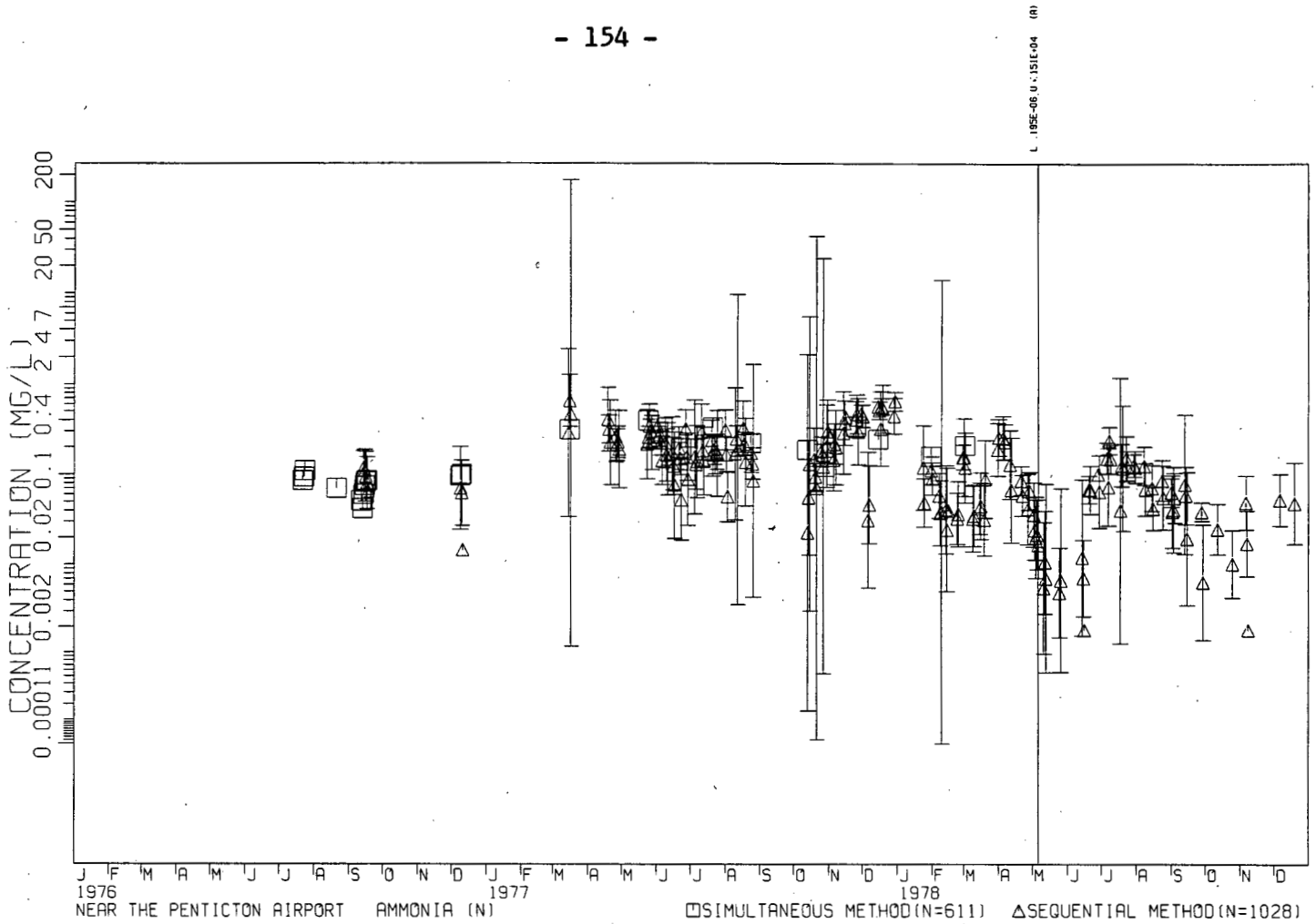

LOAD (KG/DAY)
0.4 0.8 2 3 4 6 8 20 40 70 200 400 800 2000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT NITRATE PLUS NITRITE (N) □SIMULTANEOUS METHOD(N=23) △SEQUENTIAL METHOD(N=177)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
NITRATE PLUS NITRITE(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	63	0.005	0.214	0.039	0.0445	0.0056	±0.0112							
1976 08	24	0.002	0.018	0.008	0.0045	0.0009	±0.0019							
1976 09	258	0.004	0.030	0.010	0.0037	0.0002		19	0.004	0.015	0.010	0.0035	0.0008	±0.0017
1976 12	96	0.038	0.056	0.044	0.0045	0.0005	±0.0009	14	0.038	0.049	0.043	0.0030	0.0008	±0.0017
1977 03	24	0.037	0.053	0.045	0.0063	0.0013	±0.0027	8	0.048	0.065	0.055	0.0062	0.0022	±0.0052
1977 04								38	0.021	0.045	0.031	0.0067	0.0011	±0.0022
1977 05	24	0.010	0.017	0.014	0.0019	0.0004	±0.0008	32	0.012	0.043	0.025	0.0087	0.0015	±0.0031
1977 06	24	0.009	0.027	0.017	0.0051	0.0011	±0.0022	98	0.006	0.048	0.020	0.0097	0.0010	±0.0019
1977 07	12	0.015	0.036	0.025	0.0068	0.0020	±0.0043	72	0.004	0.170	0.028	0.0240	0.0028	±0.0057
1977 08	12	0.014	0.037	0.025	0.0094	0.0027	±0.0060	64	0.007	0.360	0.045	0.0629	0.0079	±0.0157
1977 10	24	0.009	0.058	0.034	0.0189	0.0039	±0.0080	50	0.002	0.094	0.037	0.0243	0.0034	±0.0069
1977 11	12	0.036	0.054	0.045	0.0073	0.0021	±0.0046	53	0.021	0.110	0.053	0.0205	0.0028	±0.0056
1977 12	12	0.047	0.095	0.070	0.0174	0.0050	±0.0110	71	0.042	0.800	0.173	0.2022	0.0240	±0.0479
1978 01	12	0.039	0.045	0.041	0.0023	0.0007	±0.0015	23	0.043	0.140	0.079	0.0288	0.0060	±0.0125
1978 02								42	0.036	0.060	0.046	0.0051	0.0008	±0.0016
1978 03	12	0.034	0.045	0.039	0.0039	0.0011	±0.0025	62	0.003	0.160	0.037	0.0196	0.0025	±0.0050
1978 04								60	0.009	0.150	0.028	0.0201	0.0026	±0.0052
1978 05								53	0.002	0.044	0.011	0.0090	0.0012	±0.0025
1978 06								41	0.002	0.100	0.019	0.0212	0.0033	±0.0067
1978 07								80	0.007	0.130	0.028	0.0219	0.0024	±0.0049
1978 08								48	0.008	0.160	0.032	0.0273	0.0039	±0.0079
1978 09								56	0.002	0.480	0.055	0.0805	0.0108	±0.0216
1978 10								16	0.006	0.060	0.016	0.0139	0.0035	±0.0074
1978 11								16	0.027	0.049	0.040	0.0091	0.0023	±0.0048
1978 12								12	0.021	0.033	0.026	0.0043	0.0012	±0.0027
						LOAD (KG/DAY)								
1976 07	3	116.15	159.95	142.00	22.94	13.25	±57.00							
1976 08	1	17.82	17.82	17.82										
1976 09	4	20.48	26.31	23.02	2.50	1.25	±3.98	5	16.80	26.97	23.62	4.14	1.85	±5.14
1976 12	2	102.31	115.86	109.09	9.58	6.77	±86.04	3	96.00	101.27	98.77	2.64	1.53	±6.57
1977 03	1	16.76	16.76	16.76				3	19.49	21.39	20.49	0.96	0.55	±2.37
1977 04								7	15.00	20.46	17.19	1.89	0.71	±1.75
1977 05	1	8.34	8.34	8.34				5	6.21	14.51	10.23	3.35	1.50	±4.16
1977 06	1	12.92	12.92	12.92				17	5.98	14.31	10.01	2.51	0.61	±1.29
1977 07	1	21.32	21.32	21.32				12	13.46	45.28	24.21	8.57	2.47	±5.44
1977 08	1	24.31	24.31	24.31				12	19.26	119.52	43.63	33.52	9.68	±21.30
1977 10	2	15.19	48.64	31.92	23.65	16.73	±212.52	11	12.36	65.34	32.40	18.07	5.45	±12.14
1977 11	1	21.21	21.21	21.21				11	14.44	36.25	23.70	6.01	1.81	±4.04
1977 12	1	18.46	18.46	18.46				10	17.26	158.09	51.41	49.64	15.70	±35.51
1978 01	1	42.18	42.18	42.18				3	51.71	120.66	90.12	35.14	20.29	±87.31
1978 02								10	50.68	113.21	92.57	20.10	6.36	±14.38
1978 03	1	32.56	32.56	32.56				9	17.33	117.55	63.50	30.99	10.33	±23.82
1978 04								9	17.04	42.26	27.85	9.03	3.01	±6.94
1978 05								10	9.64	107.21	44.31	32.31	10.22	±23.11
1978 06								7	3.49	46.05	21.17	15.12	5.72	±13.99
1978 07								11	14.99	48.95	31.34	9.34	2.82	±6.28
1978 08								6	22.92	49.70	35.53	10.58	4.32	±11.11
1978 09								9	7.31	136.87	66.55	47.79	15.93	±36.74
1978 10								2	12.31	35.58	23.94	16.45	11.63	±147.78
1978 11								3	49.64	101.59	77.60	26.20	15.13	±65.09
1978 12								2	32.73	47.79	40.26	10.65	7.53	±95.67

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
NITRATE PLUS NITRITE(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	441	0.002	0.214	0.021	0.0233	0.0011	±0.0022	33	0.004	0.049	0.024	0.0168	0.0029	±0.0060
1977	144	0.009	0.095	0.032	0.0191	0.0016	±0.0032	486	0.002	0.800	0.054	0.0958	0.0043	±0.0085
1978	24	0.034	0.045	0.040	0.0034	0.0007	±0.0014	509	0.002	0.480	0.034	0.0358	0.0016	±0.0031
						LOAD (KG/DAY)								
1976	10	17.82	159.95	75.41	58.72	18.57	±42.00	8	16.80	101.27	51.80	39.04	13.80	±32.65
1977	9	8.34	48.64	20.80	11.50	3.83	±8.84	88	5.98	158.09	26.69	25.38	2.71	±5.41
1978	2	32.56	42.18	37.37	6.80	4.81	±61.09	81	3.49	136.87	50.96	34.12	3.79	±7.54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CONCENTRATION (MG/L)
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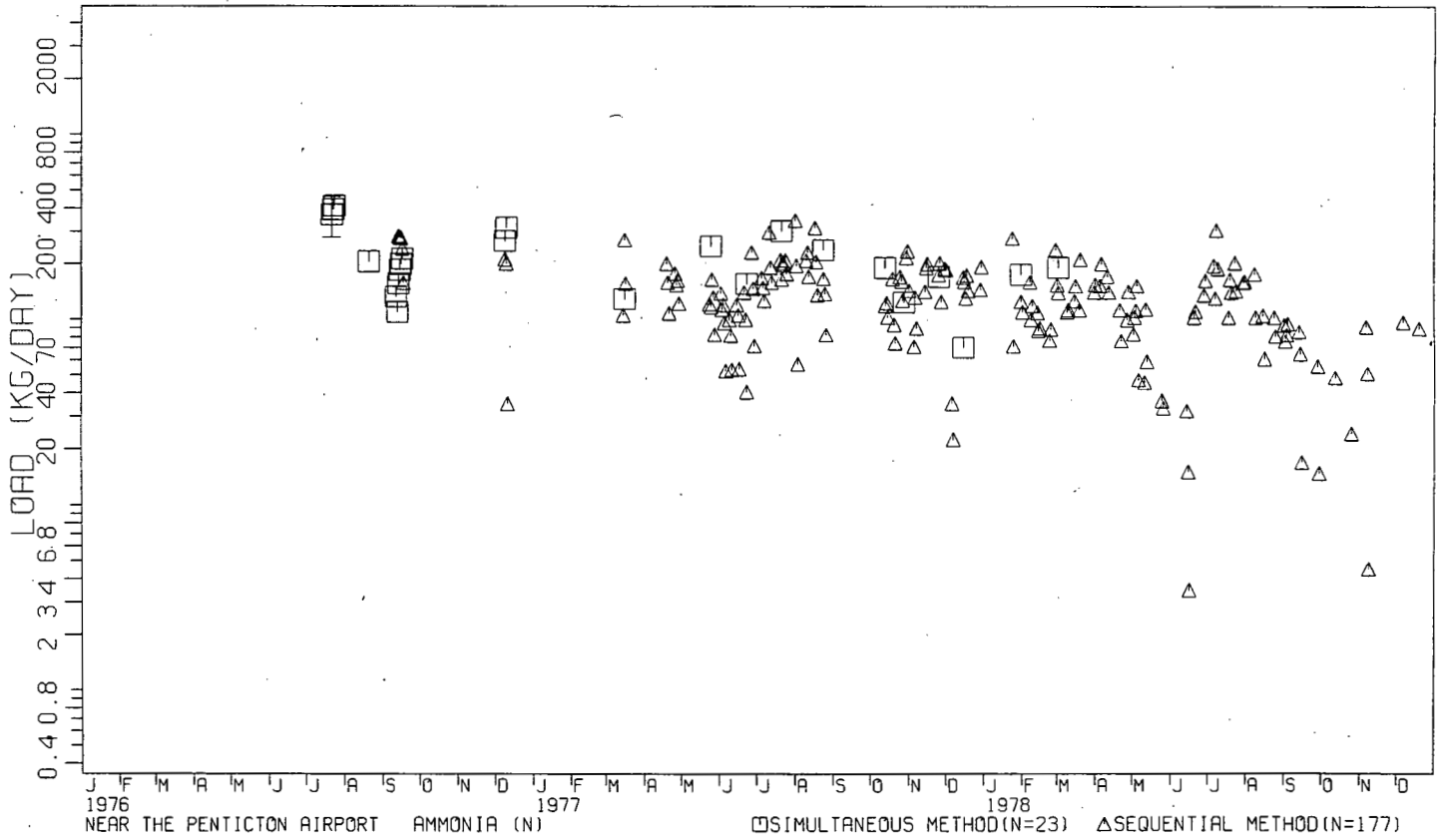
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT AMMONIA (N)
SIMULTANEOUS METHOD(N=611)
SEQUENTIAL METHOD(N=1028)


LOAD (KG/DAY)
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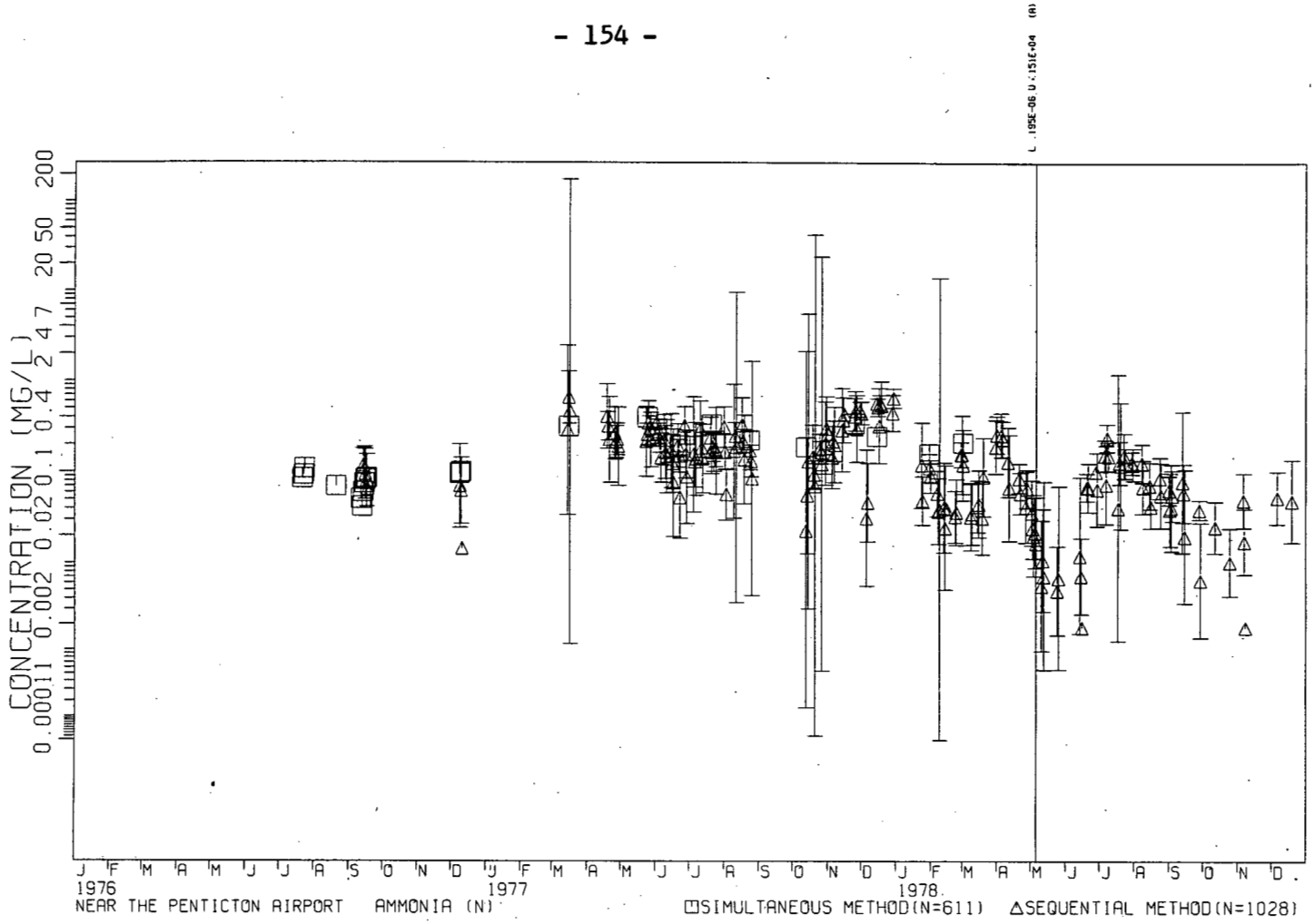
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT AMMONIA (N)
SIMULTANEOUS METHOD(N=23)
SEQUENTIAL METHOD(N=177)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
AMMONIA(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	63	0.042	0.250	0.104	0.0418	0.0053	±0.0105							
1976 08	24	0.023	0.204	0.091	0.0625	0.0128	±0.0264							
1976 09	258	0.027	0.142	0.071	0.0288	0.0018		19	0.032	0.169	0.105	0.0438	0.0100	±0.0211
1976 12	96	0.031	0.200	0.116	0.0557	0.0057	±0.0113	14	0.014	0.290	0.091	0.0850	0.0227	±0.0490
1977 03	24	0.225	0.480	0.334	0.0812	0.0166	±0.0343	8	0.250	0.925	0.563	0.2711	0.0959	±0.2267
1977 04								38	0.088	0.605	0.285	0.1302	0.0211	±0.0428
1977 05	24	0.310	0.465	0.410	0.0506	0.0103	±0.0214	32	0.110	0.755	0.316	0.1505	0.0266	±0.0543
1977 06	24	0.132	0.268	0.207	0.0498	0.0102	±0.0210	98	0.011	0.453	0.209	0.1099	0.0111	±0.0220
1977 07	12	0.250	0.450	0.348	0.0725	0.0209	±0.0461	72	0.040	0.462	0.207	0.1108	0.0131	±0.0260
1977 08	12	0.160	0.300	0.235	0.0596	0.0172	±0.0379	64	0.007	0.500	0.218	0.1231	0.0154	±0.0307
1977 10	24	0.093	0.270	0.164	0.0544	0.0111	±0.0230	50	0.002	0.470	0.164	0.1013	0.0143	±0.0288
1977 11	12	0.300	0.430	0.354	0.0399	0.0115	±0.0253	53	0.075	0.800	0.379	0.1921	0.0264	±0.0530
1977 12	12	0.190	0.310	0.256	0.0468	0.0135	±0.0297	71	0.002	0.970	0.442	0.2551	0.0303	±0.0604
1978 01	12	0.110	0.230	0.169	0.0480	0.0138	±0.0305	23	0.014	0.700	0.140	0.1703	0.0355	±0.0737
1978 02								42	0.003	0.180	0.064	0.0447	0.0069	±0.0139
1978 03	12	0.130	0.310	0.226	0.0728	0.0210	±0.0463	62	0.006	0.540	0.101	0.1062	0.0135	±0.0270
1978 04								60	0.006	0.610	0.168	0.1449	0.0187	±0.0374
1978 05								53	0.002	0.120	0.025	0.0261	0.0036	±0.0072
1978 06								41	0.002	0.410	0.076	0.0709	0.0111	±0.0224
1978 07								80	0.002	0.570	0.160	0.0984	0.0110	±0.0219
1978 08								48	0.014	0.290	0.094	0.0645	0.0093	±0.0187
1978 09								56	0.002	0.150	0.061	0.0425	0.0057	±0.0114
1978 10								16	0.002	0.055	0.024	0.0178	0.0044	±0.0095
1978 11								16	0.002	0.098	0.035	0.0311	0.0078	±0.0166
1978 12								12	0.012	0.150	0.065	0.0453	0.0131	±0.0288
						LOAD (KG/DAY)								
1976 07	3	321.74	413.46	362.94	46.56	26.88	±115.68							
1976 08	1	206.04	206.04	206.04										
1976 09	4	121.47	213.84	165.36	44.90	22.45	±71.44	5	158.41	282.92	247.83	52.70	23.57	±65.42
1976 12	2	267.14	313.89	290.52	33.05	23.37	±296.97	3	35.12	212.13	149.34	99.08	57.21	±246.16
1977 03	1	128.72	128.72	128.72				3	104.86	270.32	177.44	84.58	48.83	±210.11
1977 04								7	107.69	201.50	154.99	31.84	12.04	±29.45
1977 05	1	249.93	249.93	249.93				5	82.81	164.65	123.29	29.44	13.17	±36.55
1977 06	1	156.07	156.07	156.07				17	40.38	231.31	103.91	46.44	11.26	±23.88
1977 07	1	302.35	302.35	302.35				12	125.52	296.98	187.64	43.09	12.44	±27.38
1977 08	1	238.02	238.02	238.02				12	57.31	344.60	187.63	83.98	24.24	±53.36
1977 10	2	123.69	191.16	157.43	47.71	33.73	±428.63	11	74.32	234.85	144.70	50.49	15.22	±33.92
1977 11	1	171.00	171.00	171.00				11	71.05	203.21	151.14	44.81	13.51	±30.10
1977 12	1	70.43	70.43	70.43				10	22.46	192.63	136.30	59.83	18.92	±42.80
1978 01	1	175.54	175.54	175.54				3	71.66	275.76	157.34	105.92	61.15	±263.13
1978 02								10	76.85	239.17	118.06	48.52	15.34	±34.70
1978 03	1	191.91	191.91	191.91				9	110.04	211.76	140.04	31.77	10.59	±24.42
1978 04								9	76.59	201.11	139.24	37.87	12.62	±29.11
1978 05								10	33.23	152.67	78.67	40.50	12.81	±28.97
1978 06								7	3.49	163.39	80.50	63.08	23.84	±58.34
1978 07								11	102.53	306.04	172.50	53.43	16.11	±35.90
1978 08								6	61.47	177.44	105.20	39.27	16.03	±41.22
1978 09								9	14.76	95.31	65.22	30.67	10.22	±23.58
1978 10								2	24.22	48.58	36.40	17.22	12.18	±154.73
1978 11								3	4.52	91.60	49.12	43.58	25.16	±108.28
1978 12								2	89.80	97.21	93.51	5.24	3.70	±47.05

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
AMMONIA(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	441	0.023	0.250	0.086	0.0446	0.0021	±0.0042	33	0.014	0.290	0.099	0.0637	0.0111	±0.0226
1977	144	0.093	0.480	0.285	0.1041	0.0087	±0.0171	486	0.002	0.970	0.277	0.1855	0.0084	±0.0165
1978	24	0.110	0.310	0.197	0.0669	0.0136	±0.0282	509	0.002	0.700	0.096	0.1013	0.0045	±0.0088
LOAD (KG/DAY)														
1976	10	121.47	413.46	253.73	96.31	30.46	±68.89	8	35.12	282.92	210.90	83.60	29.56	±69.91
1977	9	70.43	302.35	181.26	72.28	24.09	±55.56	88	22.46	344.60	149.10	59.92	6.39	±12.76
1978	2	175.54	191.91	183.72	11.58	8.19	±104.03	81	3.49	306.04	111.59	58.34	6.48	±12.90


CONCENTRATION (MG/L)
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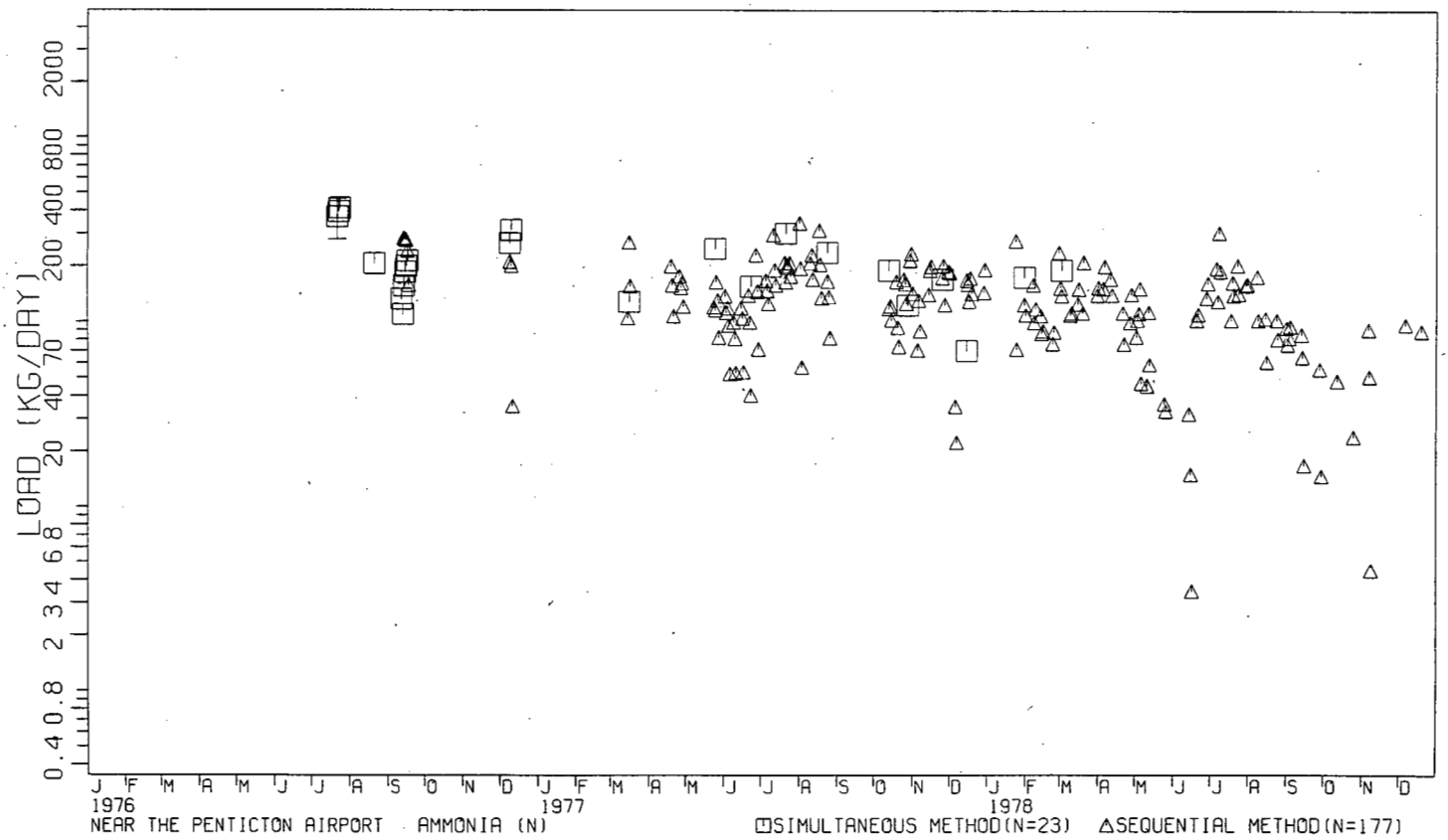
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT AMMONIA (N)
SIMULTANEOUS METHOD(N=611)
SEQUENTIAL METHOD(N=1028)


LOAD (KG/DAY)
0.4 0.8 2 3 4 6 8 20 40 70 200 400 800 2000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT AMMONIA (N)
SIMULTANEOUS METHOD(N=23)
SEQUENTIAL METHOD(N=177)

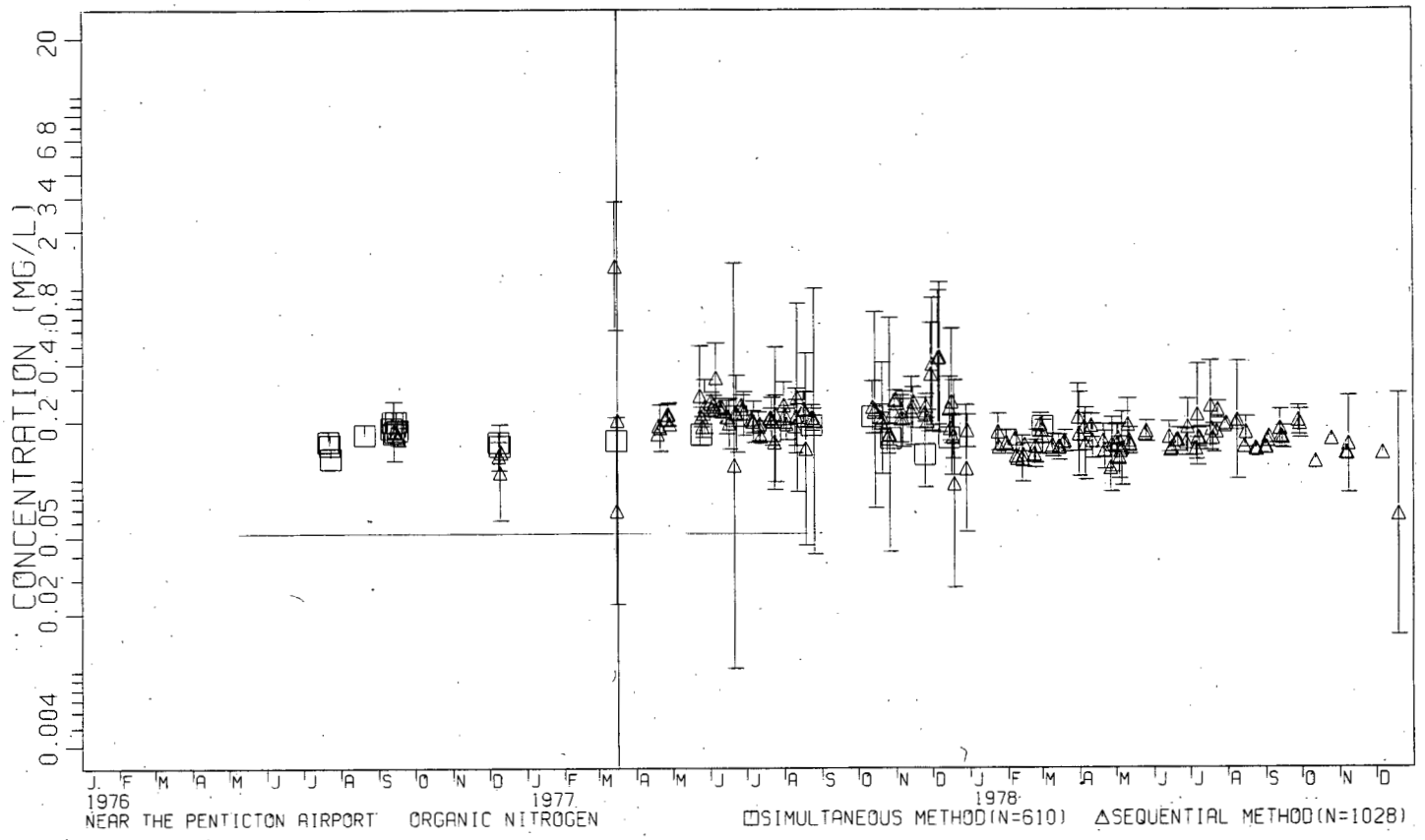
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
AMMONIA(N)

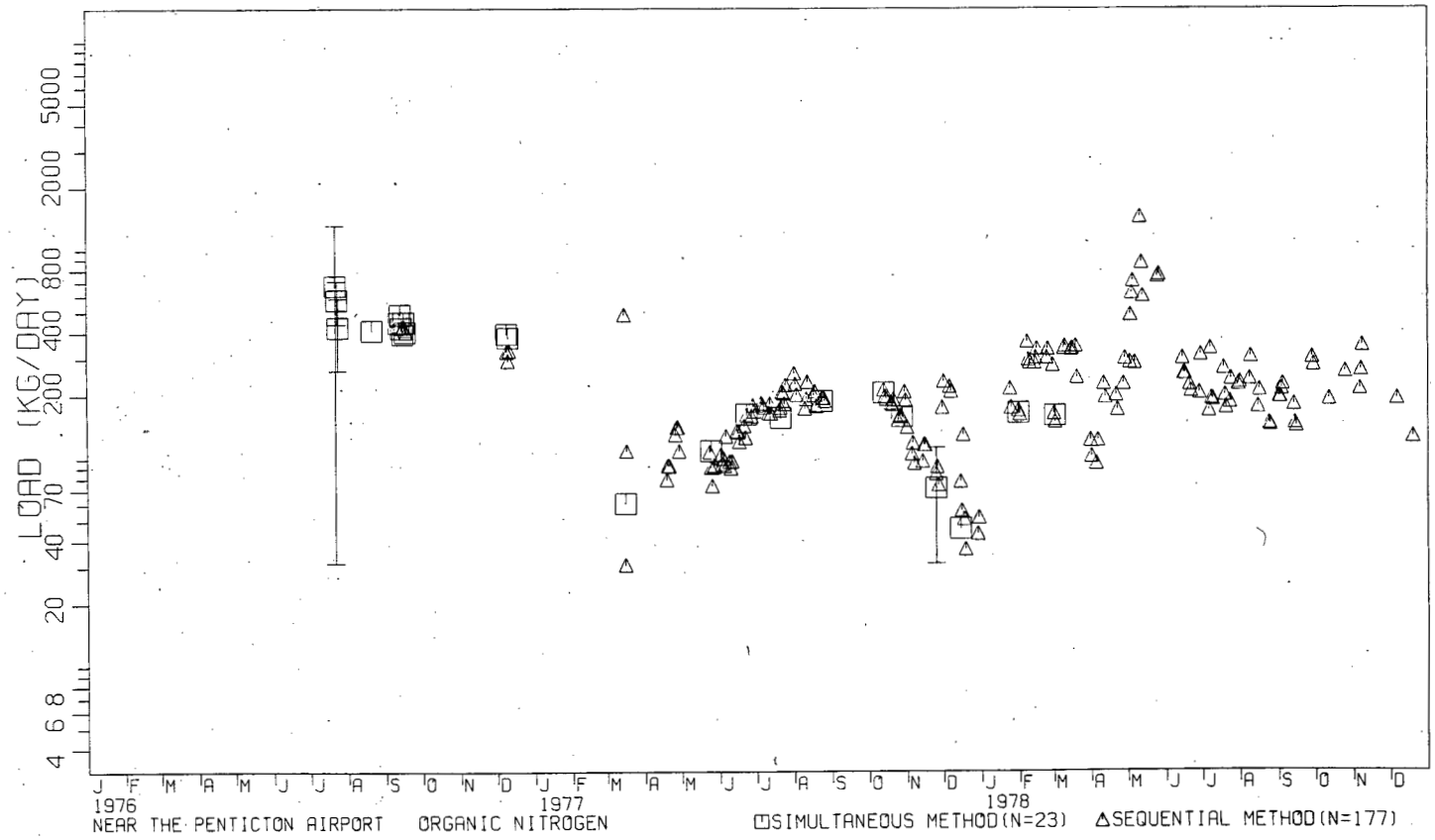
SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	63	0.042	0.250	0.104	0.0418	0.0053	±0.0105							
1976 08	24	0.023	0.204	0.091	0.0625	0.0128	±0.0264							
1976 09	258	0.027	0.142	0.071	0.0288	0.0018		19	0.032	0.169	0.105	0.0438	0.0100	±0.0211
1976 12	96	0.031	0.200	0.116	0.0557	0.0057	±0.0113	14	0.014	0.290	0.091	0.0850	0.0227	±0.0490
1977 03	24	0.225	0.480	0.334	0.0812	0.0166	±0.0343	8	0.250	0.925	0.563	0.2711	0.0959	±0.2267
1977 04								38	0.088	0.605	0.285	0.1302	0.0211	±0.0428
1977 05	24	0.310	0.465	0.410	0.0506	0.0103	±0.0214	32	0.110	0.755	0.316	0.1505	0.0266	±0.0543
1977 06	24	0.132	0.268	0.207	0.0498	0.0102	±0.0210	98	0.011	0.453	0.209	0.1099	0.0111	±0.0220
1977 07	12	0.250	0.450	0.348	0.0725	0.0209	±0.0461	72	0.040	0.462	0.207	0.1108	0.0131	±0.0260
1977 08	12	0.160	0.300	0.235	0.0596	0.0172	±0.0379	64	0.007	0.500	0.218	0.1231	0.0154	±0.0307
1977 10	24	0.093	0.270	0.164	0.0544	0.0111	±0.0230	50	0.002	0.470	0.164	0.1013	0.0143	±0.0288
1977 11	12	0.300	0.430	0.354	0.0399	0.0115	±0.0253	53	0.075	0.800	0.379	0.1921	0.0264	±0.0530
1977 12	12	0.190	0.310	0.256	0.0468	0.0135	±0.0297	71	0.002	0.970	0.442	0.2551	0.0303	±0.0604
1978 01	12	0.110	0.230	0.169	0.0480	0.0138	±0.0305	23	0.014	0.700	0.140	0.1703	0.0355	±0.0737
1978 02								42	0.003	0.180	0.064	0.0447	0.0069	±0.0139
1978 03	12	0.130	0.310	0.226	0.0728	0.0210	±0.0463	62	0.006	0.540	0.101	0.1062	0.0135	±0.0270
1978 04								60	0.006	0.610	0.168	0.1449	0.0187	±0.0374
1978 05								53	0.002	0.120	0.025	0.0261	0.0036	±0.0072
1978 06								41	0.002	0.410	0.076	0.0709	0.0111	±0.0224
1978 07								80	0.002	0.570	0.160	0.0984	0.0110	±0.0219
1978 08								48	0.014	0.290	0.094	0.0645	0.0093	±0.0187
1978 09								56	0.002	0.150	0.061	0.0425	0.0057	±0.0114
1978 10								16	0.002	0.055	0.024	0.0178	0.0044	±0.0095
1978 11								16	0.002	0.098	0.035	0.0311	0.0078	±0.0166
1978 12								12	0.012	0.150	0.065	0.0453	0.0131	±0.0288
						LOAD (KG/DAY)								
1976 07	3	321.74	413.46	362.94	46.56	26.88	±115.68							
1976 08	1	206.04	206.04	206.04										
1976 09	4	121.47	213.84	165.36	44.90	22.45	±71.44	5	158.41	282.92	247.83	52.70	23.57	±65.42
1976 12	2	267.14	313.89	290.52	33.05	23.37	±296.97	3	35.12	212.13	149.34	99.08	57.21	±246.16
1977 03	1	128.72	128.72	128.72				3	104.86	270.32	177.44	84.58	48.83	±210.11
1977 04								7	107.69	201.50	154.99	31.84	12.04	±29.45
1977 05	1	249.93	249.93	249.93				5	82.81	164.65	123.29	29.44	13.17	±36.55
1977 06	1	156.07	156.07	156.07				17	40.38	231.31	103.91	46.44	11.26	±23.88
1977 07	1	302.35	302.35	302.35				12	125.52	296.98	187.64	43.09	12.44	±27.38
1977 08	1	238.02	238.02	238.02				12	57.31	344.60	187.63	83.98	24.24	±53.36
1977 10	2	123.69	191.16	157.43	47.71	33.73	±428.63	11	74.32	234.85	144.70	50.49	15.22	±33.92
1977 11	1	171.00	171.00	171.00				11	71.05	203.21	151.14	44.81	13.51	±30.10
1977 12	1	70.43	70.43	70.43				10	22.46	192.63	136.30	59.83	18.92	±42.80
1978 01	1	175.54	175.54	175.54				3	71.66	275.76	157.34	105.92	61.15	±263.13
1978 02								10	76.85	239.17	118.06	48.52	15.34	±34.70
1978 03	1	191.91	191.91	191.91				9	110.04	211.76	140.04	31.77	10.59	±24.42
1978 04								9	76.59	201.11	139.24	37.87	12.62	±29.11
1978 05								10	33.23	152.67	78.67	40.50	12.81	±28.97
1978 06								7	3.49	163.39	80.50	63.08	23.84	±58.34
1978 07								11	102.53	306.04	172.50	53.43	16.11	±35.90
1978 08								6	61.47	177.44	105.20	39.27	16.03	±41.22
1978 09								9	14.76	95.31	65.22	30.67	10.22	±23.58
1978 10								2	24.22	48.58	36.40	17.22	12.18	±154.73
1978 11								3	4.52	91.60	49.12	43.58	25.16	±108.28
1978 12								2	89.80	97.21	93.51	5.24	3.70	±47.05

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
AMMONIA(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	441	0.023	0.250	0.086	0.0446	0.0021	±0.0042	33	0.014	0.290	0.099	0.0637	0.0111	±0.0226
1977	144	0.093	0.480	0.285	0.1041	0.0087	±0.0171	486	0.002	0.970	0.277	0.1855	0.0084	±0.0165
1978	24	0.110	0.310	0.197	0.0669	0.0136	±0.0282	509	0.002	0.700	0.096	0.1013	0.0045	±0.0088
LOAD (KG/DAY)														
1976	10	121.47	413.46	253.73	96.31	30.46	±68.89	8	35.12	282.92	210.90	83.60	29.56	±69.91
1977	9	70.43	302.35	181.26	72.28	24.09	±55.56	88	22.46	344.60	149.10	59.92	6.39	±12.76
1978	2	175.54	191.91	183.72	11.58	8.19	±104.03	81	3.49	306.04	111.59	58.34	6.48	±12.90

L .308E-03 U .134E-03



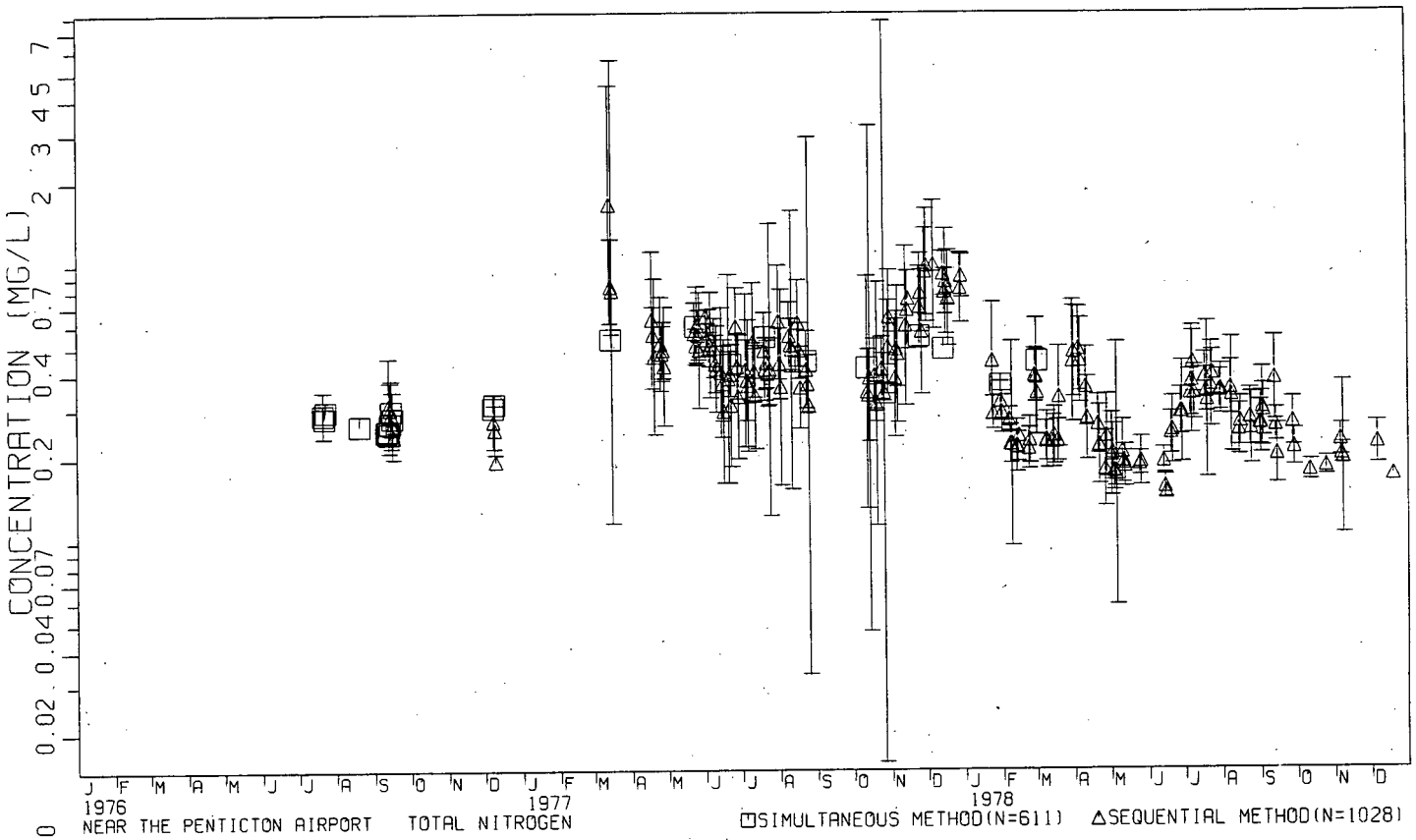


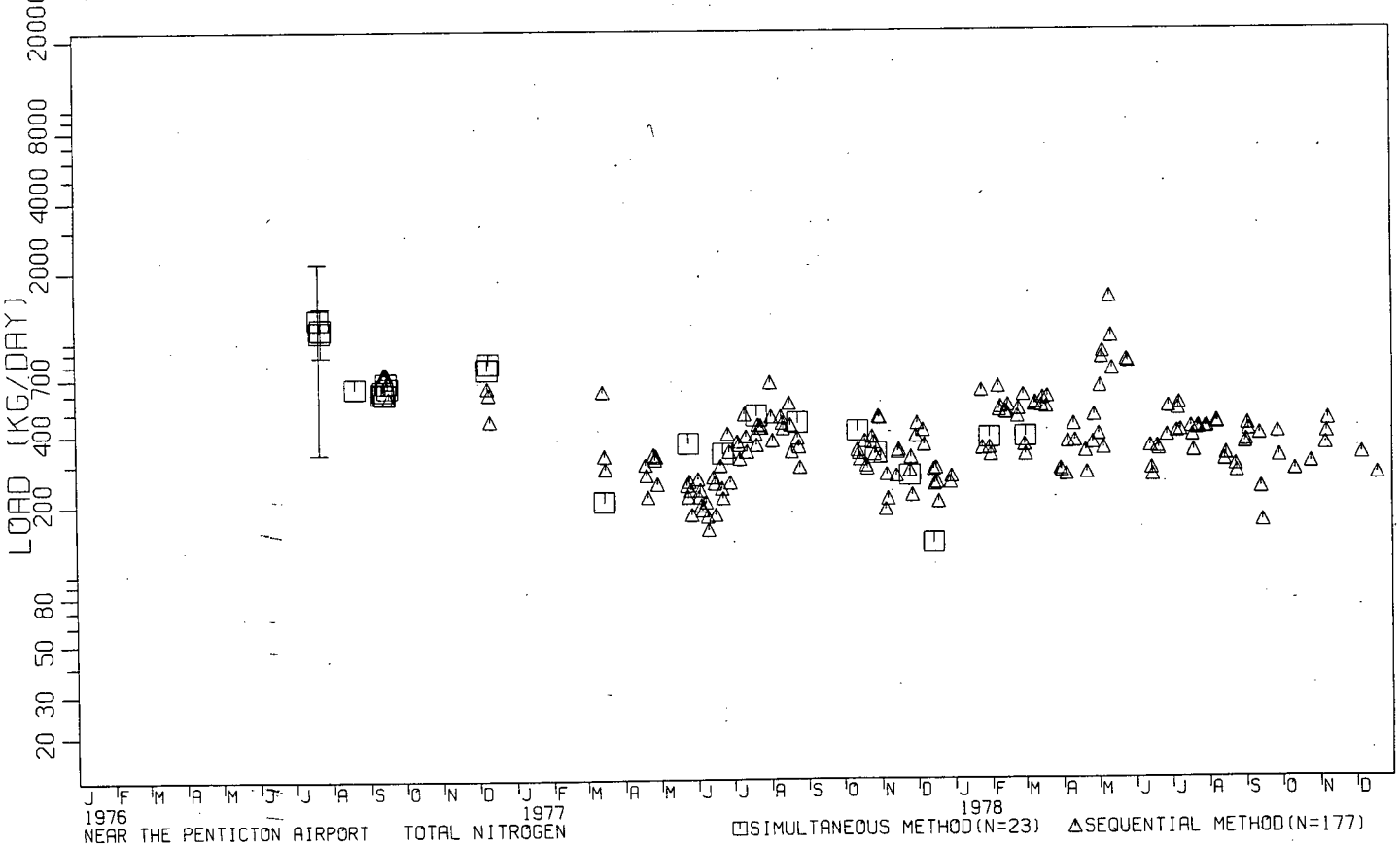
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
ORGANIC NITROGEN

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	63	0.100	0.575	0.154	0.0805	0.0101	±0.0203							
1976 08	24	0.146	0.216	0.171	0.0191	0.0039	±0.0080							
1976 09	258	0.149	0.330	0.187	0.0255	0.0016		19	0.146	0.206	0.174	0.0140	0.0032	±0.0068
1976 12	96	0.123	0.350	0.155	0.0281	0.0029	±0.0057	14	0.027	0.154	0.129	0.0328	0.0088	±0.0189
1977 03	24	0.121	0.233	0.162	0.0285	0.0058	±0.0120	8	0.027	1.386	0.425	0.5535	0.1957	±0.4628
1977 04								38	0.144	0.307	0.204	0.0303	0.0049	±0.0100
1977 05	24	0.093	0.230	0.175	0.0335	0.0068	±0.0141	32	0.158	0.472	0.224	0.0585	0.0103	±0.0211
1977 06	24	0.164	0.309	0.216	0.0329	0.0067	±0.0139	98	0.012	0.492	0.234	0.0501	0.0051	±0.0100
1977 07	12	0.160	0.202	0.179	0.0121	0.0035	±0.0077	72	0.030	0.380	0.200	0.0395	0.0047	±0.0093
1977 08	12	0.180	0.203	0.191	0.0071	0.0020	±0.0045	64	0.049	0.386	0.217	0.0497	0.0062	±0.0124
1977 10	24	0.148	0.251	0.189	0.0314	0.0064	±0.0133	50	0.136	0.285	0.206	0.0386	0.0055	±0.0110
1977 11	12	0.021	0.228	0.151	0.0502	0.0145	±0.0319	53	0.156	1.256	0.263	0.1655	0.0227	±0.0456
1977 12	12	0.134	0.274	0.169	0.0420	0.0121	±0.0267	71	0.030	2.166	0.358	0.4237	0.0503	±0.1003
1978 01	12	0.141	0.188	0.160	0.0173	0.0050	±0.0110	23	0.135	0.302	0.163	0.0358	0.0075	±0.0155
1978 02								42	0.102	0.200	0.146	0.0216	0.0033	±0.0067
1978 03	12	0.155	0.227	0.190	0.0267	0.0077	±0.0169	62	0.097	0.301	0.164	0.0393	0.0050	±0.0100
1978 04								60	0.044	0.306	0.167	0.0516	0.0067	±0.0133
1978 05								53	0.103	0.256	0.161	0.0287	0.0039	±0.0079
1978 06								41	0.130	0.483	0.168	0.0557	0.0087	±0.0176
1978 07								80	0.108	0.716	0.196	0.0895	0.0100	±0.0199
1978 08								48	0.035	0.604	0.180	0.0847	0.0122	±0.0246
1978 09								56	0.128	0.223	0.167	0.0226	0.0030	±0.0061
1978 10								16	0.115	0.172	0.144	0.0216	0.0054	±0.0115
1978 11								16	0.120	0.160	0.140	0.0112	0.0028	±0.0060
1978 12								12	0.017	0.147	0.119	0.0365	0.0105	±0.0232
						LOAD (KG/DAY)								
1976 07	3	527.99	556.21	539.61	14.76	8.52	±36.67							
1976 08	1	409.11	409.11	409.11										
1976 09	4	4C0.58	445.20	419.66	18.66	9.33	±29.68	5	400.83	426.77	417.51	10.83	4.84	±13.45
1976 12	2	374.75	391.20	382.98	11.63	8.22	±104.49	3	290.92	325.46	312.90	19.09	11.02	±47.44
1977 03	1	60.47	60.47	60.47				3	30.92	482.68	207.10	241.72	139.56	±600.52
1977 04								7	78.77	140.12	111.26	25.04	9.46	±23.16
1977 05	1	107.71	107.71	107.71				5	73.82	107.26	90.98	11.86	5.30	±14.72
1977 06	1	160.92	160.92	160.92				17	89.53	177.77	124.46	28.90	7.01	±14.86
1977 07	1	154.63	154.63	154.63				12	163.08	222.73	183.53	18.38	5.31	±11.68
1977 08	1	185.85	185.85	185.85				12	171.78	253.83	202.56	23.50	6.79	±14.93
1977 10	2	157.24	204.36	180.80	33.32	23.56	±299.40	11	150.92	211.13	183.40	19.80	5.97	±13.30
1977 11	1	71.55	71.55	71.55				11	74.35	174.38	109.93	28.10	8.47	±18.87
1977 12	1	45.94	45.94	45.94				10	36.58	231.85	110.37	79.68	25.20	±56.99
1978 01	1	164.44	164.44	164.44				3	169.28	214.38	185.90	24.77	14.30	±61.55
1978 02								10	161.78	359.59	293.63	52.92	16.73	±37.85
1978 03	1	159.38	159.38	159.38				9	122.41	344.22	262.83	94.21	31.40	±72.42
1978 04								9	94.40	299.05	181.74	67.20	22.40	±51.65
1978 05								10	285.68	1437.50	678.86	329.71	104.26	±235.84
1978 06								7	204.76	312.47	251.57	42.39	16.02	±39.21
1978 07								11	169.06	334.21	219.60	48.71	14.69	±32.72
1978 08								6	145.24	305.76	204.31	61.79	25.22	±64.85
1978 09								9	141.87	303.37	209.44	54.28	18.09	±41.72
1978 10								2	191.27	259.39	225.33	48.17	34.06	±432.76
1978 11								3	212.84	345.41	274.10	66.86	38.60	±166.09
1978 12								2	126.20	192.24	159.22	46.70	33.02	±419.59

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
ORGANIC NITROGEN

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	441	0.100	0.575	0.174	0.0414	0.0020	±0.0039	33	0.027	0.206	0.155	0.0326	0.0057	±0.0116
1977	144	0.021	0.309	0.181	0.0370	0.0031	±0.0061	486	0.012	2.166	0.245	0.1948	0.0088	±0.0174
1978	24	0.141	0.227	0.175	0.0267	0.0055	±0.0113	509	0.017	0.716	0.167	0.0567	0.0025	±0.0049
LOAD (KG/DAY)														
1976	10	374.75	556.21	447.25	66.64	21.07	±47.67	8	290.92	426.77	378.28	55.70	19.69	±46.57
1977	9	45.94	204.36	127.63	57.79	19.26	±44.42	88	30.92	482.68	146.98	63.75	6.80	±13.58
1978	2	159.38	164.44	161.91	3.58	2.53	±32.15	81	94.40	1437.50	285.96	195.86	21.76	±43.31


CONCENTRATION (MG/L)
0.02 0.04 0.07 0.2 0.4 0.7 2 3 4 5 7
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT TOTAL NITROGEN
SIMULTANEOUS METHOD(N=611) SEQUENTIAL METHOD(N=1028)

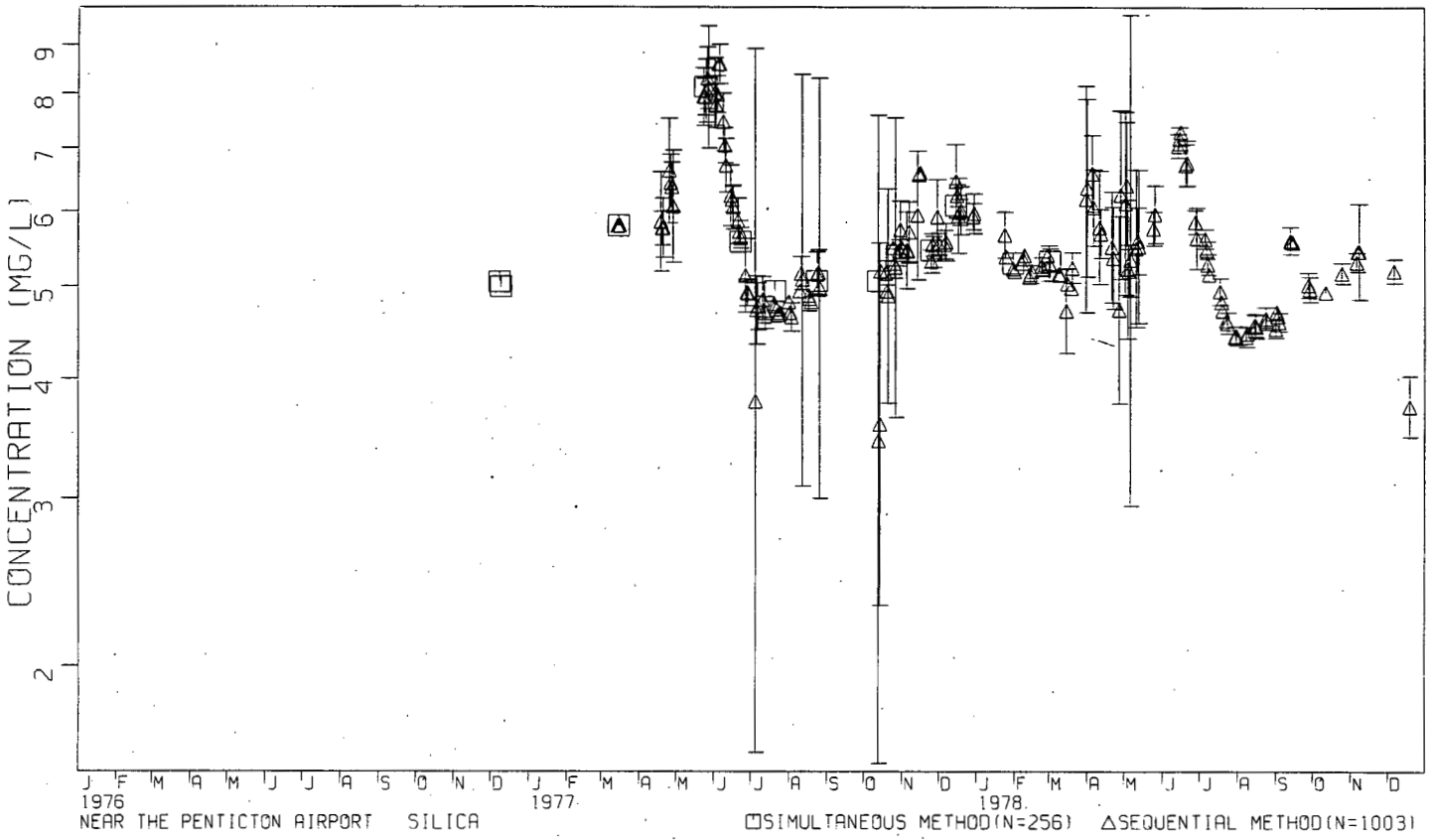

LOAD (KG/DAY)
20 30 50 80 200 400 700 2000 4000 8000 20000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT TOTAL NITROGEN
SIMULTANEOUS METHOD(N=23) SEQUENTIAL METHOD(N=177)

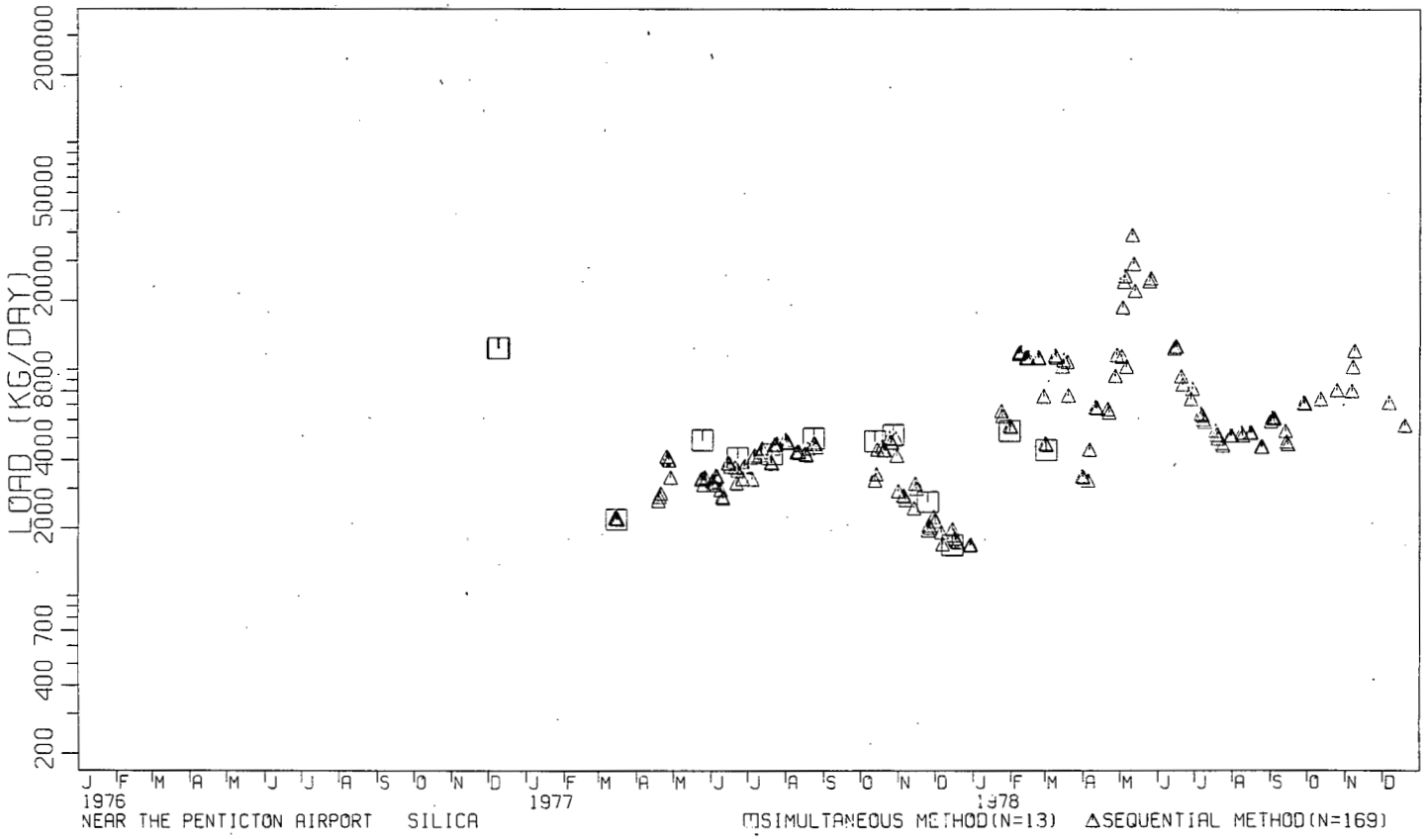
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL NITROGEN(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	63	0.165	0.963	0.298	0.1274	0.0161	±0.0321							
1976 08	24	0.177	0.398	0.270	0.0690	0.0141	±0.0292							
1976 09	258	0.190	0.439	0.267	0.0464	0.0029		19	0.183	0.365	0.289	0.0586	0.0135	±0.0283
1976 12	96	0.212	0.442	0.315	0.0639	0.0065	±0.0129	14	0.195	0.364	0.262	0.0595	0.0159	±0.0344
1977 03	24	0.420	0.650	0.540	0.0769	0.0157	±0.0325	8	0.575	1.790	1.042	0.4119	0.1456	±0.3445
1977 04								38	0.262	0.818	0.520	0.1393	0.0226	±0.0458
1977 05	24	0.420	0.660	0.599	0.0669	0.0137	±0.0283	32	0.353	1.020	0.565	0.1532	0.0271	±0.0552
1977 06	24	0.311	0.591	0.441	0.0786	0.0160	±0.0332	98	0.131	0.755	0.464	0.1379	0.0139	±0.0277
1977 07	12	0.430	0.660	0.551	0.0860	0.0248	±0.0546	72	0.236	0.710	0.435	0.1337	0.0158	±0.0314
1977 08	12	0.360	0.540	0.451	0.0699	0.0202	±0.0444	64	0.210	0.810	0.480	0.1549	0.0194	±0.0387
1977 10	24	0.290	0.540	0.387	0.0767	0.0157	±0.0324	50	0.200	0.800	0.408	0.1365	0.0193	±0.0388
1977 11	12	0.470	0.710	0.550	0.0671	0.0194	±0.0427	53	0.260	1.990	0.695	0.3125	0.0429	±0.0861
1977 12	12	0.440	0.570	0.494	0.0493	0.0142	±0.0313	71	0.380	2.400	0.973	0.4452	0.0528	±0.1053
1978 01	12	0.290	0.450	0.371	0.0650	0.0188	±0.0413	23	0.240	1.100	0.382	0.2153	0.0449	±0.0931
1978 02								42	0.190	0.430	0.256	0.0607	0.0094	±0.0189
1978 03	12	0.320	0.580	0.455	0.1019	0.0294	±0.0648	62	0.170	0.850	0.302	0.1433	0.0182	±0.0364
1978 04								60	0.150	0.920	0.362	0.1945	0.0251	±0.0502
1978 05								53	0.150	0.330	0.197	0.0394	0.0054	±0.0109
1978 06								41	0.150	0.950	0.263	0.1314	0.0205	±0.0415
1978 07								80	0.190	0.850	0.384	0.1283	0.0143	±0.0285
1978 08								48	0.100	0.650	0.306	0.1094	0.0158	±0.0318
1978 09								56	0.180	0.660	0.284	0.0898	0.0120	±0.0240
1978 10								16	0.160	0.210	0.183	0.0174	0.0044	±0.0093
1978 11								16	0.180	0.270	0.215	0.0261	0.0065	±0.0139
1978 12								12	0.170	0.320	0.211	0.0500	0.0144	±0.0318
						LOAD (KG/DAY)								
1976 07	3	997.78	1129.60	1044.60	73.79	42.60	±183.32							
1976 08	1	632.97	632.97	632.97										
1976 09	4	556.51	636.26	608.03	37.24	18.62	±59.25	5	576.05	733.07	688.95	67.32	30.11	±83.57
1976 12	2	760.66	804.50	782.58	31.00	21.92	±278.52	3	456.58	633.47	561.01	92.68	53.51	±230.24
1977 03	1	205.94	205.94	205.94				3	284.35	608.12	405.03	176.92	102.14	±439.52
1977 04								7	216.11	326.89	283.44	41.88	15.83	±38.73
1977 05	1	365.99	365.99	365.99				5	181.50	251.21	224.50	27.36	12.24	±33.97
1977 06	1	329.91	329.91	329.91				17	156.21	402.10	238.38	61.53	14.92	±31.64
1977 07	1	478.31	478.31	478.31				12	314.14	487.28	395.38	49.50	14.29	±31.45
1977 08	1	448.18	448.18	448.18				12	288.92	666.06	433.82	101.06	29.17	±64.21
1977 10	2	329.57	410.71	370.14	57.38	40.57	±515.51	11	285.50	473.88	360.51	63.45	19.13	±42.62
1977 11	1	263.77	263.77	263.77				11	190.20	388.88	284.77	62.11	18.73	±41.73
1977 12	1	134.83	134.83	134.83				10	204.06	443.42	298.08	79.18	25.04	±56.64
1978 01	1	382.16	382.16	382.16				3	343.70	610.80	433.37	153.67	88.72	±381.77
1978 02								10	322.46	632.84	504.26	80.31	25.40	±57.45
1978 03	1	383.86	383.86	383.86				9	280.39	572.00	466.37	113.65	37.88	±87.36
1978 04								9	264.14	474.03	348.83	73.39	24.46	±56.42
1978 05								10	342.43	1534.00	801.85	334.19	105.68	±239.05
1978 06								7	261.74	512.96	353.24	82.33	31.12	±76.15
1978 07								11	330.69	532.27	423.43	53.58	16.16	±35.99
1978 08								6	270.57	443.38	345.03	76.33	31.16	±80.11
1978 09								9	166.18	433.46	341.21	89.06	29.69	±68.46
1978 10								2	275.42	295.93	285.67	14.50	10.25	±130.26
1978 11								3	354.09	451.52	400.81	48.84	28.20	±121.33
1978 12								2	263.79	322.18	292.98	41.29	29.20	±370.98

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
TOTAL NITROGEN(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	441	0.165	0.963	0.282	0.0712	0.0034	±0.0067	33	0.183	0.365	0.277	0.0596	0.0104	±0.0211
1977	144	0.290	0.710	0.498	0.1019	0.0085	±0.0168	486	0.131	2.400	0.576	0.3067	0.0139	±0.0273
1978	24	0.290	0.580	0.413	0.0940	0.0192	±0.0397	509	0.100	1.100	0.297	0.1394	0.0062	±0.0121
						LOAD (KG/DAY)								
1976	10	556.51	1129.60	776.39	201.60	63.75	±144.20	8	456.58	733.07	640.97	97.10	34.33	±81.19
1977	9	134.83	478.31	329.69	112.72	37.57	±86.64	88	156.21	666.06	322.77	99.46	10.60	±21.18
1978	2	382.16	383.86	383.01	1.20	0.85	±10.80	81	166.18	1534.00	448.51	198.26	22.03	±43.84


CONCENTRATION (MG/L)
2
3
4
5
6
7
8
9
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT SILICA
□SIMULTANEOUS METHOD(N=256) △SEQUENTIAL METHOD(N=1003)


LOAD (KG/DAY)
200
400
700
2000
4000
8000
20000
50000
200000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
NEAR THE PENTICTON AIRPORT SILICA
□SIMULTANEOUS METHOD(N=13) △SEQUENTIAL METHOD(N=169)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
DISSOLVED SILICA

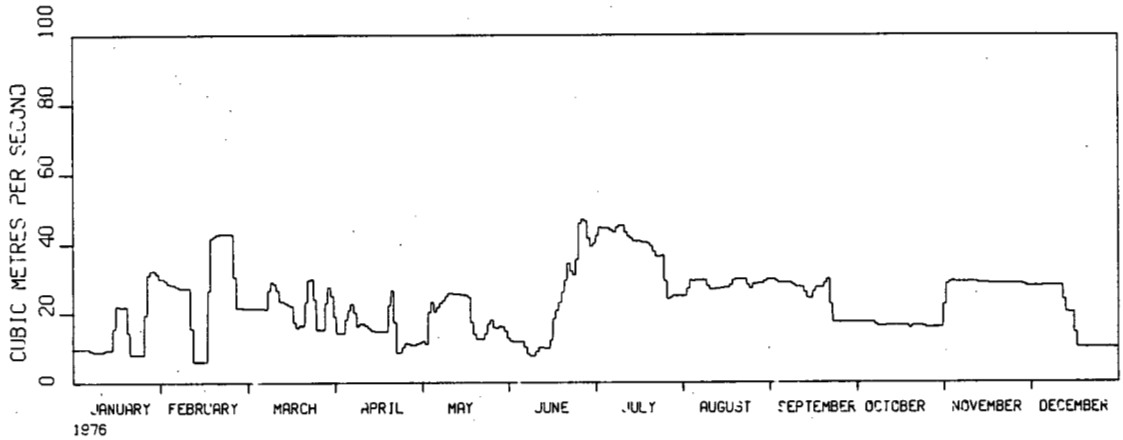
SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 12	96	5.000	5.100	5.031	0.0466	0.0048	±0.0094							
1977 03	24	5.800	5.800	5.800	0.0	0.0	±0.0	16	5.800	5.800	5.800	0.0	0.0	±0.0
1977 04								38	5.500	7.200	6.182	0.5172	0.0839	±0.1700
1977 05	24	7.500	9.300	8.150	0.4511	0.0921	±0.1905	32	7.000	9.400	8.106	0.6221	0.1100	±0.2244
1977 06	24	5.400	5.800	5.579	0.1318	0.0269	±0.0557	98	4.700	8.900	6.702	1.2567	0.1269	±0.2520
1977 07	4	4.800	5.100	4.950	0.1291	0.0645	±0.2054	72	1.700	5.300	4.706	0.4028	0.0475	±0.0946
1977 08	12	5.000	5.200	5.075	0.0866	0.0250	±0.0550	64	4.600	5.600	4.955	0.2588	0.0323	±0.0646
1977 10	24	5.000	5.600	5.238	0.1974	0.0403	±0.0834	50	2.100	6.000	4.968	0.9673	0.1368	±0.2748
1977 11	12	5.300	5.900	5.475	0.2598	0.0750	±0.1651	53	5.100	7.200	5.693	0.4898	0.0673	±0.1350
1977 12	12	5.900	6.400	6.100	0.1954	0.0564	±0.1242	71	4.800	6.800	5.897	0.3910	0.0464	±0.0925
1978 01	12	5.200	5.500	5.300	0.1279	0.0369	±0.0813	23	5.100	6.400	5.443	0.3012	0.0628	±0.1303
1978 02								42	5.000	5.400	5.250	0.1110	0.0171	±0.0346
1978 03	12	5.200	5.500	5.325	0.1357	0.0392	±0.0862	62	3.700	8.000	5.240	0.7278	0.0924	±0.1849
1978 04								60	3.600	8.300	5.962	1.1300	0.1459	±0.2919
1978 05								53	4.800	8.300	5.766	0.8456	0.1161	±0.2331
1978 06								41	4.600	7.300	6.449	0.6731	0.1051	±0.2124
1978 07								80	4.300	5.800	4.930	0.4265	0.0477	±0.0949
1978 08								48	4.300	4.800	4.546	0.1429	0.0206	±0.0415
1978 09								56	4.400	5.700	4.954	0.4382	0.0586	±0.1173
1978 10								16	4.900	5.400	5.056	0.1672	0.0418	±0.0891
1978 11								16	5.200	5.600	5.400	0.1155	0.0289	±0.0615
1978 12								12	3.600	5.500	4.717	0.7346	0.2121	±0.4668
LOAD (KG/DAY)														
1976 12	2	12387.00	12421.00	12404.00	23.74	16.79	±213.31							
1977 03	1	2184.90	2184.90	2184.90				3	2194.90	2211.20	2203.80	8.25	4.76	±20.50
1977 04								7	2650.70	4155.30	3414.50	667.60	252.33	±617.45
1977 05	1	4899.40	4899.40	4899.40				5	3123.20	3376.40	3288.20	96.38	43.10	±119.66
1977 06	1	4097.80	4097.80	4097.80				17	2721.90	3888.40	3396.00	378.33	91.76	±194.53
1977 07	1	4259.70	4259.70	4259.70				12	3307.90	4758.20	4270.80	420.09	121.27	±266.92
1977 08	1	4987.00	4987.00	4987.00				12	4228.70	4937.80	4561.20	241.82	69.81	±153.65
1977 10	2	4848.10	5183.90	5016.00	237.47	167.92	±2133.60	11	3273.20	5038.40	4418.10	574.55	173.23	±385.96
1977 11	1	2615.40	2615.40	2615.40				11	1963.70	3174.10	2557.30	429.14	129.39	±288.28
1977 12	1	1684.00	1684.00	1684.00				10	1684.20	2149.20	1828.60	150.88	47.71	±107.93
1978 01	1	5399.30	5399.30	5399.30				3	5688.40	6618.00	6198.50	471.37	272.14	±1171.00
1978 02								10	5636.80	12029.00	10581.00	2139.80	676.66	±1530.60
1978 03	1	4450.60	4450.60	4450.60				9	3425.30	11570.00	8460.40	3339.40	1113.10	±2566.90
1978 04								9	3270.60	11732.00	6592.50	2750.70	916.90	±2114.40
1978 05								10	10371.00	39271.00	23192.00	8380.40	2650.10	±5994.60
1978 06								7	7501.70	12746.00	10268.00	2315.40	875.13	±2141.40
1978 07								11	4683.10	6460.30	5486.70	623.64	188.03	±418.94
1978 08								6	4620.70	5344.20	5073.50	351.46	143.48	±368.89
1978 09								9	4736.00	7196.90	5985.70	875.63	291.88	±673.07
1978 10								2	7497.70	8182.80	7840.30	484.42	342.54	±4352.30
1978 11								3	8121.00	12191.00	10240.00	2040.30	1177.90	±5068.70
1978 12								2	5734.10	7244.30	6489.20	1067.80	755.05	±9593.70

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER NEAR THE PENTICTON AIRPORT
DISSOLVED SILICA

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	96	5.000	5.100	5.031	0.0466	0.0048	±0.0094							
1977	136	4.800	9.300	5.985	1.0731	0.0920	±0.1820	494	1.700	9.400	5.807	1.1772	0.0530	±0.1041
1978	24	5.200	5.500	5.313	0.1296	0.0265	±0.0547	509	3.600	8.300	5.328	0.8185	0.0363	±0.0713
LOAD (KG/DAY)														
1976	2	12387.00	12421.00	12404.00	23.74	16.79	±213.31							
1977	9	1684.00	5183.90	3862.20	1341.00	446.99	±1030.80	88	1684.20	5038.40	3473.70	994.25	105.99	±211.76
1978	2	4450.60	5399.30	4925.00	670.81	474.34	±6026.90	81	3270.60	39271.00	9478.00	6438.30	715.37	±1423.60

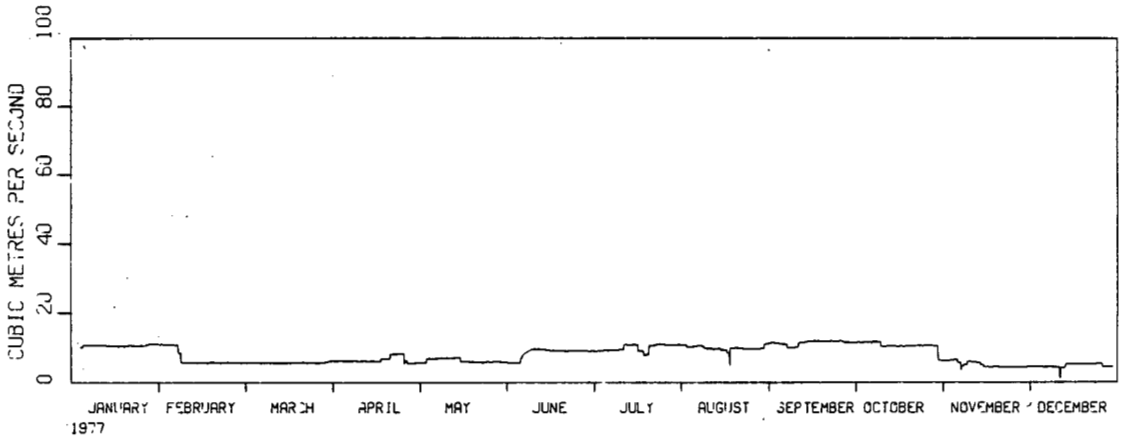
APPENDIX D

Annual hydrographs illustrating hourly discharge ($m^3 s^{-1}$) determined during the period from 1976 to 1978 in Okanagan River at Okanagan Falls (Water Survey of Canada station 08NM002).



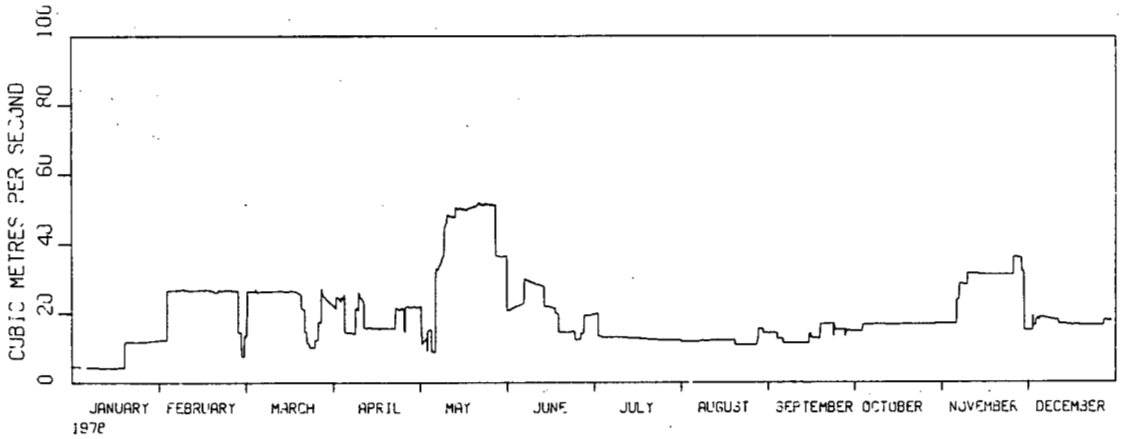
STATION 08
OKANAGAN FALLS

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 108NM002



STATION 08
OKANAGAN FALLS

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 108NM002



STATION 08
OKANAGAN FALLS

DISCHARGE IN CUBIC METRES PER SECOND
STATION NO. 108NM002

APPENDIX E

Okanagan River at Okanagan Falls, 1976 to 1978

Concentrations and loads derived from simultaneous and sequential measurements are shown in (1) graphs and (2) tables.

1. Graphs

   Graphs illustrate time series of

   (a) the daily geometric concentration means (mg l^{-1}) and their 95 percent confidence limits, and

   (b) the daily total loads (kg day^{-1}) of nutrients during the three-year period.

2. Tables

   Tables show statistical characteristics of nutrient concentrations and loads, reduced to the (a) monthly and (b) annual basis, in terms of

   (a_i) the arithmetic concentration means (mg l^{-1}), and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given month of sampling,

   (a_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given month of sampling.

   (b_i) the arithemetic concentration means (mg l^{-1}) and their 95 percent confidence intervals, calculated for all individual concentration measurements during any given year of sampling,

   (b_{ii}) the arithmetic load means (kg day^{-1}) and their 95 percent confidence intervals, calculated for all individual load data determined during any given year of sampling.

E1 Time series of total phosphorus (P) concentration and loads, 1976 to 1978

E2 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual months of sampling

E3 Statistical characteristics of concentration and load data of total phosphorus (P) determined for the individual year of sampling

E4 Time series of total dissolved phosphorus (P) concentration and loads, 1976 to 1978

E5 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual months of sampling

E6 Statistical characteristics of concentration and load data of total dissolved phosphorus (P) determined for the individual year of sampling

E7 Time series of nitrate plus nitrite (N) concentration and loads, 1976 to 1978

E8 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual months of sampling

E9 Statistical characteristics of concentration and load data of nitrate plus nitrite (N) determined for the individual year of sampling

E10 Time series of ammonia (N) concentration and loads, 1976 to 1978

E11 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual months of sampling

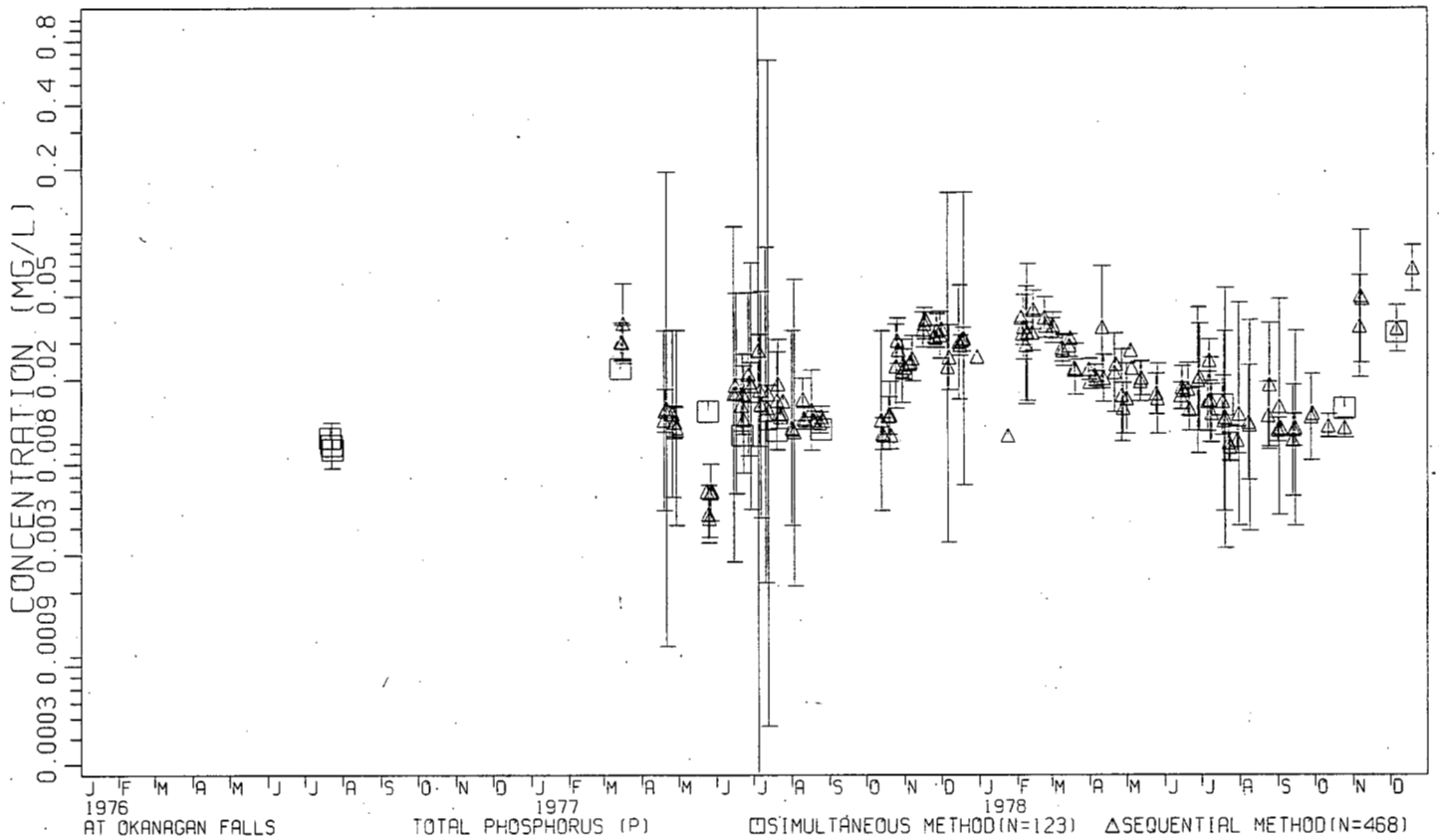
E12 Statistical characteristics of concentration and load data of ammonia (N) determined for the individual year of sampling

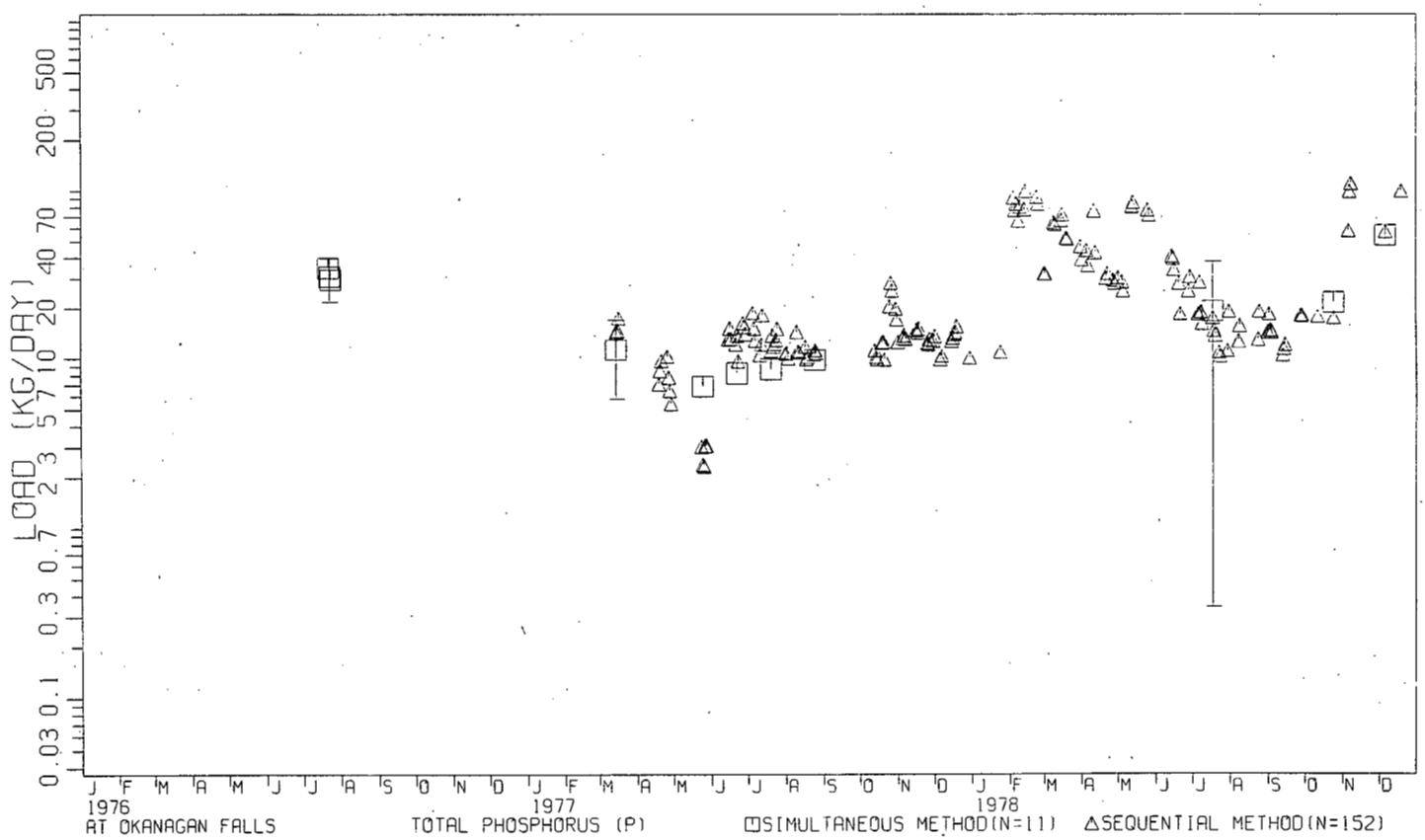
E13 Time series of organic nitrogen (N) concentration and loads, 1976 to 1978

E14 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual months of sampling

E15 Statistical characteristics of concentration and load data of organic nitrogen (N) determined for the individual year of sampling

E16 Time series of total nitrogen (N) concentration and loads, 1976 to 1978


CONCENTRATION (MG/L)
0.0003 0.0009 0.003 0.008 0.02 0.05 0.2 0.4 0.8
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS
TOTAL PHOSPHORUS (P)
SIMULTANEOUS METHOD(N=123)
SEQUENTIAL METHOD(N=468)

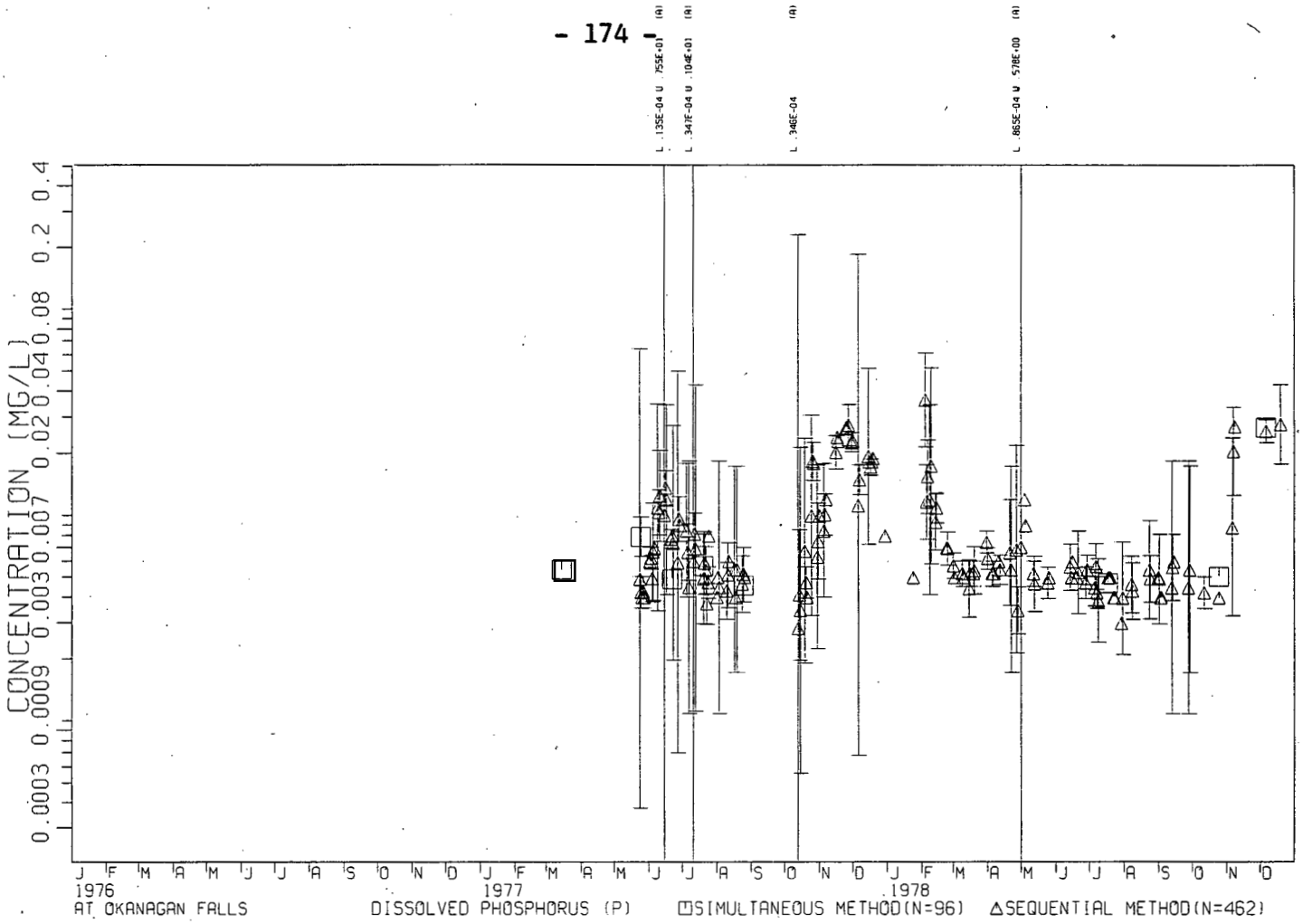

LOAD (KG/DAY)
0.03 0.1 0.3 0.7 2 3 5 7 10 20 40 70 200 500
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS
TOTAL PHOSPHORUS (P)
SIMULTANEOUS METHOD(N=11)
SEQUENTIAL METHOD(N=152)

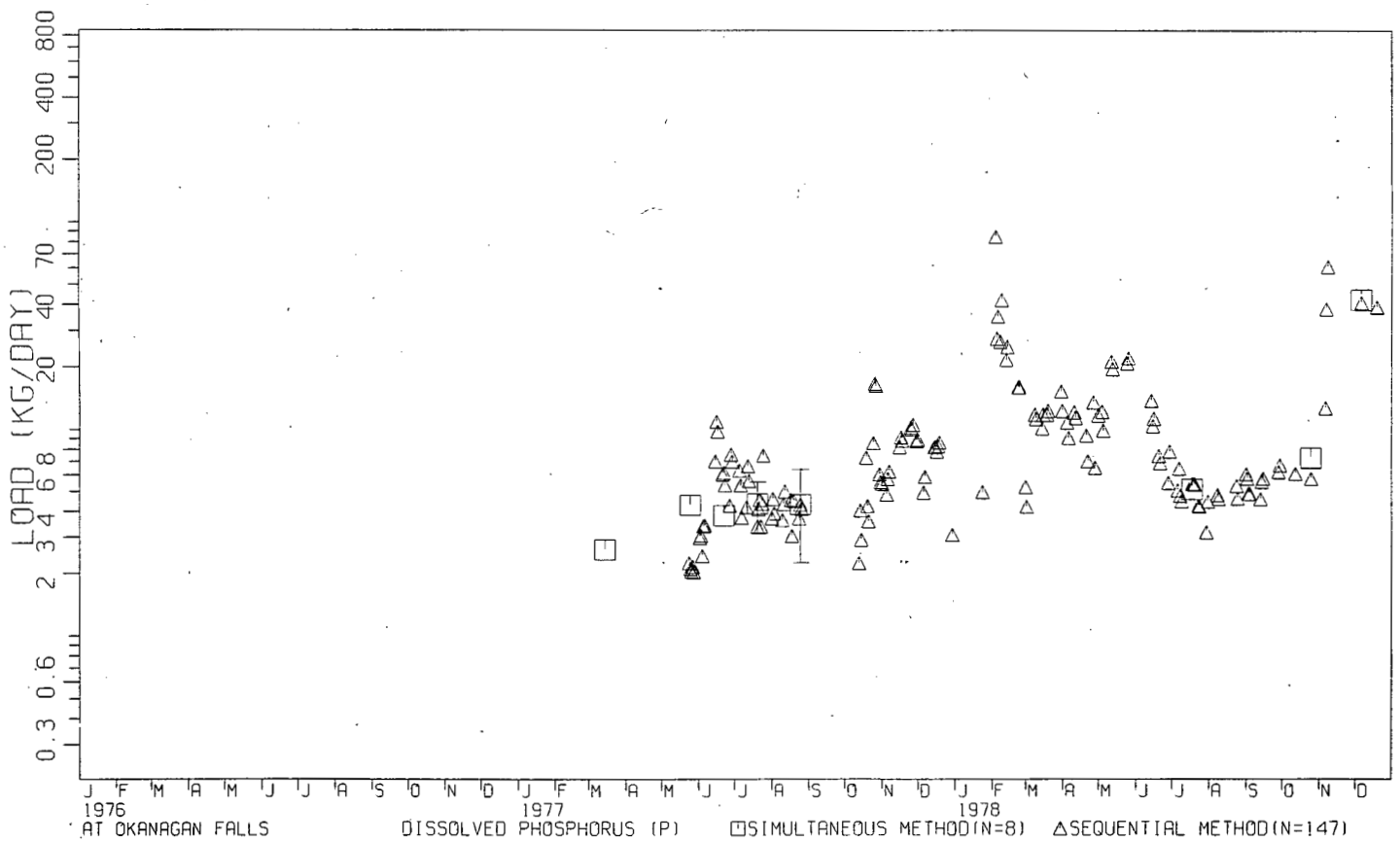
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	27	0.006	0.019	0.010	0.0029	0.0006	±0.0011							
1977 03	12	0.020	0.042	0.023	0.0062	0.0018	±0.0039	9	0.027	0.044	0.033	0.0053	0.0018	±0.0041
1977 04								20	0.011	0.018	0.013	0.0019	0.0004	±0.0009
1977 05	12	0.013	0.017	0.014	0.0013	0.0004	±0.0008	16	0.004	0.007	0.005	0.0010	0.0003	±0.0005
1977 06	12	0.009	0.014	0.011	0.0014	0.0004	±0.0009	27	0.010	0.025	0.018	0.0035	0.0007	±0.0014
1977 07	12	0.011	0.014	0.012	0.0009	0.0003	±0.0006	36	0.012	0.043	0.017	0.0060	0.0010	±0.0020
1977 08	12	0.010	0.020	0.012	0.0027	0.0008	±0.0017	32	0.010	0.018	0.013	0.0015	0.0003	±0.0006
1977 10								31	0.010	0.038	0.019	0.0077	0.0014	±0.0028
1977 11								31	0.023	0.041	0.031	0.0054	0.0010	±0.0020
1977 12								26	0.020	0.037	0.030	0.0041	0.0008	±0.0016
1978 01								1	0.011	0.011	0.011			
1978 02								28	0.028	0.049	0.037	0.0053	0.0010	±0.0020
1978 03								35	0.020	0.039	0.028	0.0053	0.0009	±0.0018
1978 04								33	0.012	0.064	0.022	0.0089	0.0016	±0.0032
1978 05								18	0.015	0.028	0.019	0.0035	0.0008	±0.0017
1978 06								24	0.012	0.040	0.019	0.0063	0.0013	±0.0027
1978 07	12	0.012	0.075	0.019	0.0179	0.0052	±0.0113	37	0.008	0.043	0.015	0.0071	0.0012	±0.0024
1978 08								14	0.009	0.028	0.016	0.0061	0.0016	±0.0035
1978 09								26	0.010	0.026	0.012	0.0030	0.0006	±0.0012
1978 10	12	0.013	0.024	0.015	0.0036	0.0010	±0.0023	8	0.011	0.013	0.012	0.0008	0.0003	±0.0007
1978 11								8	0.031	0.092	0.047	0.0200	0.0071	±0.0167
1978 12	12	0.032	0.036	0.034	0.0014	0.0004	±0.0009	8	0.032	0.082	0.052	0.0197	0.0070	±0.0165
						LOAD (KG/DAY)								
1976 07	3	29.46	34.69	31.64	2.72	1.57	±6.77							
1977 03	1	11.34	11.34	11.34				3	14.44	17.36	15.49	1.62	0.93	±4.02
1977 04								7	5.39	10.34	7.89	1.76	0.67	±1.63
1977 05	1	6.84	6.84	6.84				5	2.32	3.07	2.77	0.39	0.17	±0.48
1977 06	1	8.17	8.17	8.17				9	9.64	16.28	13.67	1.98	0.66	±1.52
1977 07	1	8.66	8.66	8.66				12	10.46	18.80	13.73	2.64	0.76	±1.68
1977 08	1	9.85	9.85	9.85				12	9.94	14.47	11.05	1.19	0.34	±0.76
1977 10								11	9.90	28.34	16.15	6.58	1.99	±4.42
1977 11								11	12.22	15.07	13.45	0.95	0.29	±0.64
1977 12								9	9.86	15.57	12.70	2.10	0.70	±1.61
1978 01								1	11.04	11.04	11.04			
1978 02								9	66.39	100.35	83.82	9.99	3.33	±7.68
1978 03								9	32.05	72.42	53.69	14.76	4.92	±11.34
1978 04								9	28.26	76.40	39.94	14.88	4.96	±11.44
1978 05								7	25.48	85.88	57.38	27.58	10.42	±25.50
1978 06								7	18.62	41.07	31.22	7.96	3.01	±7.37
1978 07	1	19.20	19.20	19.20				11	10.43	28.73	16.42	5.22	1.58	±3.51
1978 08								4	12.79	19.23	15.24	2.99	1.49	±4.75
1978 09								9	10.50	18.46	14.74	3.00	1.00	±2.30
1978 10	1	21.58	21.58	21.58				2	17.50	17.78	17.64	0.20	0.14	±1.76
1978 11								3	57.98	111.14	89.52	27.93	16.12	±69.39
1978 12	1	54.21	54.21	54.21				2	57.11	99.72	78.42	30.13	21.31	±270.70

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	27	0.006	0.019	0.010	0.0029	0.0006	±0.0011							
1977	60	0.009	0.042	0.014	0.0055	0.0007	±0.0014	228	0.004	0.044	0.020	0.0093	0.0006	±0.0012
1978	36	0.012	0.075	0.023	0.0132	0.0022	±0.0045	240	0.008	0.092	0.023	0.0128	0.0008	±0.0016
LOAD (KG/DAY)														
1976	3	29.46	34.69	31.64	2.72	1.57	±6.77							
1977	5	6.84	11.34	8.97	1.71	0.76	±2.12	79	2.32	28.34	12.35	4.36	0.49	±0.98
1978	3	19.20	54.21	31.67	19.56	11.29	±48.59	73	10.43	111.14	41.96	28.84	3.38	±6.73


L .135E-04 U .755E-01 (A)
L .347E-04 U .104E-01 (A)
L .346E-04 (A)
L .865E-04 U .578E-00 (A)
CONCENTRATION (MG/L)
0.0003 0.0009 0.003 0.007 0.02 0.04 0.08 0.2 0.4
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS DISSOLVED PHOSPHORUS (P) □SIMULTANEOUS METHOD(N=96) △SEQUENTIAL METHOD(N=462)

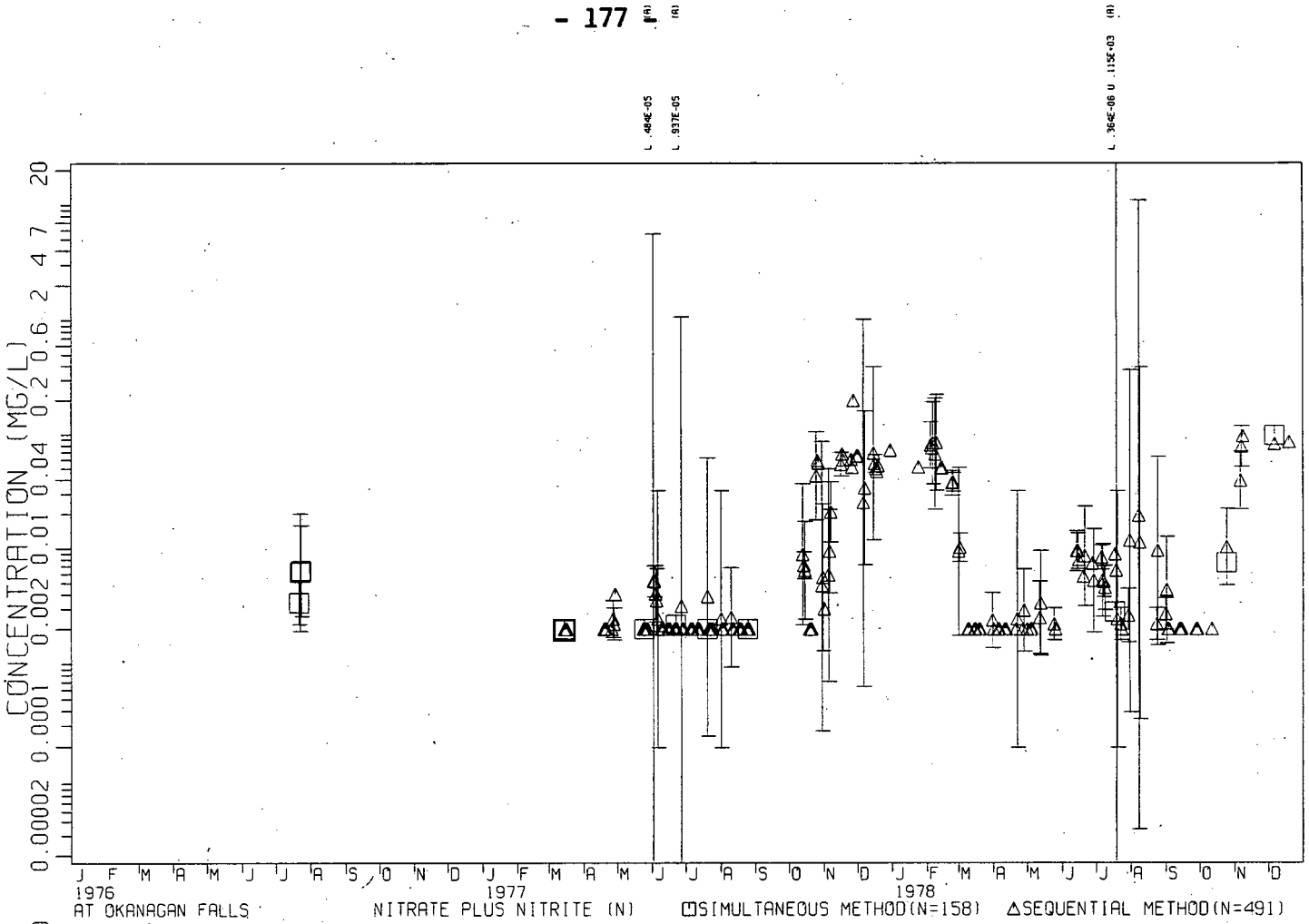

LOAD (KG/DAY)
0.3 0.6 2 3 4 6 8 20 40 70 200 400 800
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS DISSOLVED PHOSPHORUS (P) □SIMULTANEOUS METHOD(N=8) △SEQUENTIAL METHOD(N=147)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1977 03	12	0.005	0.007	0.005	0.0007	0.0002	±0.0004							
1977 05	12	0.006	0.014	0.008	0.0033	0.0009	±0.0021	16	0.004	0.006	0.004	0.0006	0.0001	±0.0003
1977 06	12	0.004	0.007	0.005	0.0010	0.0003	±0.0007	51	0.004	0.017	0.009	0.0031	0.0004	±0.0009
1977 07	12	0.005	0.008	0.006	0.0009	0.0002	±0.0006	36	0.003	0.010	0.006	0.0018	0.0003	±0.0006
1977 08	12	0.003	0.009	0.005	0.0015	0.0004	±0.0010	32	0.004	0.007	0.005	0.0008	0.0001	±0.0003
1977 10								31	0.002	0.022	0.008	0.0054	0.0010	±0.0020
1977 11								31	0.008	0.028	0.020	0.0070	0.0013	±0.0026
1977 12								26	0.008	0.024	0.018	0.0037	0.0007	±0.0015
1978 01								1	0.005	0.005	0.005			
1978 02								28	0.006	0.038	0.012	0.0076	0.0014	±0.0030
1978 03								35	0.004	0.008	0.005	0.0010	0.0002	±0.0003
1978 04								33	0.003	0.011	0.006	0.0016	0.0003	±0.0006
1978 05								18	0.004	0.012	0.006	0.0022	0.0005	±0.0011
1978 06								24	0.004	0.008	0.005	0.0008	0.0002	±0.0003
1978 07	12	0.004	0.006	0.005	0.0006	0.0002	±0.0004	37	0.003	0.007	0.004	0.0010	0.0002	±0.0003
1978 08								14	0.004	0.009	0.005	0.0013	0.0003	±0.0008
1978 09								26	0.004	0.008	0.005	0.0010	0.0002	±0.0004
1978 10	12	0.003	0.007	0.005	0.0010	0.0003	±0.0007	8	0.004	0.005	0.004	0.0004	0.0001	±0.0003
1978 11								8	0.007	0.029	0.017	0.0085	0.0030	±0.0071
1978 12	12	0.025	0.032	0.027	0.0019	0.0006	±0.0012	7	0.024	0.034	0.027	0.0035	0.0013	±0.0033
LOAD (KG/DAY)														
1977 03	1	2.62	2.62	2.62										
1977 05	1	4.33	4.33	4.33				5	2.05	2.26	2.13	0.09	0.04	±0.11
1977 06	1	3.85	3.85	3.85				14	2.45	10.99	5.72	2.64	0.71	±1.52
1977 07	1	4.39	4.39	4.39				12	3.40	7.54	4.97	1.36	0.39	±0.87
1977 08	1	4.35	4.35	4.35				12	3.06	5.05	4.15	0.55	0.16	±0.35
1977 10								11	2.25	16.78	7.09	5.06	1.53	±3.40
1977 11								11	4.86	10.65	8.06	2.09	0.63	±1.40
1977 12								9	3.10	8.94	7.15	2.02	0.67	±1.56
1978 01								1	5.02	5.02	5.02			
1978 02								9	16.06	85.23	32.87	21.35	7.12	±16.41
1978 03								9	4.26	15.42	10.52	3.55	1.18	±2.73
1978 04								9	6.59	13.55	10.32	2.42	0.81	±1.86
1978 05								7	9.97	22.19	16.90	5.29	2.00	±4.89
1978 06								7	5.57	13.89	9.11	2.93	1.11	±2.71
1978 07	1	5.18	5.18	5.18				11	3.20	6.54	4.89	0.88	0.26	±0.59
1978 08								4	4.67	5.39	4.90	0.34	0.17	±0.53
1978 09								9	4.64	6.79	5.67	0.71	0.24	±0.55
1978 10	1	7.34	7.34	7.34				2	5.83	6.17	6.00	0.24	0.17	±2.12
1978 11								3	12.84	61.24	37.46	24.21	13.98	±60.14
1978 12	1	42.55	42.55	42.55				2	39.25	41.11	40.18	1.32	0.93	±11.84

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL DISSOLVED PHOSPHORUS(P)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1977	60	0.003	0.014	0.006	0.0022	0.0003	±0.0006	223	0.002	0.028	0.010	0.0068	0.0005	±0.0009
1978	36	0.003	0.032	0.012	0.0105	0.0017	±0.0036	239	0.003	0.038	0.007	0.0057	0.0004	±0.0007
LOAD (KG/DAY)														
1977	5	2.62	4.39	3.91	0.75	0.34	±0 93	74	2.05	16.78	5.83	2.97	0.35	±0.69
1978	3	5.18	42.55	18.36	20.98	12.11	±52 12	73	3.20	85.23	13.69	13.92	1.63	±3.25


L .484E-05 (A)
L .937E-05 (A)
L .366E-06 U .115E-03 (A)
CONCENTRATION (MG/L)
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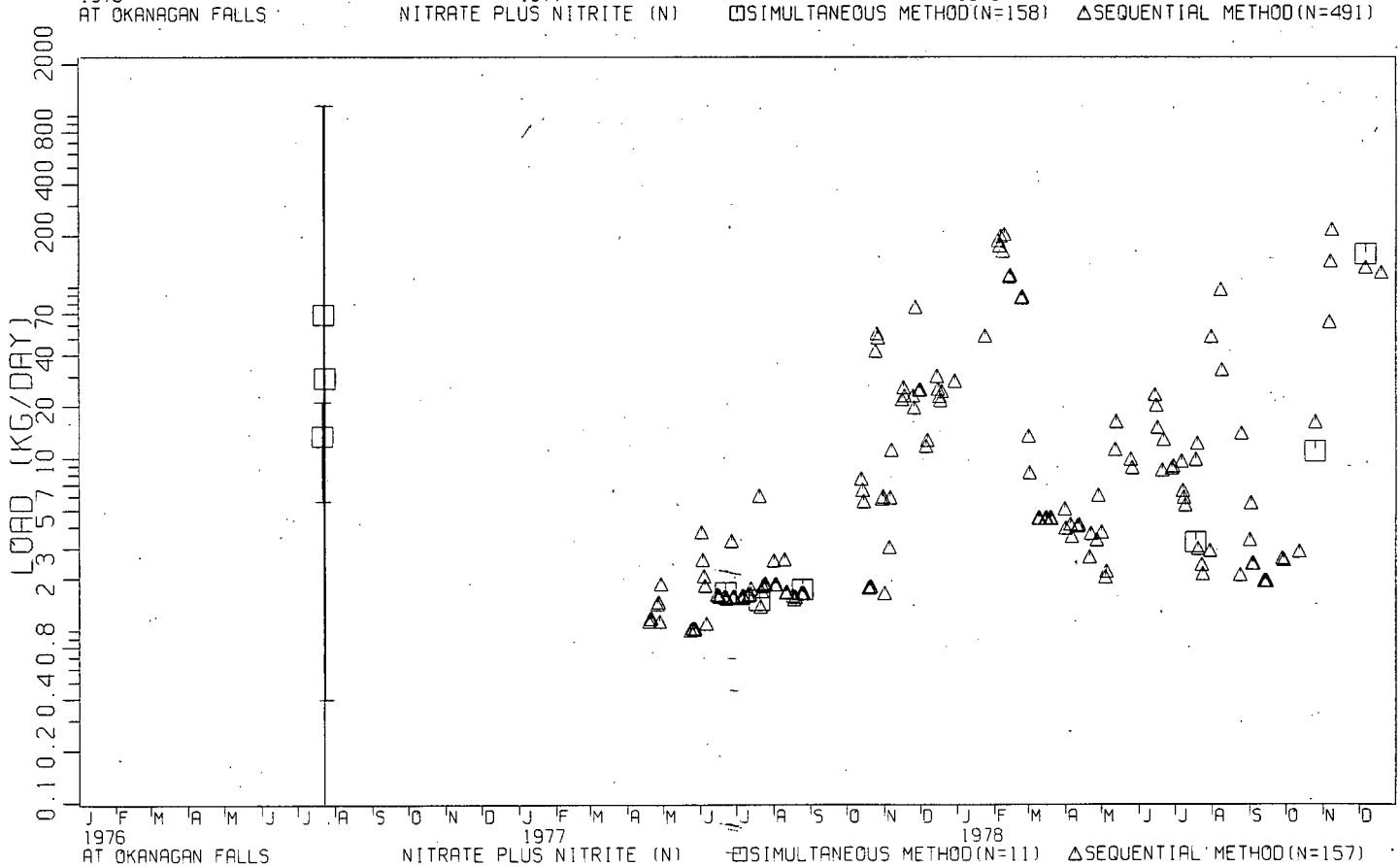
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS
NITRATE PLUS NITRITE (N)
SIMULTANEOUS METHOD(N=158)
SEQUENTIAL METHOD(N=491)


LOAD (KG/DAY)
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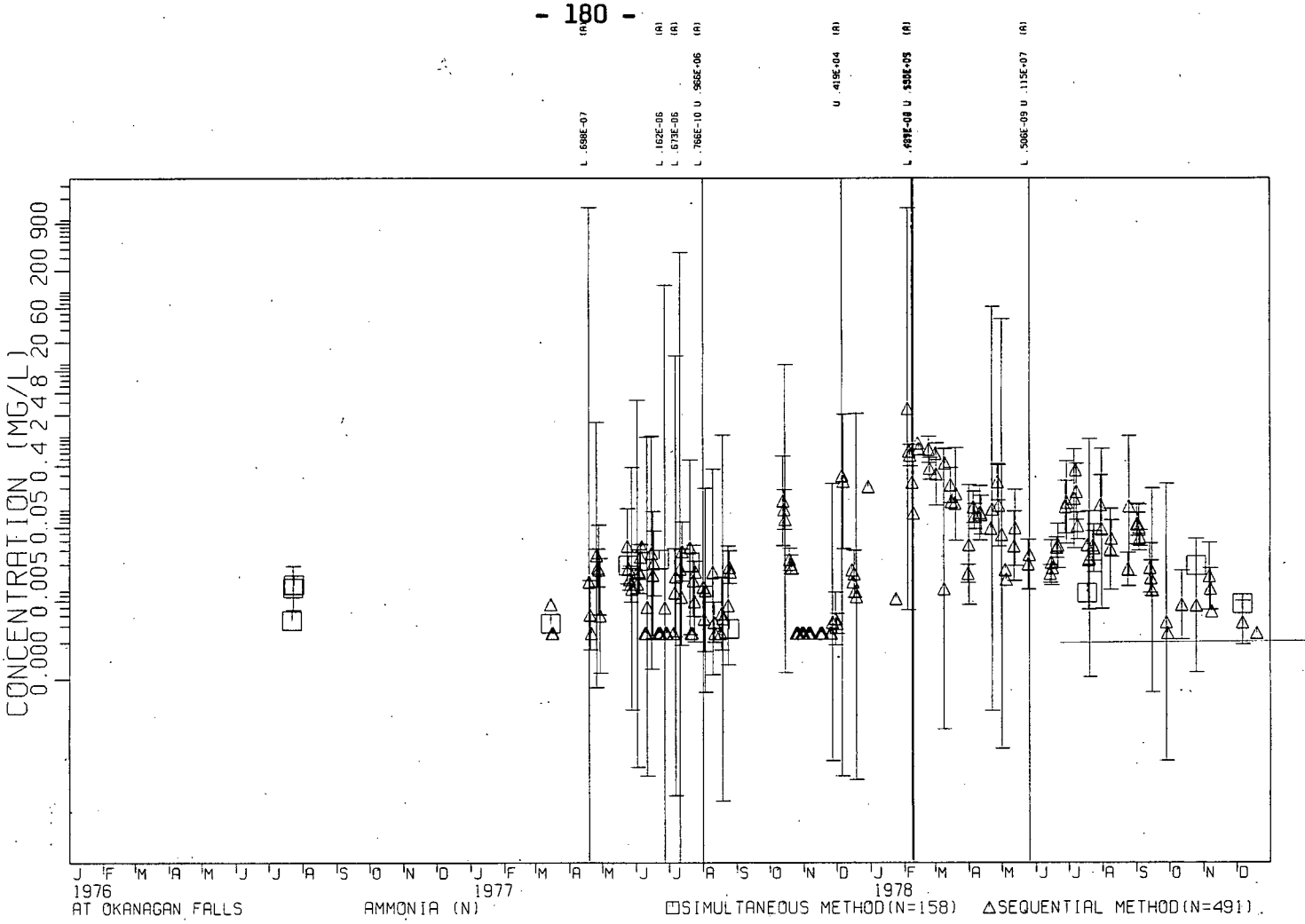
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976 1977 1978
AT OKANAGAN FALLS
NITRATE PLUS NITRITE (N)
SIMULTANEOUS METHOD(N=11)
SEQUENTIAL METHOD(N=157)

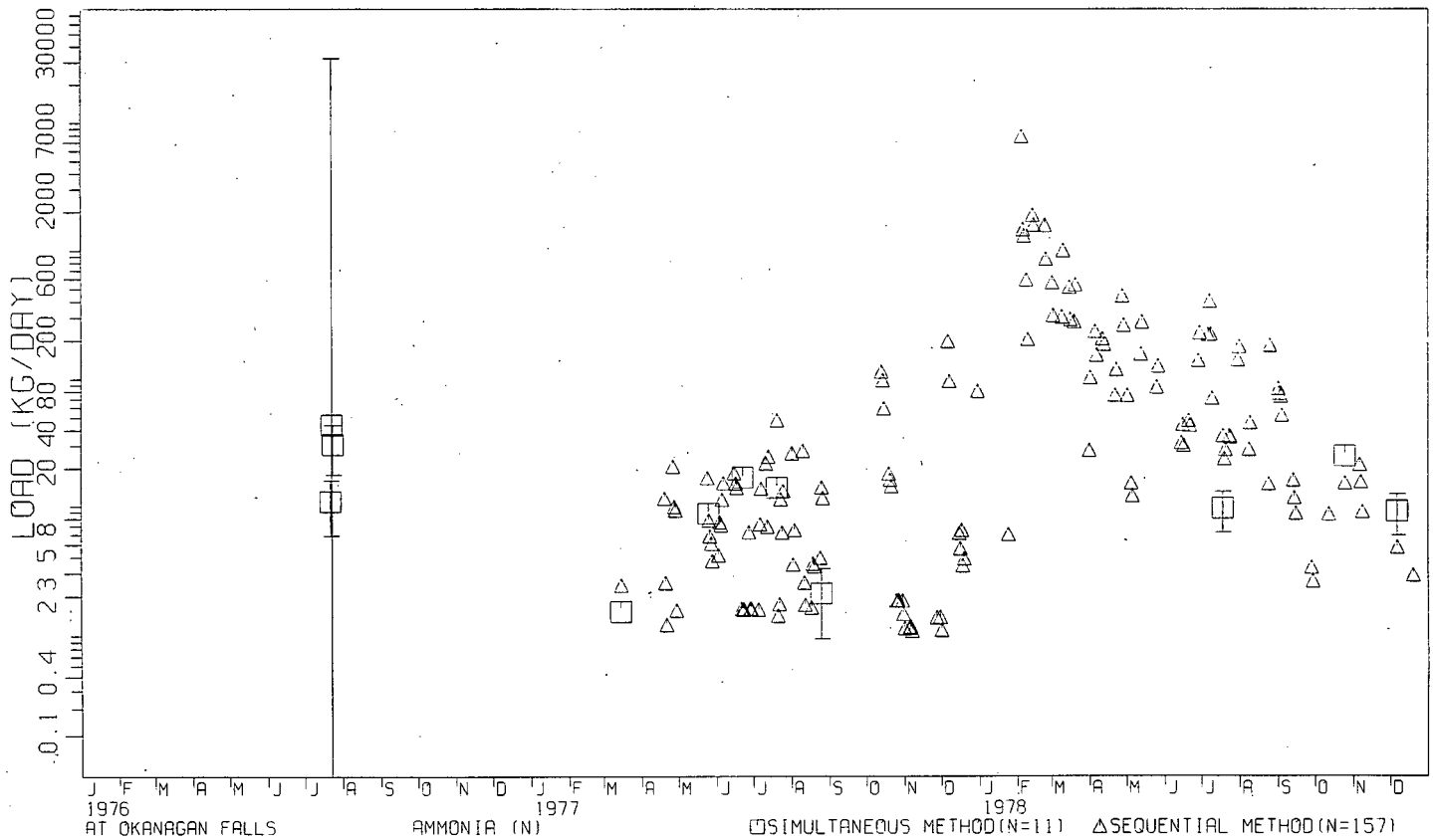
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
NITRATE PLUS NITRITE(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	27	0.002	0.148	0.013	0.0289	0.0056	±0.0114							
1977 03	24	0.002	0.002	0.002	0.0	0.0	±0.0	8	0.002	0.002	0.002	0.0	0.0	±0.0
1977 04								20	0.002	0.004	0.002	0.0007	0.0001	±0.0003
1977 05	24	0.002	0.002	0.002	0.0	0.0	±0.0	16	0.002	0.002	0.002	0.0	0.0	±0.0
1977 06	24	0.002	0.005	0.002	0.0007	0.0002	±0.0003	51	0.002	0.009	0.003	0.0015	0.0002	±0.0004
1977 07	11	0.002	0.002	0.002	0.0	0.0	±0.0	36	0.002	0.014	0.002	0.0020	0.0003	±0.0007
1977 08	12	0.002	0.002	0.002	0.0	0.0	±0.0	32	0.002	0.004	0.002	0.0004	0.0001	±0.0001
1977 10								31	0.002	0.063	0.018	0.0223	0.0040	±0.0082
1977 11								31	0.003	0.200	0.055	0.0452	0.0081	±0.0166
1977 12								26	0.017	0.079	0.052	0.0142	0.0028	±0.0057
1978 01								1	0.052	0.052	0.052			
1978 02								28	0.032	0.092	0.059	0.0187	0.0035	±0.0073
1978 03								35	0.002	0.020	0.004	0.0046	0.0008	±0.0016
1978 04								33	0.002	0.006	0.002	0.0007	0.0001	±0.0003
1978 05								18	0.002	0.008	0.003	0.0016	0.0004	±0.0008
1978 06								24	0.002	0.022	0.008	0.0036	0.0007	±0.0015
1978 07	12	0.002	0.004	0.003	0.0008	0.0002	±0.0005	37	0.002	0.160	0.010	0.0260	0.0043	±0.0087
1978 08								14	0.002	0.370	0.037	0.0972	0.0260	±0.0561
1978 09								26	0.002	0.007	0.002	0.0011	0.0002	±0.0004
1978 10	12	0.007	0.010	0.008	0.0010	0.0003	±0.0006	8	0.002	0.017	0.007	0.0060	0.0021	±0.0050
1978 11								8	0.032	0.100	0.067	0.0271	0.0096	±0.0227
1978 12	12	0.094	0.100	0.098	0.0016	0.0005	±0.0010	8	0.077	0.095	0.084	0.0062	0.0022	±0.0051
						LOAD (KG/DAY)								
1976 07	3	13.39	68.91	37.16	28.61	16.52	±71.07							
1977 03	1	0.96	0.96	0.96				3	0.95	0.96	0.96	0.01	0.0	±0.01
1977 04								7	1.13	1.87	1.34	0.27	0.10	±0.25
1977 05	1	0.95	0.95	0.95				5	1.00	1.03	1.02	0.01	0.01	±0.02
1977 06	1	1.66	1.66	1.66				14	1.10	3.75	1.95	0.76	0.20	±0.44
1977 07	1	1.50	1.50	1.50				12	1.38	6.07	2.04	1.28	0.37	±0.81
1977 08	1	1.73	1.73	1.73				12	1.53	2.60	1.83	0.37	0.11	±0.23
1977 10								11	1.78	53.73	16.75	21.01	6.33	±14.11
1977 11								11	1.65	76.72	21.64	20.43	6.16	±13.73
1977 12								9	11.82	30.21	22.57	6.34	2.11	±4.88
1978 01								1	52.17	52.17	52.17			
1978 02								9	87.16	205.12	149.33	47.27	15.76	±36.34
1978 03								9	4.52	13.46	6.01	3.05	1.02	±2.35
1978 04								9	2.69	6.12	3.98	0.93	0.31	±0.72
1978 05								7	2.06	16.55	7.81	5.40	2.04	±4.99
1978 06								7	8.60	23.56	14.08	5.98	2.26	±5.53
1978 07	1	3.27	3.27	3.27				11	2.14	51.89	10.20	14.24	4.29	±9.57
1978 08								4	2.11	97.95	36.79	42.71	21.36	±67.96
1978 09								9	1.95	5.54	2.77	1.13	0.38	±0.87
1978 10	1	11.04	11.04	11.04				2	2.90	16.41	9.65	9.55	6.75	±85.80
1978 11								3	63.12	220.02	142.51	78.46	45.30	±194.93
1978 12	1	156.67	156.67	156.67				2	123.49	132.17	127.83	6.13	4.34	±55.11

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
NITRATE PLUS NITRITE(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	27	0.002	0.148	0.013	0.0289	0.0056	±0.0114							
1977	95	0.002	0.005	0.002	0.0004	0.0	±0.0001	251	0.002	0.200	0.016	0.0278	0.0018	±0.0035
1978	36	0.002	0.100	0.036	0.0444	0.0074	±0.0150	240	0.002	0.370	0.018	0.0356	0.0023	±0.0045
						LOAD (KG/DAY)								
1976	3	13.39	68.91	37.16	28.61	16.52	±71.07							
1977	5	0.95	1.73	1.36	0.38	0.17	±0.47	84	0.95	76.72	8.53	13.80	1.51	±3.00
1978	3	3.27	156.67	56.99	86.41	49.89	±214.67	73	1.95	220.02	35.97	58.92	6.90	±13.74


CONCENTRATION (MG/L)
0.000 0.005 0.05 0.4 2 4 8 20 60 200 900
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
AMMONIA (N)
□SIMULTANEOUS METHOD(N=158) △SEQUENTIAL METHOD(N=491)


LOAD (KG/DAY)
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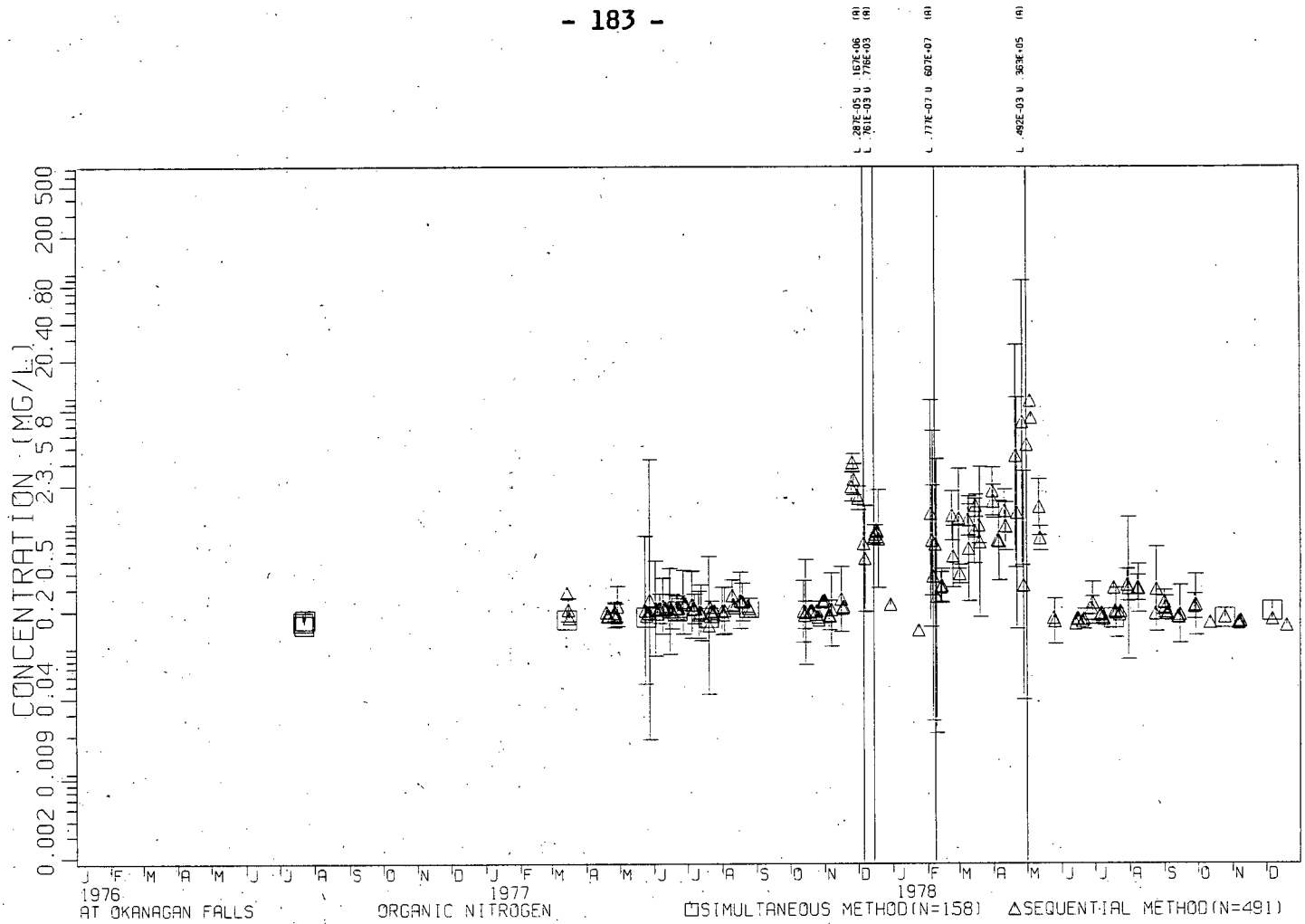
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
AMMONIA (N)
□SIMULTANEOUS METHOD(N=11) △SEQUENTIAL METHOD(N=157)

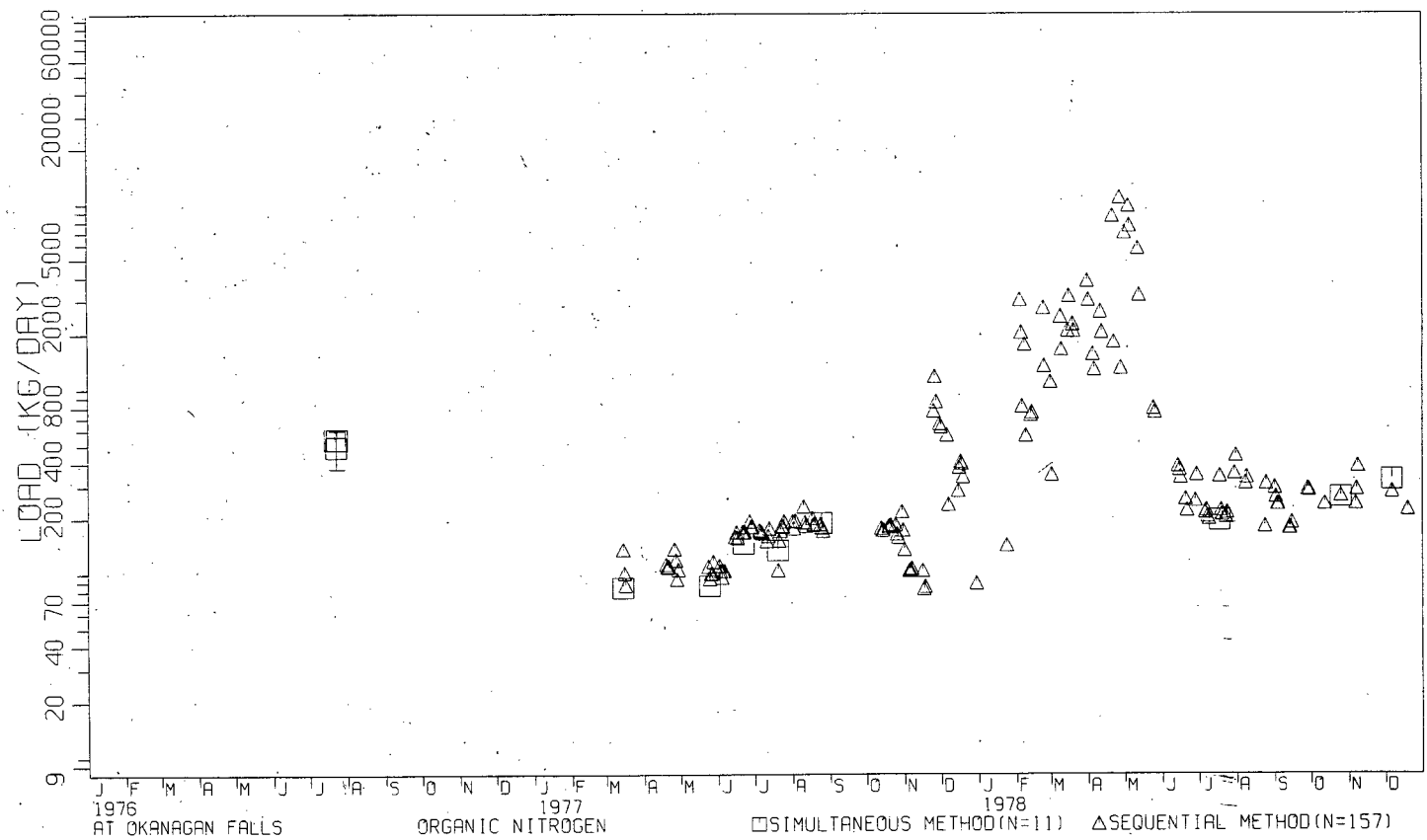
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
AMMONIA(N)

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976 07	27	0.002	0.040	0.009	0.0097	0.0019	±0.0039							
1977 03	24	0.002	0.006	0.003	0.0014	0.0003	±0.0006	8	0.002	0.005	0.002	0.0011	0.0004	±0.0009
1977 04								20	0.002	0.033	0.012	0.0104	0.0023	±0.0049
1977 05	24	0.011	0.036	0.018	0.0071	0.0015	±0.0030	16	0.006	0.035	0.014	0.0078	0.0019	±0.0041
1977 06	24	0.006	0.060	0.024	0.0146	0.0030	±0.0061	51	0.002	0.036	0.010	0.0104	0.0015	±0.0029
1977 07	11	0.015	0.037	0.020	0.0065	0.0020	±0.0044	36	0.002	0.110	0.012	0.0188	0.0031	±0.0064
1977 08	12	0.002	0.005	0.002	0.0010	0.0003	±0.0006	32	0.002	0.055	0.009	0.0114	0.0020	±0.0041
1977 10								31	0.002	0.150	0.034	0.0486	0.0087	±0.0178
1977 11								31	0.002	0.005	0.002	0.0008	0.0001	±0.0003
1977 12								26	0.002	0.630	0.079	0.1595	0.0313	±0.0644
1978 01								1	0.006	0.006	0.006			
1978 02								28	0.032	4.100	0.747	0.7163	0.1354	±0.2778
1978 03								35	0.002	0.730	0.248	0.2150	0.0363	±0.0738
1978 04								33	0.010	0.300	0.107	0.0676	0.0118	±0.0240
1978 05								18	0.006	0.100	0.041	0.0339	0.0080	±0.0169
1978 06								24	0.012	0.410	0.065	0.0866	0.0177	±0.0366
1978 07	12	0.002	0.017	0.008	0.0047	0.0014	±0.0030	37	0.016	0.600	0.132	0.1464	0.0241	±0.0488
1978 08								14	0.012	0.350	0.076	0.1152	0.0308	±0.0665
1978 09								26	0.002	0.117	0.036	0.0295	0.0058	±0.0119
1978 10	12	0.014	0.029	0.017	0.0042	0.0012	±0.0026	8	0.002	0.034	0.008	0.0110	0.0039	±0.0092
1978 11								8	0.004	0.019	0.010	0.0051	0.0018	±0.0043
1978 12	12	0.002	0.011	0.006	0.0028	0.0008	±0.0018	8	0.002	0.005	0.002	0.0011	0.0004	±0.0009
						LOAD (KG/DAY)								
1976 07	3	10.93	43.92	28.54	16.61	9.59	±41.27							
1977 03	1	1.48	1.48	1.48				3	0.96	2.39	1.44	0.82	0.47	±2.04
1977 04								7	1.17	20.67	8.08	7.03	2.66	±6.50
1977 05	1	8.76	8.76	8.76				5	3.71	16.85	7.83	5.24	2.35	±6.51
1977 06	1	16.87	16.87	16.87				14	1.54	18.41	7.64	6.11	1.63	±3.53
1977 07	1	13.96	13.96	13.96				12	1.38	47.80	13.14	13.27	3.83	±8.43
1977 08	1	2.06	2.06	2.06				12	1.60	27.55	8.85	9.29	2.68	±5.91
1977 10								11	1.43	114.53	29.91	41.44	12.49	±27.84
1977 11								11	0.76	1.35	1.00	0.23	0.07	±0.15
1977 12								9	1.07	198.34	44.65	68.42	22.81	±52.59
1978 01								1	6.02	6.02	6.02			
1978 02								9	205.72	7889.00	1940.20	2296.30	765.42	±1765.10
1978 03								9	27.77	1008.10	430.73	274.81	91.60	±211.24
1978 04								9	75.71	448.10	200.63	112.27	37.42	±86.30
1978 05								7	12.19	282.30	108.35	93.55	35.36	±86.52
1978 06								7	30.37	232.34	81.69	76.68	28.98	±70.92
1978 07	1	9.62	9.62	9.62				11	23.84	406.79	128.41	122.20	36.85	±82.09
1978 08								4	15.00	183.70	68.12	78.07	39.04	±124.21
1978 09								9	2.58	84.89	36.77	34.85	11.62	±26.79
1978 10	1	24.79	24.79	24.79				2	8.71	15.31	12.01	4.67	3.30	±41.97
1978 11								3	9.07	21.29	15.31	6.11	3.53	±15.18
1978 12	1	9.16	9.16	9.16				2	2.88	4.79	3.83	1.35	0.95	±12.13

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
AMMONIA(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1976	27	0.002	0.040	0.009	0.0097	0.0019	±0.0039							
1977	95	0.002	0.060	0.014	0.0124	0.0013	±0.0025	251	0.002	0.630	0.020	0.0584	0.0037	±0.0073
1978	36	0.002	0.029	0.011	0.0064	0.0011	±0.0022	240	0.002	4.100	0.177	0.3438	0.0222	±0.0437
						LOAD (KG/DAY)								
1976	3	10.93	43.92	28.54	16.61	9.59	±41.27							
1977	5	1.48	16.87	8.63	6.90	3.09	±8.57	84	0.76	198.34	14.44	29.71	3.24	±6.45
1978	3	9.16	24.79	14.52	8.90	5.14	±22.10	73	2.58	7889.00	364.03	984.14	115.18	±229.56


CONCENTRATION (MG/L)
0.002 0.009 0.04 0.2 0.5 2.3 5 8 20 40 80 200 500
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
ORGANIC NITROGEN
SIMULTANEOUS METHOD(N=158)
SEQUENTIAL METHOD(N=491)


LOAD (KG/DAY)
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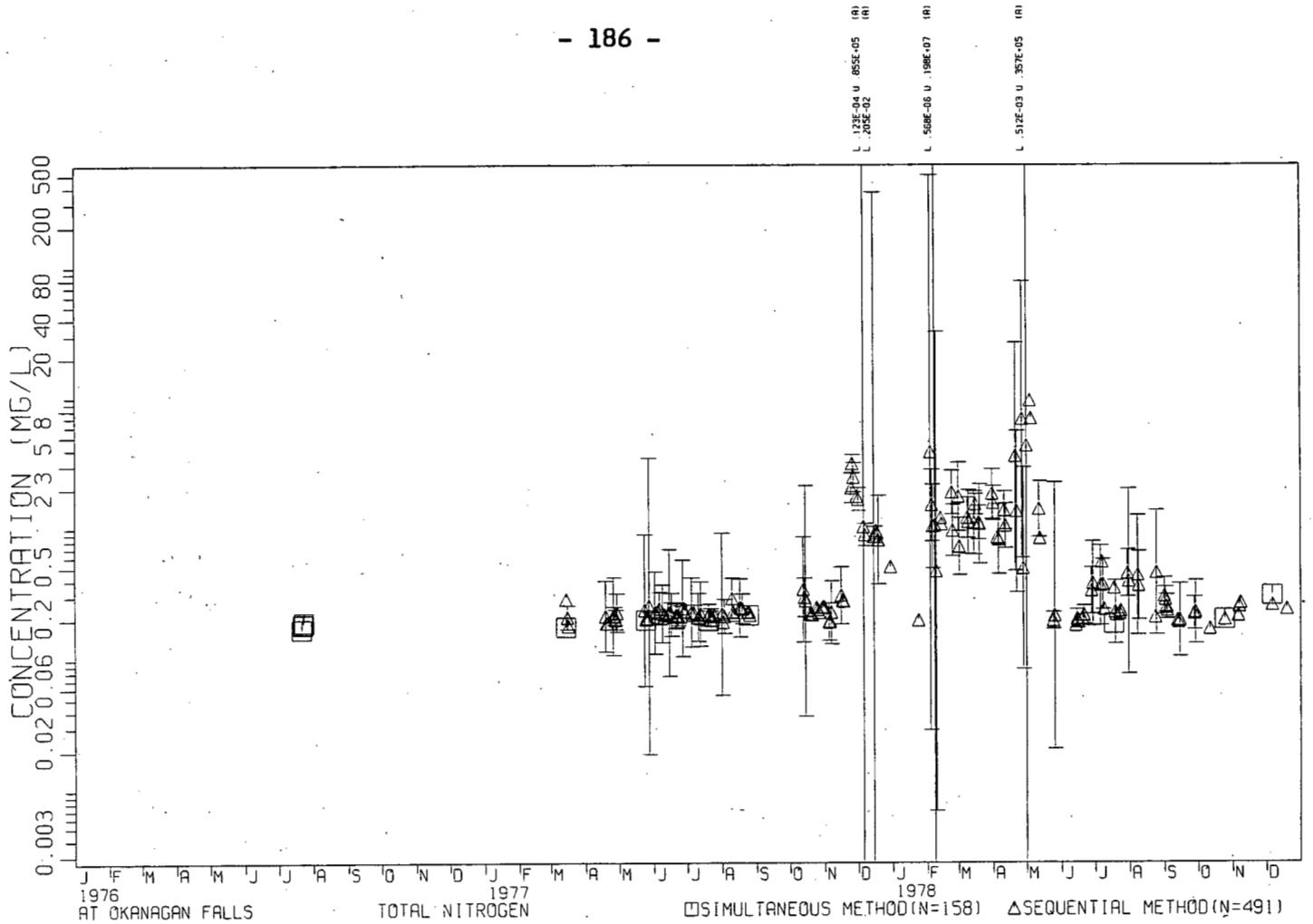
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
ORGANIC NITROGEN
SIMULTANEOUS METHOD(N=11)
SEQUENTIAL METHOD(N=157)

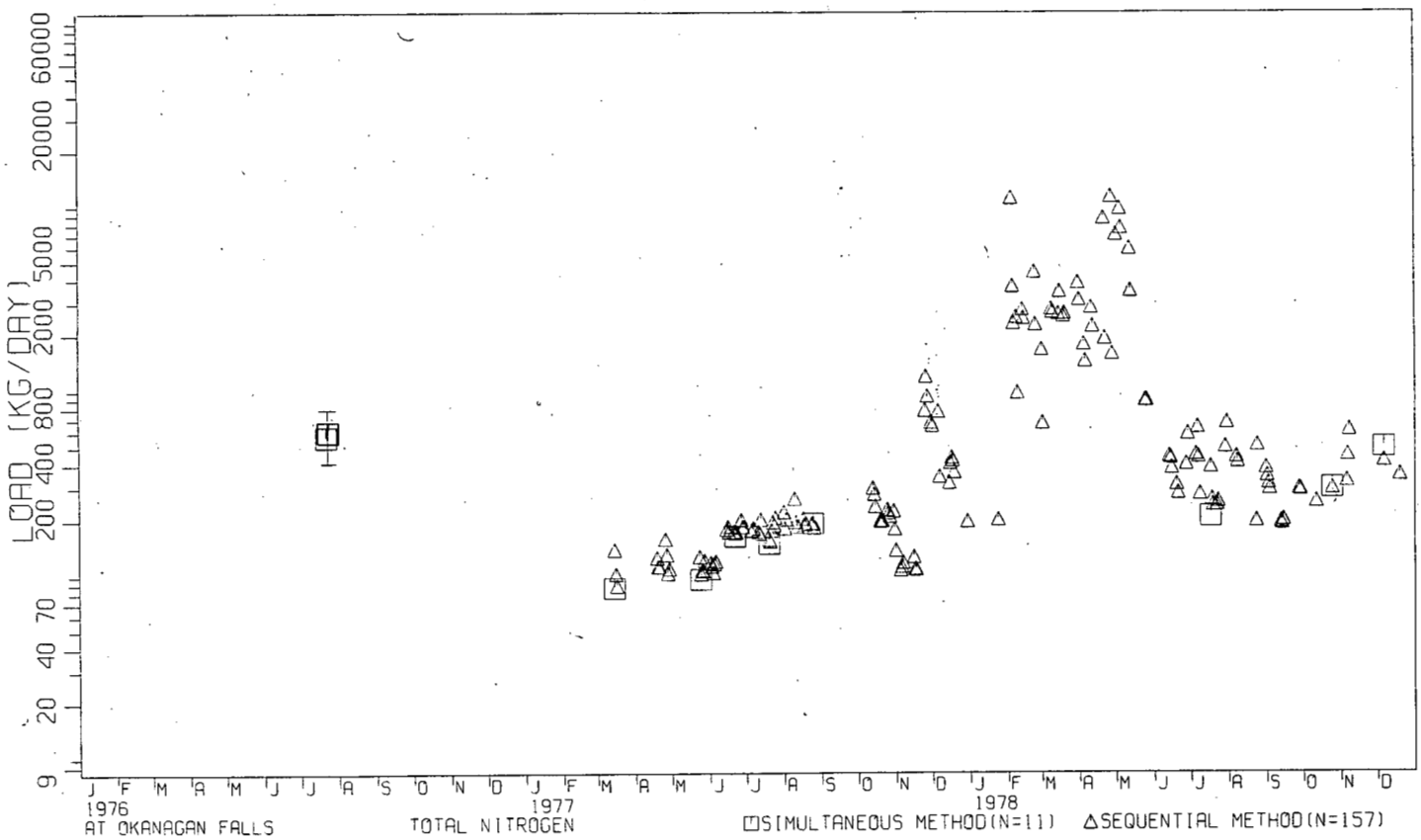
STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
ORGANIC NITROGEN

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 07	27	0.112	0.218	0.165	0.0190	0.0036	±0.0075							
1977 03	24	0.156	0.212	0.174	0.0123	0.0025	±0.0052	8	0.171	0.283	0.206	0.0396	0.0140	±0.0331
1977 04								20	0.169	0.228	0.192	0.0153	0.0034	±0.0072
1977 05	24	0.163	0.216	0.182	0.0119	0.0024	±0.0050	16	0.182	0.303	0.202	0.0296	0.0074	±0.0158
1977 06	24	0.166	0.443	0.210	0.0743	0.0152	±0.0314	51	0.188	0.264	0.213	0.0177	0.0025	±0.0050
1977 07	11	0.163	0.201	0.179	0.0117	0.0035	±0.0079	36	0.086	0.246	0.201	0.0250	0.0042	±0.0084
1977 08	12	0.196	0.243	0.215	0.0151	0.0044	±0.0096	32	0.185	0.306	0.224	0.0254	0.0045	±0.0092
1977 10								31	0.153	0.256	0.205	0.0254	0.0046	±0.0093
1977 11								31	0.176	3.342	1.131	1.1065	0.1987	±0.4058
1977 12								26	0.227	1.836	0.925	0.4373	0.0858	±0.1767
1978 01								1	0.142	0.142	0.142			
1978 02								28	0.195	2.418	0.697	0.5678	0.1073	±0.2202
1978 03								35	0.248	2.482	1.073	0.5155	0.0871	±0.1771
1978 04								33	0.124	17.945	2.345	3.8862	0.6765	±1.3780
1978 05								18	0.161	9.483	2.046	2.9885	0.7044	±1.4863
1978 06								24	0.154	0.328	0.189	0.0385	0.0079	±0.0163
1978 07	12	0.165	0.209	0.176	0.0118	0.0034	±0.0075	37	0.166	1.040	0.232	0.1457	0.0240	±0.0486
1978 08								14	0.185	0.498	0.281	0.0977	0.0261	±0.0564
1978 09								26	0.172	0.290	0.204	0.0255	0.0050	±0.0103
1978 10	12	0.165	0.192	0.177	0.0072	0.0021	±0.0046	8	0.155	0.190	0.173	0.0116	0.0041	±0.0097
1978 11								8	0.160	0.172	0.165	0.0040	0.0014	±0.0033
1978 12	12	0.180	0.227	0.202	0.0156	0.0045	±0.0099	8	0.152	0.184	0.164	0.0119	0.0042	±0.0099
LOAD (KG/DAY)														
1976 07	3	485.79	537.05	519.88	29.53	17.05	±73.35							
1977 03	1	83.14	83.14	83.14				3	86.06	135.09	107.12	25.24	14.57	±62.70
1977 04								7	92.60	135.69	111.56	13.19	4.99	±12.20
1977 05	1	85.35	85.35	85.35				5	93.40	116.29	103.72	8.99	4.02	±11.16
1977 06	1	144.72	144.72	144.72				14	95.22	191.75	146.79	35.37	9.45	±20.42
1977 07	1	133.04	133.04	133.04				12	103.57	192.30	164.28	22.76	6.57	±14.46
1977 08	1	187.27	187.27	187.27				12	169.51	231.03	188.88	15.79	4.56	±10.03
1977 10								11	156.69	215.99	177.72	15.05	4.54	±10.11
1977 11								11	81.80	1172.90	377.60	401.41	121.03	±269.66
1977 12								9	87.85	624.90	367.78	162.44	54.15	±124.86
1978 01								1	142.46	142.46	142.46			
1978 02								9	559.91	3014.00	1518.90	914.90	304.97	±703.25
1978 03								9	344.44	3822.00	2099.60	1032.90	344.30	±793.95
1978 04								9	1283.60	10824.00	3664.40	3515.30	1171.80	±2702.10
1978 05								7	750.99	9751.80	4975.20	3489.00	1318.70	±3226.90
1978 06								7	220.95	385.31	307.98	65.24	24.66	±60.34
1978 07	1	194.21	194.21	194.21				11	198.39	439.08	255.91	81.36	24.53	±54.65
1978 08								4	179.75	333.65	283.39	69.99	34.99	±111.35
1978 09								9	177.10	293.13	238.65	47.57	15.86	±36.56
1978 10	1	259.26	259.26	259.26				2	238.72	263.61	251.17	17.60	12.45	±158.13
1978 11								3	238.54	383.33	303.02	73.68	42.54	±183.05
1978 12	1	322.49	322.49	322.49				2	222.87	278.21	250.54	39.13	27.67	±351.58

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
ORGANIC NITROGEN

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	27	0.112	0.218	0.165	0.0190	0.0036	±0.0075							
1977	95	0.156	0.443	0.191	0.0418	0.0043	±0.0085	251	0.086	3.342	0.396	0.5386	0.0340	±0.0669
1978	36	0.165	0.227	0.185	0.0169	0.0028	±0.0057	240	0.124	17.945	0.824	1.8378	0.1186	±0.2337
LOAD (KG/DAY)														
1976	3	485.79	537.05	519.88	29.53	17.05	±73.35							
1977	5	83.14	187.27	126.70	43.71	19.55	±54.26	84	81.80	1172.90	206.34	178.27	19.45	±38.69
1978	3	194.21	322.49	258.65	64.14	37.03	±159.35	73	142.46	10824.00	1516.10	2287.60	267.74	±533.61


L .123E-04 U .855E-05 (A)
L .205E-02 (A)
L .508E-06 U .198E-07 (A)
L .512E-03 U .357E-05 (A)
CONCENTRATION (MG/L)
0.003
0.02
0.06
0.2
0.5
2
3
5
8
20
40
80
200
500
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
TOTAL NITROGEN
SIMULTANEOUS METHOD(N=158)
SEQUENTIAL METHOD(N=491)

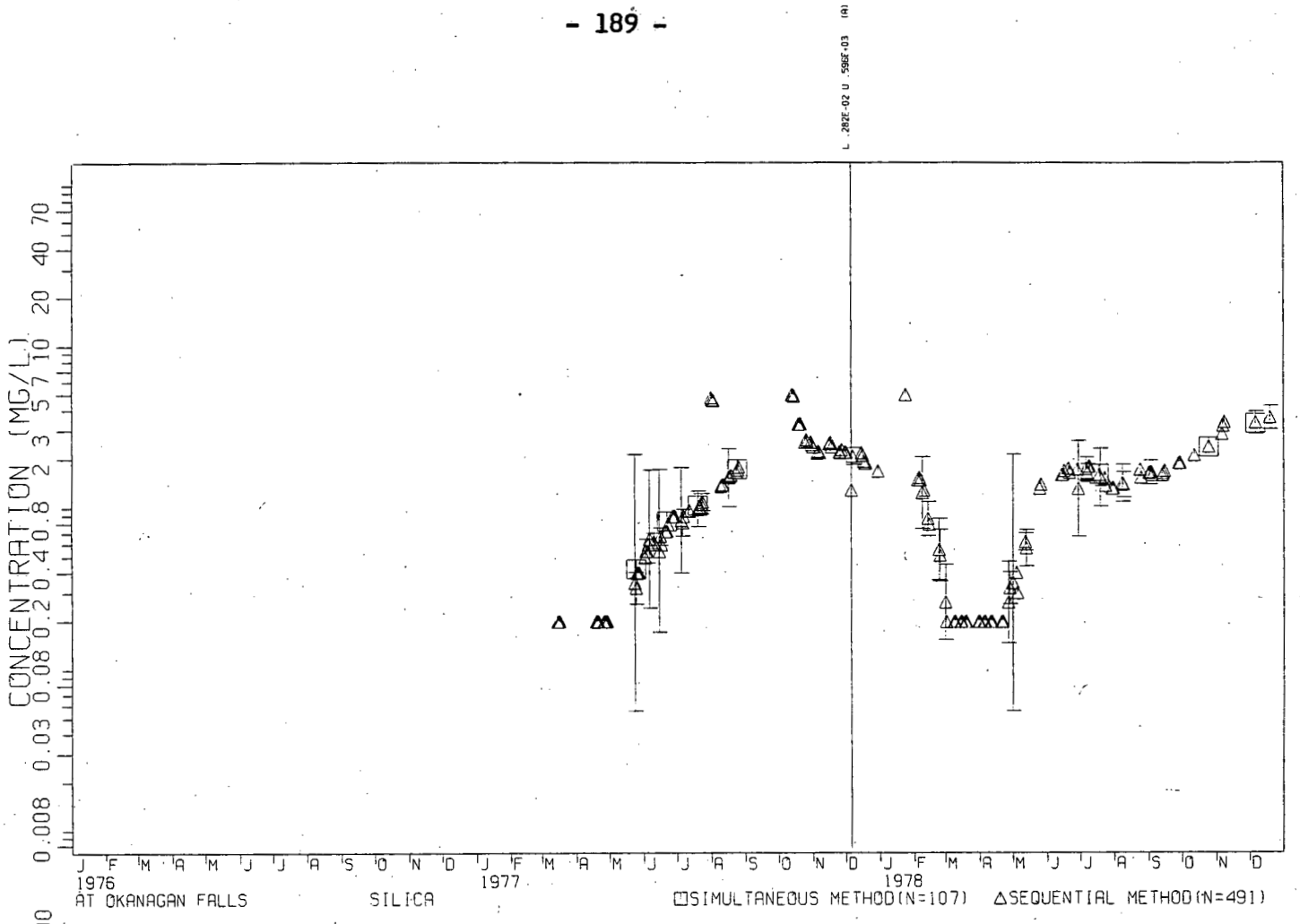

LOAD (KG/DAY)
9
20
40
70
200
400
800
2000
5000
20000
60000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
TOTAL NITROGEN
SIMULTANEOUS METHOD(N=11)
SEQUENTIAL METHOD(N=157)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL NITROGEN(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976 07	27	0.150	0.365	0.187	0.0428	0.0082	±0.0169							
1977 03	24	0.160	0.220	0.178	0.0131	0.0027	±0.0055	8	0.175	0.290	0.211	0.0405	0.0143	±0.0338
1977 04								20	0.175	0.245	0.207	0.0188	0.0042	±0.0088
1977 05	24	0.185	0.235	0.202	0.0126	0.0026	±0.0053	16	0.198	0.316	0.218	0.0307	0.0077	±0.0164
1977 06	24	0.174	0.508	0.237	0.0860	0.0176	±0.0363	51	0.200	0.270	0.226	0.0187	0.0026	±0.0053
1977 07	11	0.180	0.240	0.201	0.0170	0.0051	±0.0114	36	0.180	0.250	0.216	0.0148	0.0025	±0.0050
1977 08	12	0.200	0.250	0.219	0.0156	0.0045	±0.0099	32	0.190	0.320	0.235	0.0293	0.0052	±0.0106
1977 10								31	0.220	0.380	0.257	0.0436	0.0078	±0.0160
1977 11								31	0.190	3.400	1.188	1.1273	0.2025	±0.4134
1977 12								26	0.420	2.500	1.057	0.4595	0.0901	±0.1856
1978 01								1	0.200	0.200	0.200			
1978 02								28	0.340	5.600	1.503	1.0662	0.2015	±0.4135
1978 03								35	0.580	2.500	1.325	0.4791	0.0810	±0.1646
1978 04								33	0.210	18.000	2.455	3.8966	0.6783	±1.3817
1978 05								18	0.180	9.500	2.089	2.9858	0.7037	±1.4849
1978 06								24	0.180	0.740	0.262	0.1226	0.0250	±0.0518
1978 07	12	0.170	0.230	0.188	0.0154	0.0045	±0.0098	37	0.220	1.800	0.373	0.2757	0.0453	±0.0919
1978 08								14	0.200	0.860	0.394	0.2239	0.0599	±0.1293
1978 09								26	0.190	0.410	0.242	0.0485	0.0095	±0.0196
1978 10	12	0.190	0.220	0.202	0.0075	0.0022	±0.0048	8	0.170	0.210	0.188	0.0167	0.0059	±0.0140
1978 11								8	0.210	0.270	0.243	0.0260	0.0092	±0.0218
1978 12	12	0.280	0.330	0.306	0.0162	0.0047	±0.0103	8	0.240	0.270	0.251	0.0125	0.0044	±0.0104
LOAD (KG/DAY)														
1976 07	3	561.36	598.62	585.59	21.00	12.13	±52.18							
1977 03	1	85.59	85.59	85.59				3	87.99	138.43	109.52	26.02	15.02	±64.65
1977 04								7	103.04	157.78	120.98	18.67	7.06	±17.27
1977 05	1	95.05	95.05	95.05				5	102.13	126.99	112.57	10.79	4.82	±13.39
1977 06	1	163.26	163.26	163.26				14	104.39	201.36	156.38	33.85	9.05	±19.54
1977 07	1	148.50	148.50	148.50				12	153.32	207.38	179.46	16.49	4.76	±10.48
1977 08	1	191.06	191.06	191.06				12	180.95	261.18	199.56	22.29	6.43	±14.16
1977 10								11	179.00	298.62	224.38	35.52	10.71	±23.86
1977 11								11	107.02	1193.40	400.23	412.12	124.26	±276.85
1977 12								9	197.37	773.87	435.00	175.26	58.42	±134.71
1978 01								1	200.64	200.64	200.64			
1978 02								9	970.75	11092.00	3608.50	2964.20	988.07	±2278.50
1978 03								9	668.97	3854.90	2536.30	928.02	309.34	±713.33
1978 04								9	1442.40	11276.00	3869.00	3560.90	1187.00	±2737.10
1978 05								7	885.52	9769.20	5091.30	3437.00	1299.10	±3178.80
1978 06								7	277.77	585.25	403.75	100.29	37.91	±92.76
1978 07	1	207.10	207.10	207.10				11	240.42	670.60	394.51	157.98	47.63	±106.13
1978 08								4	196.86	506.70	388.30	133.73	66.86	±212.76
1978 09								9	190.80	381.40	278.19	68.52	22.84	±52.67
1978 10	1	295.09	295.09	295.09				2	250.33	295.33	272.83	31.82	22.50	±285.90
1978 11								3	322.95	612.42	460.84	145.22	83.84	±360.78
1978 12	1	488.31	488.31	488.31				2	349.24	415.17	382.20	46.62	32.96	±418.83

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
TOTAL NITROGEN(N)

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1976	27	0.150	0.365	0.187	0.0428	0.0082	±0.0169							
1977	95	0.160	0.508	0.207	0.0491	0.0050	±0.0100	251	0.175	3.400	0.432	0.5643	0.0356	±0.0701
1978	36	0.170	0.330	0.232	0.0550	0.0092	±0.0186	240	0.170	18.000	1.019	1.8795	0.1213	±0.2390
LOAD (KG/DAY)														
1976	3	561.36	598.62	585.59	21.00	12.13	±52.18							
1977	5	85.59	191.06	136.69	45.13	20.18	±56.03	84	87.99	1193.40	229.31	189.95	20.73	±41.22
1978	3	207.10	488.31	330.17	143.85	83.05	±357.37	73	190.80	11276.00	1916.20	2577.80	301.71	±601.31


L .282E-02 U .596E-03 (A)
CONCENTRATION (MG/L)
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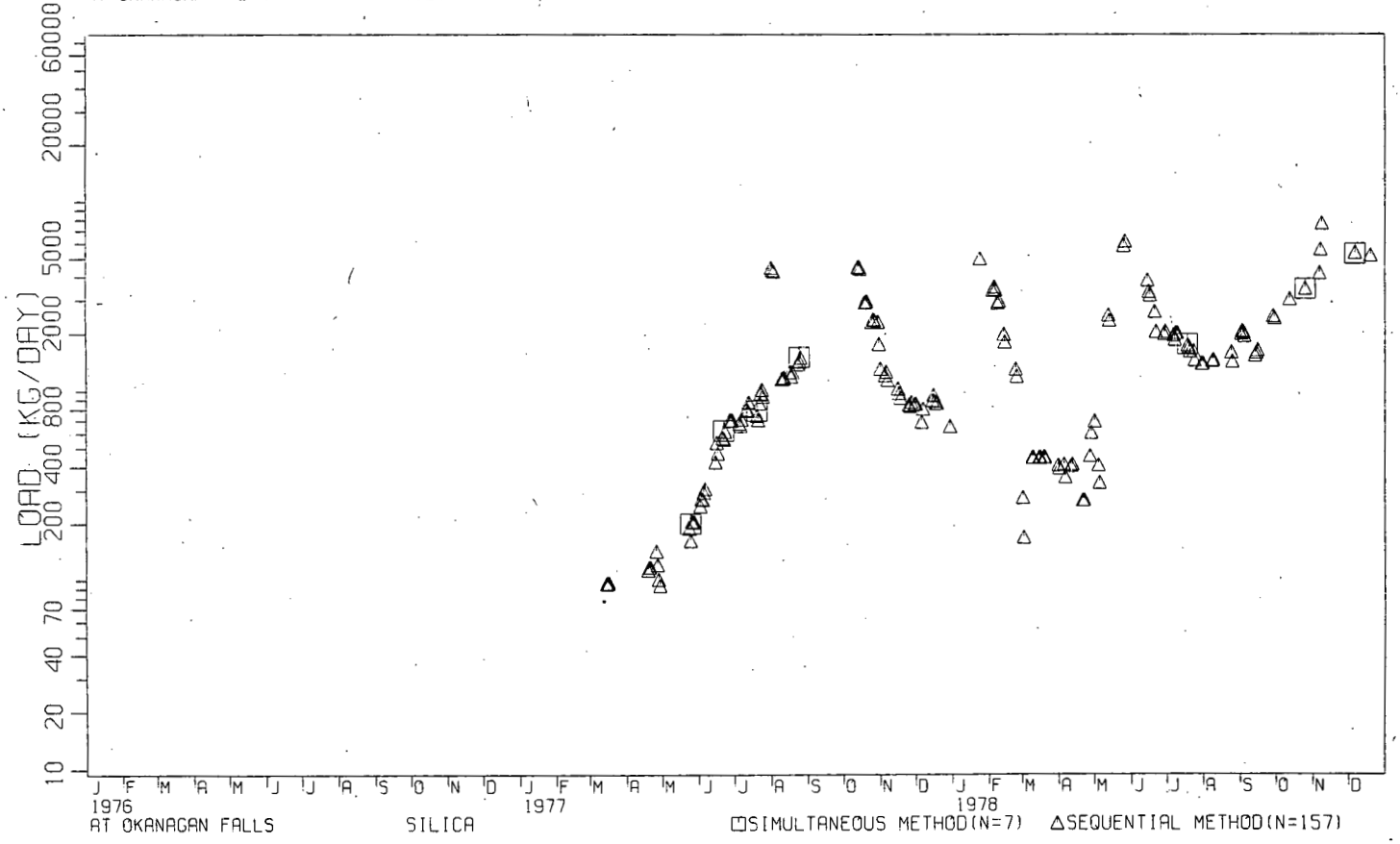
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
SILICA
SIMULTANEOUS METHOD(N=107)
SEQUENTIAL METHOD(N=491)


LOAD (KG/DAY)
10 20 40 70 200 400 800 2000 5000 20000 60000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
AT OKANAGAN FALLS
SILICA
SIMULTANEOUS METHOD(N=7)
SEQUENTIAL METHOD(N=157)

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
DISSOLVED SILICA

SAMPLING PERIOD	SIMULTANEOUS SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	SEQUENTIAL SAMPLING METHOD NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
						CONCENTRATION (MG/L)								
1977 03								8	0.200	0.200	0.200	0.0	0.0	±0.0
1977 04								20	0.200	0.200	0.200	0.0	0.0	±0.0
1977 05	24	0.400	0.500	0.425	0.0442	0.0090	±0.0187	16	0.300	0.400	0.375	0.0447	0.0112	±0.0238
1977 06	24	0.700	1.000	0.837	0.0711	0.0145	±0.0300	51	0.500	0.900	0.674	0.1278	0.0179	±0.0359
1977 07	11	1.000	1.100	1.045	0.0522	0.0157	±0.0351	36	0.700	1.200	0.989	0.1036	0.0173	±0.0350
1977 08	12	1.700	1.800	1.750	0.0522	0.0151	±0.0332	32	1.300	4.800	2.341	1.3828	0.2444	±0.4987
1977 10								31	2.400	5.000	3.377	1.0075	0.1810	±0.3695
1977 11								31	2.100	2.600	2.307	0.1389	0.0249	±0.0509
1977 12								26	0.800	2.300	1.996	0.2877	0.0564	±0.1162
1978 01								1	5.000	5.000	5.000			
1978 02								28	0.400	1.600	1.014	0.4098	0.0774	±0.1589
1978 03								35	0.200	0.400	0.209	0.0373	0.0063	±0.0128
1978 04								33	0.200	0.400	0.221	0.0485	0.0084	±0.0172
1978 05								18	0.300	1.400	0.794	0.4207	0.0992	±0.2092
1978 06								24	0.700	1.900	1.625	0.2111	0.0431	±0.0892
1978 07	12	1.600	1.700	1.617	0.0389	0.0112	±0.0247	37	1.300	1.900	1.565	0.1989	0.0327	±0.0663
1978 08								14	1.300	1.800	1.543	0.1604	0.0429	±0.0926
1978 09								26	1.500	1.900	1.685	0.1156	0.0227	±0.0467
1978 10	12	2.300	2.400	2.375	0.0452	0.0131	±0.0287	8	2.100	2.500	2.262	0.1598	0.0565	±0.1336
1978 11								8	2.800	3.400	3.113	0.2295	0.0811	±0.1919
1978 12	12	3.300	3.400	3.317	0.0389	0.0112	±0.0247	8	3.000	3.900	3.500	0.3464	0.1225	±0.2897
						LOAD (KG/DAY)								
1977 03								3	95.47	96.42	96.06	0.51	0.29	±1.27
1977 04								7	93.66	142.65	115.21	15.56	5.88	±14.39
1977 05	1	200.40	200.40	200.40				5	162.27	206.04	193.15	18.67	8.35	±23.17
1977 06	1	622.61	622.61	622.61				14	249.44	705.87	478.26	175.17	46.82	±101.12
1977 07	1	788.66	788.66	788.66				12	661.62	1020.00	815.40	120.94	34.91	±76.84
1977 08	1	1514.90	1514.90	1514.90				12	1163.50	4470.20	2052.80	1397.20	403.33	±887.74
1977 10								11	1778.70	4527.40	3047.40	985.22	297.06	±661.84
1977 11								11	840.15	1316.50	1031.10	179.70	54.18	±120.71
1977 12								9	657.90	963.42	836.08	99.36	33.12	±76.38
1978 01								1	5016.10	5016.10	5016.10			
1978 02								9	1207.80	3562.20	2528.90	941.84	313.95	±723.96
1978 03								9	170.28	455.07	397.49	103.20	34.40	±79.33
1978 04								9	269.21	612.24	400.64	103.52	34.51	±79.57
1978 05								7	332.39	6212.40	2635.90	2493.00	942.26	±2305.70
1978 06								7	2028.40	3865.30	2757.40	739.36	279.45	±683.82
1978 07	1	1777.30	1777.30	1777.30				11	1410.40	2043.70	1728.90	239.79	72.30	±161.08
1978 08								4	1453.90	1617.10	1502.10	77.50	38.75	±123.30
1978 09								9	1562.10	2510.00	1995.40	342.15	114.05	±263.00
1978 10	1	3471.10	3471.10	3471.10				2	3083.80	3500.20	3292.00	294.44	208.20	±2645.40
1978 11								3	4220.30	7711.90	5853.00	1756.80	1014.30	±4364.40
1978 12	1	5303.80	5303.80	5303.80				2	5220.60	5392.10	5306.30	121.28	85.76	±1089.60

STATISTICAL CHARACTERISTICS OF NUTRIENT CONCENTRATION AND LOAD FOR SPECIFIED SAMPLING PERIOD AND NUMBER OF SAMPLES
OKANAGAN RIVER AT OKANAGAN FALLS
DISSOLVED SILICA

	SIMULTANEOUS SAMPLING METHOD							SEQUENTIAL SAMPLING METHOD						
SAMPLING PERIOD	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL	NO. OF SAMPLES	MINIMUM	MAXIMUM	ARITH. MEAN	STANDARD DEVIATION	STANDARD ERROR	95% CONF. INTERVAL
CONCENTRATION (MG/L)														
1977	71	0.400	1.800	0.885	0.4569	0.0542	±0.1081	251	0.200	5.000	1.532	1.2058	0.0761	±0.1499
1978	36	1.600	3.400	2.436	0.7064	0.1177	±0.2390	240	0.200	5.000	1.232	0.9008	0.0581	±0.1145
LOAD (KG/DAY)														
1977	4	200.40	1514.90	781.65	548.00	274.00	±871.86	84	93.66	4527.40	1137.60	1128.10	123.08	±244.81
1978	3	1777.30	5303.80	3517.40	1763.70	1018.30	±4381.70	73	170.28	7711.90	2061.00	1630.90	190.88	±380.42