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# Effects of Livestock Activity on Surface Water Quality: Project 20: Final Report for International Reference Group on Great Lakes Pollution from Land Use Activities, Task C

Beak Consultants Limited

# INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES



INTERNATIONAL JOINT COMMISSION

# EFFECTS OF LIVESTOCK ACTIVITY ON SURFACE WATER QUALITY

Effects of Livestock Activity
on Surface Water Quality
Project 20

Final Report

for:

International Reference Group on Great
Lakes Pollution From Land Use Activities
Task C

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DISCLAIMER

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TABLE OF CONTENTS:

TABLE OF CONTENTS (Cont'd)

TABLES: (Cont'd)



FIGURES:



APPENDICES:

## 1.0 SUMMARY

The objective of this study is to evaluate the losses of nutrients and bacteria to surface water due to the effects of livestock activities in the Little Ausable River Sub-basin (Watershed AG-3).

The following investigations were selected to attain this goal:

1. To determine the annual flux of nutrients into surface waters of the drainage basin from different segments of the basin representing various types and levels of livestock operations.

2. To determine the seasonal baseline and event contributions to this total flux of nutrients.

3. To determine in which form the nutrients, nitrogen and phosphorus are transported.

4. To determine the effects of various livestock operations and practices on the release of total and fecal coliforms to surface waters.

5. To determine the effect of drained versus undrained fields upon the flux of nutrients and bacteria into surface waters.

The basin (drainage area, 20.6 mi.$^2$) consists mainly of clay soils with corn the major crop, followed by hay, small grains and soybeans. Cash crop and livestock operations are equally notable. Crops grown on the former are normally marketed while those grown on the latter are mostly used for feed. At present beef cattle operations predominate with lesser numbers of dairy and hog operations. Turnover of type of operation is fairly high throughout the basin.

The approach to the study is to measure the flux of nutrients and bacteria on a regular and event-oriented basis over a period of at least two years. Surface water loadings from farm operations would be related to the intensity and type of agricultural practice.

To accomplish this strategy, 26 sampling stations were established to monitor the loadings to surface waters from 17 farm operations, representing beef and dairy cattle, swine and non-livestock controls.

The sampling stations were located to determine the contribution of nutrients and bacteria from each of these operations on a seasonal and event basis. The study farms and the monitoring stations are shown in Figures 1 and 2 respectively. Flows are measured at all stations at the time of sampling either directly by volume or through a stage discharge relationship with permanently established guages. Water quality analysis for total phosphorus, nitrate, nitrite, pH, conductivity, total alkalinity, total hardness, total and fecal coliforms were performed in BEAK's mobile laboratory installed near AG-3. Samples were analysed with a minimum of delay after sampling. Other analyses such as total kjeldahl nitrogen, ammonia nitrogen and dissolved phosphorus were conducted at BEAK's Toronto Laboratory.

Analyses of concentration data as a function of flow from a chemograph and from the two years of data at each station indicate that phosphorus concentrations are flow sensitive (phosphorus concentrations increase as the flow rate increases) but that nitrogen concentrations are not flow sensitive. These relationships hold for both surface streams and tile drains. To estimate flow at each station in between sampling dates, regression equations were obtained relating flow at station i to the flow at the main station on the same day. A regression equation for station i coupled with the daily hydrograph at the mouth station gives an estimate of the daily hydrograph at station i. Since phosphorus concentrations are flow sensitive, relationships of phosphorus export at a station as a function of flow at the mouth station were obtained by regressing the phosphorus export (the measured flow times the measured concentration) on each sampling date with the corresponding flow at the mouth station, Qmsn. The relationship is of the form: $f_i = a_i Qmsn^{b_i}$ where $a_i$ and $b_i$ are station coefficients ($b_i \simeq 1.2$ for each station), and $f_i$ is the station export, gm/day. Use of the station regression with the hydrograph at the main station gives an estimate of the daily export at a station. Nitrogen export was estimated using the average seasonal concentration and average seasonal flow rates.

With respect to the export of nutrients, from different sub-basins or due to different livestock management factors, the following conclusions are made:

1) The annual export rate is 0.48 Kg P/ha/yr,57 Kg N/ha/yr and 1.4 cfs/mi$^2$ of water. The basin consists of three sub-basins; the north sub-basin occupies ~50 percent of the area and contributes 0.51 Kg P/ha/yr, 61 Kg N/ha/yr and 1.3 cfs/mi$^2$ of water; the middle sub-basin

occupies ~13 percent of the area and contributes 0.45 Kg P/ha/yr, 32 Kg N/ha/yr and 1.0 cfs/mi$^2$ of water; the south sub-basin occupies ~33 percent of the area and contributes 0.52 Kg P/ha/yr, 67 Kg N/ha/yr and 1.6 cfs/mi$^2$ of water. The export of P, N and water from each sub-basin does not significantly differ from each other. (as opposed to previous reports where some discrepancies in the middle branch were observed. These discrepancies have been corrected with the inclusion of late-winter, early-spring runoff data and our methods for calculating export). These sub-basin exports demonstrate consistency in our data.

2) For phosphorus, BEAK estimates that the export from non-livestock areas (i.e. controls) is 0.33 Kg P/ha/yr. Export from livestock areas vary from this rate up to 2.3 Kg P/ha/yr. Two livestock operations export less than 0.33 Kg P/ha/yr. These particular estimates are made on tile drains which represent only a fraction of total export from that area. The average export of phosphorus from livestock areas sampled at surface sources is 0.87 Kg P/ha/yr. For nitrogen, the controls yield 42 Kg P/ha/yr while livestock areas yield 47 Kg N/ha/yr. There is no significance difference between these two yields.

3) Differences in export of nutrients cannot be attributed to type of livestock operation. The mean export rate and range of values are approximately the same for beef, dairy, swine and cash crop operations.

4) Differences in phosphorus export between farms and bacterial contamination are attributable to specific physical and management factors. These relationships are described below; the operations for which these relationships seem to predominate are indicated in brackets. Phosphorus export is related to: distance from watercourse (No.s 1, 2, 3, 10, 20), improper subsurface drainage (No.s 2, 8), winter manure spreading in close proximity to watercourses (No.s 3, 4, 2), winter manure spreading upon the floodplain (No.s 3, 16), artificial channel reconstruction (No.5), streams flowing through open pastureland (No.10 stn. N9), residential communities (No.18) and the location of feedlots and manure storage (No.s 3, 18, 4).

5) Compared to many large sized feedlots, all livestock operations in AG-3 are small to moderately sized (<500 individuals/operation). For this scale of operation, phosphorus export appears to be linked more to the management of an agricultural operation rather than to the type and density of livestock. A well managed feedlot of

this size exports a low amount of nutrient and bacteria (No.1) regardless of the type and density while a poorly managed operation exports a large amount of phosphorus proportional to the number of livestock and related directly to the type of livestock. The type and density of livestock are secondary factors mediated by management factors.

6) With respect to seasonal effects, the greatest part of phosphorus export occurs during the spring period from March 1 to May 31. This period is dominated by the export during spring breakup with the associated snowmelt and rain showers. More phosphorus leaves the basin during this season than the other three seasons combined. Nitrogen export occurs predominantly in the winter and sring periods.

During any season, the daily export of nutrients during an event is an order of magnitude larger than the daily mean export for that season. The export of nutrient (both nitrogen and phosphorus) during one day in the spring breakup is of the order of 50X the value of nutrient export in one day for any other event.

7) With respect to forms of nutrients, surface water stations export 60 to 85 percent of the total phosphorus as dissolved phosphorus; the greatest part of this is soluble reactive P. Tile drains export 80 to 100 percent of its phosphorus in the dissolved form all of which is soluble reactive P. More than 85 percent of all nitrogen exported from operations under study is in the nitrate form. 3 (tiles) to 13 (surface water) percent of the nitrogen is in the organic form; nitrite and ammonia are present in trace amounts. In tile drains, 95 percent of the nitrogen is in nitrate form.

8) Values for chemical parameters pH, conductivity, hardness and alkalinity are typical of a moderately hard water.

9) The geometric mean (i) of total coliforms ranges from 290 to 52000 per 100mℓ, (ii) of fecal coliforms ranges from 9 to 8100/100mℓ, and (iii) fecal streptococci ranges from 5 to 1100/100mℓ for all stations. The ranges of 3000-5000/100mℓ for total coliforms, 200-400/100mℓ for fecal coliforms and 100-300mℓ for fecal streptococci include approximately 80 percent of all stations. These are the normal ranges for most surface stations. One tile station which is an order of magnitude higher than these normal ranges drains a farmyard; three tile stations which are an order of magnitude lower than these normal ranges drain field which are not influenced by either livestock or manure. The discharge of the tile drain, with large bacterial concentrations to the surface stream is not seen 200 feet downstream due to dilution.

## 2.0 INTRODUCTION

### 2.1 Study Objectives

Article VI of the Great Lakes Water Quality Agreement, 1972, requested that the International Joint Commission inquire into and report on "pollution of the boundary water of the Great Lakes System from agricultural, forestry and other land use activities, in accordance with the terms of reference attached to this agreement". The International Joint Commission (I.J.C.) established the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) to plan and implement the requested study.

In March 1973, PLUARG submitted to the International Joint Commission a study plan to assess pollution of the Great Lakes from land use activities. This preliminary study plan outlined four main tasks including assessment of the problem (Task A), inventory of land use activities (Task B), watershed studies (Task C) and lake studies (Task D). A "Detailed Study Plan to Assess Great Lakes Pollution from Land Use Activities" was prepared (February 1974) and formed the basis for the PLUARG study.

Task C was described as, "Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes Basin, and to relate contamination of water quality, which may be found at river mouths on the Great Lakes to specific land uses and practices".

Activity 1 (Canada) of Task C called for "Pilot Agricultural Watershed Surveys". The objective of this activity was "to obtain data on the inputs of pollutants into the Great Lakes Drainage System which have their origins in the complex land use activities known as agriculture".

In February 1974, the Agricultural Sub-Committee of the Task C Technical Committee, PLUARG, prepared a "Detailed Plan for the Study of Agricultural Watersheds in the Great Lakes Drainage Basin - Canada - 1974-1975". This plan called for a preliminary phase consisting of a monitoring programme and additional studies for collection of background data. The second and intensive phase would consist of detailed studies of pollutants associated with agricultural land use.

The preliminary study phase, April 1974-1975, has been reported in detail in "Agricultural Watershed Studies, Great Lakes Drainage Basin, Canada, Annual Report, 1974-1975". The requirements for continuation of the study were identified in that report and included a monitoring network, a detailed studies programme, and a programme for remedial measures or other future requirements.

The objective identified for the Phase I Monitoring Programme was to measure the ambient concentrations and loading rates for various pollutants that occur with agricultural land use. The Phase II Detailed Studies would be directed towards the determination of the effects of soil, land use and associated practices on concentrations and loading rates of selected pollutants; the study of mechanisms of transport and storage of these pollutants in selected agricultural watersheds; and finally, the development of a predictive capability to allow extrapolation to other areas.

Six agricultural watersheds were selected as sites for detailed study under Phase II. Project 20 is involved in studying one of these watersheds designated AG-3 (Upper Little Ausable River Sub-basin). The objective of this study is to evaluate the losses to surface water of nutrients and bacteria directly related to livestock activity. In order to assess these, several areas of study were selected:

1) determine the annual nutrients flux into the surface waters of the AG-3 sub-basin from various types and densities of livestock operations.

2) breakdown this total flux of nutrients into seasonal baseline and event contributions

3) identify the forms in which the nutrients, nitrogen and phosphorus are transported

4) analyse the effect of various livestock operations and practices on the release of bacteria to surface waters

5) assess the effect of tile drainage upon nutrient and bacterial fluxes into surface waters

## 2.2 Study Approach

The Little Ausable River Sub-basin (AG-3) is located in south-western Ontario approximately 30 kilometres due north of London Ontario. The

Little Ausable is a sub-basin of the Ausable River Watershed that drains into Lake Huron at Grand Bend.

The AG-3 basin is relatively flat, predominantly clay-loam, encompassing 5,670 ha which drains through both natural ditches and municipal drains. The area is almost exclusively (97%) agricultural usage, mainly small mixed and cash crop farms. Main crop is corn with lesser amounts of mixed grains, white beans, hay and pasture; crops on mixed farms are grown primarily for feed, those on cash crop farms grown for marketing. Beef feedlots presently predominate livestock operations with lesser density of swine and dairy operations in the basin. Turnover of type of operation is frequent with many operations switching from livestock to cash-cropping.

The study approach chosen was to measure the flux of nutrient and bacteria on a regular and event-oriented basis over a period of two years from June 1975 to June 1977. Surface water loadings from various operations are then related to the intensity and type of agricultural practice.

In order to accomplish this, 26 sampling sites were established at locations with relatively continuous water flow to monitor the surface water loadings from 17 farm operations representing major livestock operations and non-livestock controls from the 94 farming operations in the basin. Flows are measured at all stations at the time of sampling either directly by volume or through a staff discharge relationship. The samples collected are then analyzed for nutrient and bacterial concentrations. The data is then run on a mathematical model in order to determine fluxes and meet the study objectives.

The watershed has two main branches (the north and south) and a third smaller branch (the middle branch). The south branch, which is spring fed, tends to flow most of the year and was chosen for examination of the different forms of nutrients. The middle branch, which is the smallest, is the most intermittent, resulting in some summer and fall periods where no measurable flow occurs. The north branch, which drains approximately one-half of the basin is characterized as being somewhat intermittent and having two small hamlets. An equal diversity of farming types (dairy, beef, swine and cash crops) and agricultural practice is found on each branch. These branches together with livestock operations selected in this study are shown in Figure 1, the sampling stations selected are shown in Figure 2.

## 3.0 DATA COLLECTION METHODS

### 3.1 Sampling Procedures

In the AG-3 study area, twenty-six sampling locations were selected at points where water movement was relatively continuous and where the station could be related directly to one agricultural operation. Of the twenty-six stations chosen, eight are tile drain outlets, two are open channel single stations, fourteen are open channel difference (above and below) stations and two are mass-balance stations. These twenty-six stations can then be directly related to seventeen individual operations, six beef feedlots, three dairy farms, five swine producers and three cash crop operations.

The basin was subdivided into three branches for ease of identification; these were identified as the north (N), middle (M) and south (S) branches and the stations on each branch numbered sequentially from 1 at the mouth upriver to the source; hence, station M4 is the fourth station up the middle branch.Two samples were collected at each station, one in an acid-washed 1ℓ. nalgene bottle for chemical analysis and one in a 250 mℓ acid-washed autoclaved glass bottle for bacterial analysis. Both samples were then stored immediately in portable coolers on ice. With each sampling a measurement of volume per unit time or stage was taken. Samples were collected branch by branch from the uppermost station downstream. All samples from one branch were transported to BEAK's mobile laboratory in Exeter and refrigerated before collecting samples from the next branch. Samples were refrigerated at 4°C within two hours of collection and kept on ice in the interim. (between 4 and 10°C). All collecting was done by grab sampling, collected consecutively, no samples were split. Additional 1ℓ samples were collected at random locations consequent to regular samples; these samples were taken for additional analyses, replicate samples or sent to O.M.E. laboratories for cross-checks.

### 3.2 Chemical Analysis

Samples collected and transported back to BEAK's mobile laboratory in Exeter were subsequently analysed for nutrient and bacteria content. The major analyses, phosphate, nitrate and bacteria were performed as outlined in Standard Methods 13th. edition and are outlined in detail in Appendix 1, methods of analysis.

In addition, several standard water analyses were performed on each sample.

i) Analysis for pH was performed according to section 144A Standard Methods[1] using a Metrohm E488 meter with EA152 combination glass electrode.

ii) Specific Conductance was measured according to section 154 Standard Methods[1] using a labline MC-1 conductivity bridge and a K=.1 conductivity cell. The readings were then corrected to 25°C.

iii) Total Hardness was determined by EDTA titrimetry, Standard Methods[1] section 122B.

iv) Total Alkalinity was determined by acid titration using the pH meter described in i) following the procedure in section 102 Standard Methods[1].

v) Nitrite Nitrogen was analysed following section 134 Standard Methods[1].

vi) Phosphate (total, soluble and total reactive) were analysed following the procedures outlined in section 223C and 223E Standard Methods[1] incorporating several modifications outlined in Appendix 1.

vii) Nitrate Nitrogen was analysed according to section 213C Standard Methods[1] with modifications outlined in Appendix .

viii) Total and Fecal Coliforms were determined by membrane filtration as outlined in Appendix 1.

ix) Fecal Streptococci bacteria were added for analysis during the last year of the program using the same membrane filtration technique as in viii) and following procedures outlined in section 409C Standard Methods[1] using M-Enterococcus Agar.

In addition to these analyses, three stations S1, S4 and S9 were selected for Ammonia and Total Kjeldahl Analysis on each sampling collection; this analysis performed at BEAK's Toronto Laboratory. Standard Methods[1] sections 132 and 135 outline the procedures involved.

1 Analytical text is Standard Methods for the Examination of Water and Wastewater, thirteenth edition APHA 1971.

## 4.0 EXPERIMENTAL RESULTS

### 4.1 Hydrology

The Upper Little Ausable River Basin Consists of 5,670 ha. of drainage area in the corner of southwestern Ontario where Perth, Huron and Middlesex counties meet. The AG-3 sub-basin consists of three main branches which we have designated the north, middle and south branches. There are sampling stations on all branches of two types: open channel stations where flow is determined through a stage discharge relationship and tile drain stations (locations where a tile drain system empties into the channel) where flows are determined by collecting a known volume over a measured time period.

These three branches have different characters; the south branch originating in several spring areas flows year-round except in high drought periods, the middle branch which is considerably smaller than the other two is intermittent and dries up during some summer and fall periods. The north branch, which drains approximately one-half of the basin is occasionally intermittent depending on the water table; for most of the summer the section north of country road six has no measurable flow. Hence, the section that passes through Elimville and Winchelsea has the only consistent flow pattern. The drainage areas of each branch are similar in soil, crop, livestock and topography; Hydrological differences only seem to appear when the water table is down.

The AG-3 sub-basin of the Ausable River contributes an annual mean discharge of 1.07 $m^3$/sec (1976 calendar year only). Discharge varies from 20-30 $m^3$/sec during spring runoff to .02-.03 $m^3$/sec during mid-summer. Maximum containable runoff is $\sim$20 $m^3$/sec; at most times of the year streamflow is contained within the natural channel; however, during the couple of days that spring breakup occurs most open channel reaches in the sub-basin overflow onto the surrounding fields. During this short period of time, considerable surface erosion occurs, alternately scouring and silting the stream bed. After this period the bed virtually stabilizes until the next spring; luxurient vegetational growth occurs in the channel and on both banks throughout April to November and little channel alteration occurs during this period. This "stabilization" allows for a stage-discharge relationship to be established for each open channel station. This stage-discharge relationship is based on a series of flow measurements during the year and must be revised after each spring breakup and back-water corrections applied during certain periods.

Ontario Ministry of the Environment has established a continuous monitoring station at the outlet from the drainage basin. We have attempted, as best as possible, to establish a daily flow relationship between this station and each open channel station upstream for the periods between samplings.

Each of the stations at the outlet of the tile drains are measured directly by volume per unit time at the time of sampling. Daily flow through these systems was similarly interpolated.

Over the course of a year, the hydrological scheme of the basin fluctuates. During the winter months December to February no streams have open water; flow in drains and channels are similar to those during the fall period but the water flows to a depth of around 10 cm. beneath 0.2-0.5m. of ice which lies beneath 1-2m. of snow. In most cases, stream channels are completely filled by ice and snow; hydrology estimates are extremely hard to determine for this period.

Spring ice breakup occurs first in the south branch around the end of February with 1-2m. snow still on the ground. The middle branch breaks up approximately 1 week later and the north branch opens up generally around mid-March.

During this breakup period, high flows of the order of 3-10$m^3$/sec are common. After open water or at north branch breakup maximum flows occur at the mouth station up to discharges of 20-30$m^3$/sec over a period of a day or two. At this point flow spills over the banks and across the fields and up to the top of bridge abutments. After this point the hydrograph for all stations gradually tapers off with occasional spring thundershowers creating small peaks in the hydrograph. During the spring period, flows are areally related. As the growing season progresses, vegetation starts in the streambed and on the banks stabilizing the prior siltation. At this point flows cease an areal relationship and tend towards dependence on production by springs that govern the flow regime all summer and into the fall season. Flows during late July and early August drop to 0.02-0.03$m^3$/sec total for the entire basin. Throughout the low flow period April to November, the topography excludes the possibility of precipitation entering water courses via surface runoff except during extensive events.

In the late fall the hydrograph again starts to rise, abetted by late fall rainshowers and the flow tends back towards an areal relationship. Winter snowstorms and low temperatures commence the freezeup in mid-December and the hydrograph levels off. The Ausable R. basin is reknowned for its snowbelt location and severe winter conditions; however in AG-3 the snowfall buildup (usually 1-2m on the ground) tends to a slow snowmelt rather than creating the extensive flooding in the major watersheds.

4.2 Water Quality

In June 1975 water sampling was begun on the AG-3 sub-basin and continued until May 1977. During this two year period, thirty-two sample collections were made and the water samples analysed for pH, specific conductance, total hardness, total alkalinity, total phosphorus, total dissolved phosphorus, reactive phosphorus, nitrate, nitrite, ammonia, organic nitrogen, total and fecal coliforms and fecal streptococci bacteria. Analytical results of these collections are displayed in table 1. Omissions from the tables include only;

i) Stations where no water sample was taken marked by a line of blanks (due to being either dry, frozen solid or inaccessible).

ii) Analyses where only selected stations were chosen (ammonia, Kjeldahl or dissolved phosphorus).

iii) Analyses that were added during the course of the study (orthophosphorus and fecal strep.).

iv) Bacterial samples that did not plate properly.

In addition to these regular collections and analyses, one collection was made to assess nitrogen and phosphorus in groundwater (table 11) and the distribution of nitrate and phosphate over the course of an event (chemograph). This chemograph was performed during the period of April 25-28, 1977, and the results appear in Table 12 .

pH values throughout the study fluctuated very little with most values falling into the 7.0 - 8.0 range or slightly outside; no startling values for this chemical parameter were observed. Collection GG in March 1977 has dubious pH values due to a malfunctioning electrode which was subsequently replaced. All other pH values for the project fall within acceptable limits for receiving waters.

Specific Conductance values vary seasonally at most stations from a high in the spring and dropping off through the fall to a low in late-winter. Several exceptions to this pattern appear in the tables but these are special cases where nutrient values also vary from the norm.

Total Hardness and Total Alkalinity vary minimally throughout the year; most values are similar for one collection as well as for any station and generally the values obtained are within those normally found in south-western Ontario.

Bacteria are found in varying numbers at different stations and different times of the year; their significance is outlined in detail in section 5.5. Generally speaking, bacterial counts for a water course are of the same order of magnitude for a collection; variations occur with lower than average (by an order) indicating source or near-source water and higher than average (by at least an order) indicating some contamination point problem. Most of the high counts occur at stations where animals have direct or indirect access to the watercourse.

Phosphorus has been isolated as one of the major pollutants to the Great Lakes Basin; therefore, during this study, greater emphasis was placed on investigating phosphorus significance and is discussed in much greater detail in sections 5 and 6. In most cases total phosphate as phosphorus analysed to less than 0.1 ppm. Sites displaying higher values of phosphorus tend to display lower than average values of nitrogen and would tend to indicate some source of pollution which is a point source rather than a diffuse one. These problems seem to be practice oriented; measures to correct or reduce the problem should be possible and are discussed in section 4.4. Samples were analysed for reactive phosphorus (ortho) and dissolved total phosphorus. Indications seem to be that for most samples, greater than 70 percent of the phosphorus is both dissolved and reactive; assays for both of these are the same. Very little of the total phosphorus is colloidal and this seems to hold with the lack of suspended sediment in the samples. However, at spring breakup, the sediment load greatly increases for a 1-2 week period and accordingly the amount of particulate phosphorus increases during this period. The fine particulate clay soil in the area is extremely susceptible to erosion during the short period of flooding and probably more sediment and the associated particulate phosphorus enter the water regime at this time than during the rest of the year.

Nitrogen is also one of the major nutrient inputs to the Great Lakes and the evaluation of its fluxes and impact are discussed in detail in sections 5 and 6. Water samples were analysed for nitrate, nitrite, ammonia and kjeldahl nitrogen. Essentially concentrations of these forms range: 1.0 - 15.0 ppm nitrate N, 0 - 0.1 ppm nitrite N, 0 - 0.2 ppm ammonia N, 0 - 1.0 ppm kjeldahl N. i.e. greater than 90 percent of nitrogen entering the surface water system is in the nitrate form.

Table 10 indicates values of these constituents for three typical stations, S1, S4 and S9 which were chosen for more detailed analysis at the start of the study. These stations were selected as they appeared to show analytical values close to the norm and appeared to be relatively free from interference from point sources. S9 is the headwaters station on the south branch, a municipal drain with a manhole access. S4 is a surface water station approximately half-way down the branch below several agricultural operations but more than 1 km. from the nearest buildings. S1 is the mouth station of the south branch just above the confluence with the middle branch and again about 1 km. from the nearest buildings.

## 4.3 Agricultural Practices

The Little Ausable River Watershed (AG-3) is predominantly agricultural (97 percent) in nature, most of the operations have associated livestock activity, primarily beef, swine and dairy, although recently the trend has been towards a greater amount of cash crop farming. 1975 figures show 45 beef feedlots, 41 swine farms, 16 dairy herds and 9 poultry operations. There has been considerable interchange of livestock types in the past few years.

The operations under study in this project total 17 consisting of 6 beef, 4 swine, 3 dairy and 4 control (cash crop) farm operations. A summary of the operations appears in tables 5a and 5b.

1975 data for the AG-3 basin shows that manure was applied to 20 percent of the agricultural land at an average rate of 28.2 tons per hectare to 25 percent of the cropland and 71 percent of the hay and pasture. Manure was applied from October to May on the former and June to September on the latter. Most of this fertilizer is handled in the solid form with occasional operations handling the liquid form. Solid manure is stored outside in piles susceptible to rainfall leaching.

Of the 111 dwellings in the area, 94 are involved in mixed and cash crop farming. The major crop is corn (32 percent) with lesser amounts of mixed grain (16 percent), white beans (12 percent) hay (10 percent) and pasture (8 percent). (figures in brackets represent 1975 data). Residues from these crops were either removed for silage or incorporated.

Almost all land under cropping is plowed in the fall and disked in the spring; the exception is the wheat crop which is plowed in August and tilled in September.

This study covered 17 operations in detail with a range of crops with the same ratio as those for the entire basin. These crops are listed in table 5a for each farm in order of abundance.

Inorganic fertilizer was applied prior to or during planting in most cases (75 percent) and to almost all major marketable crops listed above. This is done between April and June except for wheat which is fertilized in September. Nitrogen based fertilizer is also applied after planting to significant areas of corn (41 percent) and wheat (78 percent).

## 4.4 Description of Operations Under Study.

This section deals with a description of each operation being studied in Project 20, along with annual flux estimates and a short discussion of these estimates.

The average for the AG-3 Little Ausable River sub-basin is measured in Operation No. 14 which is a station (MSN) on the river where it exits the study basin. Operation No. 7 is a similar station close by on the north branch to enable some mass balance calculations on the three main branches.

The remaining operations are all single-unit agricultural activities which include:

a) beef feedlot operations No. 1, 2, 3, 5, 11 and 16.

b) dairy cattle operations No. 8, 9 and 10.

c) swine operations No. 4, 12, 18 and 20.

d) cash crop (non-livestock) operations No. 6, 13, 15 and 17.

### Operation No. 1

This is a beef feeder operation of app 100 head. Drainage area is 93.4 ha. generating a flux of 58.77 gmP/ha. annually. The area, drained by a surface ditch is untiled; it is predominantly flat terrain in barley, and hay. (Fields are cropped to within 3m. of ditch). Manure is stored in a bunker beside the feedlot and spread year-round on fields close-by; nearest point to watercourse is approximately 100 m., storage 250 m. from watercourse.

This operation is monitored at the point where the drainage ditch empties out of the area. Flux supports evaluation that no great problems should arise from this operation; sources of pollution are well removed from access to surface water, slope and small vegetated strips on streambank aid in reducing surface runoff. This operation is an example of good farming practices in producing a relatively low amount of nutrient to the surface water.

Operation No. 2

A beef feeder operation of ~200 head, this is a highly concentrated feedlot. The barn/feedlot/storage bunker sits atop a small hill overlooking the watercourse approximately 100m. away. Manure is spread year-round on fields surrounding the storage including the one between the buildings and stream. A farm laneway and 2m. grass verge help to buffer the effects of surface runoff. The area involved is 9ha. in size, generating an annual flux of 1127.79 gmP/ha. For the years of study this area has been exclusively cultivated in corn. It is also well tiled and most sampling occurs at the header outlet when accessible.

The high flux value supports field observations that a problem exists for this operation. Although this area provides very small flows, nutrient concentrations are almost always higher than any other sampling station. The presence of solid material and other evidence of bacterial decay lead us to believe that the sewage system of barn and/or house are connected to the tile drainage system. During high flow periods surface runoff to the watercourse is evident despite buffering effects of laneway and grass verge.

This operation could probably be markedly improved by locating the link-up of sewage and drainage systems and separating them.

Operation No. 3

This 114.6 ha. area has a 220 head beef feedlot located 10m. from the watercourse. Manure is contained in a concrete/wood bunker beside the barn the same distance from the stream. Manure is spread year-round on the field beside the feedlot cultivated solely in hay during the period of study. This application is made to within 5 m. of the stream. A grass verge 3-5 m. in width aids in surface runoff containment but during the spring breakup period, this field and "buffer-zone" are flooded as the stream overflows its banks. The buildings on a small rise are not in the flood plain. The area is untiled, a total of 114.6 ha. in size producing an annual flux of 1047.46 gmP/ha; it is cultivated mainly in corn (67 percent), barley (17 percent) and hay (8 percent). This operation is sampled above and below its area and the data calculated by difference.

The high flux (2x basin average) upholds our assessment that although there is a buffer strip, the proximity of such a dense operation to the watercourse plus pre-breakup manure application to the flood-plain are problems associated with this operation at times of high water/ rainfall.

The problem in this case seems to be proximity of livestock wastes to the stream; as the relocation of the operation is probably impractical, possibly the feedlot could be relocated on the far side of the barn, storage moved or completely contained and winter spreading on the flood plain prohibited.

Operation No. 4

A moderate-sized (120 individuals) swine operation was begun in 1975 after several years of cash cropping, situated in a small barn 20-25 m. from the watercourse. Manure (solid-liquid) is stored in an open pile behind the barn and is spread year-round on the surrounding fields although no closer to the channel. A 2-3 m. wide strip of vegetation (grass) borders the river and the cropland, which is flat, in wheat (26 percent), mixed grains (24 percent) and barley (18 percent). Spring runoff swells the river in this location but does not overflow the banks. This farm is 89.2 hectares in size; data is measured by the difference of two stations (M2 and M3) above and below the area and has a yearly flux of 582.30 gm.P/ha.

We expected this operation to show above average flux figures; however, they are not as high as expected possibly due to the flat terrain, grass buffer strip, smallness of operation or a combination of all three.

This operation could probably be improved by some type of waste containment facility to prevent leaching.

Operation No. 5

This is a 280 head beef feeder operation; manure is piled unsheltered beside the feedlot, all 280-300 m. from stream. Manure is spread year-round on field behind farmyard (within 30 m. of stream). A grass strip 2-3 m. wide borders each bank providing a small buffer zone from the fields which produce crops of hay, corn and mixed grains. The channel running through this study area was dredged in 1975 and the area extensively tiled in 1976. Despite this disturbance to the water system, the flux of 457.25 gmP/ha. annually from these 191.6 ha. is close to the basin average. Data for this operation is measured by difference of stations above and below.

The open pile/feedlot were expected to have some effect upon the stream but the flux value obtained is similar to that for the entire basin, hence it is possible that the flat terrain and the distance from the watercourse are sufficient for containment. It is difficult to assess the effect of channel improvements/new tile drainage on the water quality ie., whether in the long run, clearing the channel of vegetation and sediment and improving the drainage is harmful or beneficial.

Operation No. 6

Operation 6 is a 173.2 hectare cash cropping set-up just recently converted from a beef feedlot. This farm sits near the watershed perimeter and there is a slight gradient from the buildings to the sampling point which is the point where the drainage water surfaces to a ditch from two old tiling systems and three new ones (1975). The buildings are ~800 m. from the sampling point although closer to the tile drains. During spring breakup, surface runoff also enters the channel at this point. The annual flux of phosphorus from this area is 266.49 gm/ha., about half of the basin average. Crops grown on this land include corn (23 percent), barley (17 percent) and fall wheat (16 percent).

Although there may be some residual nutrient runoff from the old livestock operation, it appears that the nutrient contribution from this farm is acceptable.

Operation No. 7

This is not a farming operation per se, but an additional station to aid in calculating the mass balance for the AG-3 basin; this station is the farthest downstream on the north branch. An area of 2409.7 hectares drains into this point with a flux of 505.94 gm.P/ha. Agriculture above this point is mixed; very similar to that of the entire AG-3 basin, (Operation No. 14). The slight amount that this is larger than the flux for No. 14 may be due to the two small hamlets that sit alongside the north branch (which also appear to affect Operation No. 18).

Operation No. 8

A dairy farm of 80 milkers is being studied here, on a drainage area of 55.6 hectares drained by a recently installed municipal drain/tiling system. Sampling is done at the outlet of this drain to the streambed. The building and pasture is located approximately 1000 meters from the stream although the underground drainage system goes very close to the buildings. The terrain at this location is flat, although there is detectable surface runoff along the path of the drain (long depression) during spring snow-melt. Main crops grown on this land are hay (or pasture) (25 percent), corn (23 percent) and mixed grains (22 percent). Flux for this area is 498.36 gmP/ha.

Although this flux is similar in size to the basin average, there is considerable evidence (solid matter and objectionable odours) that the sewage system from the farm buildings is interconnected with the municipal drainage system. Phosphorus concentrations as high as 14 ppm tend to corroborate this fact, occurring in mid-autumn and the drain outflow has a high percentage of liquor from silo-drainage. As with operation No. 2, improvement should be possible by removing the interconnection in the systems and suggesting application of the liquor/waste silage to the soil.

Operation No. 9

A drainage area of 56.9 hectares occupied by a 35 head dairy cattle setup is situated on a fairly new municipal drain/tiling system. Pasture land is close by the main barn but no closer to the surface water. Manure is stored in a bunker beside the barn and applied year-round to the fields close by. The buildings, pastures and fields under application are 300-350 m. from surface water channels. The topography of the area is flat and land use is hay and pasture (34 percent) mixed grains (24 percent) and corn (22 percent). Flux for operation No. 9, is 335.91 gmP/ha. annually.

This is what we expect from an efficiently tiled operation in the AG-3 area, with livestock and storage a sufficient distance from the surface water channels, no slope to the terrain and a sound tiling system with no direct sewage hook-up. The flux of the area is considerably lower than the basin average and the operation itself appears to have little effect on the water quality.

Operation No. 10

This farm is monitored by one station above and one below, data calculated by difference. A 48 milker dairy herd occupies most of the 142.0 hectares studied here. The farm buildings sit on a gradual slope approximately 100 m. from the watercourse; manure is stored in an open pile behind the barn (no closer to the river) and is spread year-round to the fields on the side of the buildings distant from the river (also over a small rise). The land has a slight slope, the farm buildings sitting atop a low "ridge", the river on one side and the cultivated fields on the other. Crops associated with this operation are corn (33 percent), mixed grain (31 percent) and hay/pasture (18 percent). The creek flows through the middle of the pasture for the entire length of the operation. Total annual flux is 1244.28 gm P/ha.

Although storage may be an issue, winter application of manure is not, due to a slight slope away from the watercourse at this point. The problem with this operation is the direct access cattle have to the surface water from spring to late fall, resulting in high nutrient and bacteria levels during this period. Isolating the cattle from direct contact with the river(by-pass)pond should improve water quality in this area.

Operation No. 11

A 230 head beef feedlot is the main occupant of this 167.7 hectare study location. The municipal drain from this area is sampled through a manhole; the underground drain continues below this point. The farm is located 1700 meters above the sampling point and the tiling system approaches fairly close to the feedlot. Manure is stored in a bunker beside the farm buildings and applied year-round to the surrounding fields although still no closer than 1200 m. from the sampling point. The farm is located on the rim of the watershed and there is a slight gradient to the land which is cultivated in corn (54 percent), hay (21 percent) and mixed grains (11 percent). Some surface flow does occur during the spring snow-melt period. Flux of phosphorus from this area is 442.75 gm./ha./yr.

This figure is slightly higher than other tile drain systems although very similar to the basin average. It is possible that somewhere near the hamlet of Woodham that one or more residential sewage systems wash into the municipal drain.

Operation No. 12

A swine raising operation of 300 feeder hogs situated on 128.5 hectares at the edge of the drainage basin. The sampling location is 20 m. below the outlet of the drainage tile headers. The tile systems go from the outlet point towards the farm buildings 1000 m. distant. Manure is stored in liquid form in a large metal vat (covered) and not applied during the winter period. There is a slight gradient to the land and during spring snow-melt, surface runoff does occur. Mixed grain (64 percent) and soybeans (34 percent) are the only crops grown. Annual flux is 488.42 gmP/ha.

Flux figures for this area are slightly high for a tile drainage system but comparable to the basin flux figure. No particular reason is evident for the figure and no remedial measure can be suggested.

Operation No. 13

Although associated with a swine raising operation, the area studied here is considered a cash crop non-livestock control as no livestock/animal confinement occurs on the drainage area monitored. A residence/barn are situated on the land but have been unused the past couple of years. The sampling station occurs where a tile drainage header pipe discharges into the river channel. No manure is stored or applied to this land where soybeans (34 percent), barley (23 percent) and fall wheat (19 percent) are grown. This 58.7 hectare area produces a yearly flux of 148.71 gm P/ha.

This station monitors a very old clay tile drainage system still functioning well; however, during spring runoff/snow-melt some sediment does enter the system (as well as some surface runoff) and most of the phosphorus flux occurs at this time. Little or no remedial action can or need be taken.

Operation No. 14

This "operation" monitors no single livestock activity. The data collected for Operation 14, represents data for the entire AG-3 sub-basin, collected and analysed at the same location as the QME station

02FF102. Area of the drainage basin is 5680 hectares producing an average 477.94 grams of phosphorus per hectare annually.

Operation No. 15

This is a cash crop proposition; no livestock, buildings or human habitation has occurred here for several years. The area measures 14.9 hectares and is monitored at the outlet of a tile header draining the field under study which has grown corn for the last five years. The area is characterized by a fair-sized hillock. During spring runoff the outlet and lower areas are submerged as the river overflows. Flux for the area is 4.38 gm.P/ha./yr.

Operation No. 16

A small (35 head) beef feeder (400-1000 lb. gain) operation has been instituted (1975) on a previous cash crop setup. The feedlot and open manure pile are located 380 meters from the river. Manure is spread year round on the surrounding fields >200 m. from surface water although floodplain extends to ~70 m. of this point and some manure may be spread on the floodplain during winter. No tiling is in existence on this section of land measuring 108.4 hectares. There is virtually no slope to the terrain where soybeans (36 percent) fall wheat (29 percent) and mixed grains (25 percent) are the major crops. Annual flux for operation 16 is 973.66 gm.P/ha. Station is monitored by difference between upstream and downstream stations.

We had expected a flux figure at or below that calculated for the basin and there does not seem to be justification for a higher figure except in the fact that a considerable amount of the area monitored is in the floodplain and is submerged at breakup; the washing of tilled soil in the floodplain may account for the oversized flux estimates. There doesn't seem to be much in the way of remedial measures that can be applied if this is indeed the case.

Operation No. 17

This operation has been a cash crop setup since 1968, an area of 118.1 hectares monitored by two stations above and below the operation. There is no livestock, no manure pile and no winter application. Farm buildings sit on a slight grade approximately 120 meters from the stream. Crops grown for market include corn (47 percent) soybeans (25 percent) and barley (15 percent). Flux is 581.01 gm.P/ha./yr.

The only accountable cause of the large flux figure is the slope of terrain in this area. Fields are cropped to within 1 m. of the channel and precipitation may be causing some sheet erosion. Perhaps a larger grass buffer zone would be the solution here.

Operation No. 18

The difference in two stations (above and below) is used to provide data on this swine raising area which supports 300 weiners and 42 farrowing sows and boars on an area of 69.5 hectares. The animals are raised indoors and the manure produced is stored in an open pile between barn and river. Manure is spread on fields behind and beside the buildings year-round. Buildings and pile are 100 m. from stream, manure spread to within 10 m. on a gradually sloped field. Crops grown are mixed grain (64 percent) and soybeans (34 percent). Flux for this setup is 2313. gm.P/ha./yr.

Extremely high flux may be due to bad management/practice in storing and spreading too close to stream; however, the hamlet of Winchelsea also appears in this area close to the creek and some septic tank systems may be (and probably are) failing and the contents entering the watercourse. Remedial measures for the agricultural operation includes proper containment of waste, relocation of winter spreading (if spreading is necessary at all) and reassessment of residential pollution point/diffuse sources.

Operation No. 20

This study is a combination of four individual swine operations side by side along a concession with a drainage ditch flowing through one barnyard after another until it merges with the creek itself. This area is monitored by a station 10 m. above the confluence. These four farms have a combined 2400 individual swine covering 222.6 hectares of land. The ditch flows through part of each barnyard, half of which are open pig lots (the other two indoor pens). Indoors, 1600 feeder hogs produce liquid manure which is stored in sealed vats; outdoors, 700 feeder hogs and 116 sows/boars have barnyard access and the manure (solid-liquid) is stored in piles and spread year round in nearby fields (within 100 m. of ditch). The area is cropped in corn (51 percent) hay/ pasture (20 percent) and mixed grains (13 percent).

Figure for flux for this operation is higher than the basin average but much lower than would be expected considering the potential for nutrient/ bacterial contamination of water. Main solution would be to reroute the drainage ditch away from the barnyards as far as possible. Lower than expected figure may be due to either the amount of non-livestock cropland draining in and/or confinement of individuals indoors.

## 5.0 DATA ANALYSIS AND INTERPRETATION

### 5.1 Hydrographic Analysis

The stage of flow at each station was observed on each sampling date except for tile drains at which flow rates were determined using a volumetric cylinder and stop-watch. Using stage-discharge relationships developed for each station, the volumetric flow rate was determined. This gives observations on stream flow at approximately bi-weekly intervals. Under an assumption that the flow observed on a sampling date is representative of the flow rate for approximately a two week period, it is possible to calculate the annual and seasonal stream flow at each station. Such an assumption is reasonable during periods of constant low flow, but not during other periods when flow can vary by an order of magnitude over a two week period. Since a continuous daily flow record is available at the mouth station, various hydrological models were explored to relate flow at the sampling stations to flow at the mouth station, so as to estimate the flow pattern at each station in between sampling dates.

Two types of models were considered. The first type relates rainfall to runoff by considering water budgets on the various hydrological reservoirs (e.g., surface water, soil, moisture, ground water). In this class are models of varying complexity including, the Stanford Watershed Model (see Linsley, Kohler, Paulhus, ), HYMO (being modified in an allied PLUARG study by Dr. H.R. Whiteley, University of Guelph, Ontario, to include snow-melt), and STORM. These models are deterministic, quite complex and attempt to model phenomena whose time scale is of the order of an hour. The second type of model seeks statistical relationships between various hydrological parameters and the observed flow at a given station. Such models are simple, empirical and describe time-scales of a longer duration than the first type.

The first type of model was rejected for this study. Its data requirements are large (e.g., soil moisture content over time as required). It generally does not consider snow-melt conditions. It is used primarily for flood-flow and flood-routing calculations, necessitating the adoption of some base level to describe groundwater flow. It demands large amounts of computer calculations.

Relationships (lines of regression) were sought between the flow rate at a sampling station and the flow rate at the main station on the same sampling date for each station. Calculations of time of travel for the AG-3 watershed indicate a value of the order of 0.5 days for a wave. Hence, when flow is high at the upper station, it will be correspondingly high at the mouth station. During flood events, the rise and fall of the hydrograph at an upper station will preceed that of the lower station by an amount due to the time of travel of a flood wave, local rainfall variations, and different soil conditions. Some refinement could be introduced in these regression relationships if the time of travel from sampling station to main station was included. Since an estimate of the average daily flow rate is desired, such a refinement was not attempted (the strength of the regressions of flow at various upstream stations on flow at the main station shown below, indicate that such a refinement is not needed).

Two regressions were tested:

1) Log (flow at station) vs. Log (flow at main station)

2) (flow at station) vs. (flow at main station).

A few typical results are shown for the log-log model in table 13. For all stations, analysis (t - test, 95% level of confidence) indicated that m´ is not significantly different from 1. That is, the linear model relating flow at station to flow at main station on the same day of sampling is the appropriate model. The regression model of flow for each station is shown in Table 14. The high correlation coefficient for each station indicates the strength of the relationship. For all tile stations, the strength of the relationship is not as strong as for main stream stations, since the rise and fall of a tile drain is much faster than that for stream stations; hence, larger errors are made in observing that tile flow rate which corresponds to similar behaviour at the main station. In fact, since the tiles do not flow for many periods while water flows past the main station, the regressions for tile stations mathematically result in flow estimates which, while finite, are infinitesimally small during these periods.

A daily flow record for a station is generated using the daily flow record of the mouth station and the appropriate correlation. To check the regression models, three checks were made. Firstly, the sum of the annual average runoff from the north (N1), middle (M1) and south (S1) branches is 91% of that of the mouth station; since this sum flows from 92% of the area of the waterbasin, the runoff budget from each branch is consistent with that measured for the whole basin. Secondly, the strength of the correlation between flow at each station and main station suggests that the runoff estimates at each station are excellent, except for a few tile drains. Thirdly, a plot of the slope of the Qi-Qmsn relationship as a function of drainage area of a station shows a consistently increasing though non-linear relationship; such a relationship is expected because of changing area/per length ratios of the different stations. It is concluded that this flow model is sufficient for purposes of this investigation.

5.2 Determination of Nutrient Fluxes

Fuhs (1972) observed no general relationship between materials as nitrates and flow rate but a positive relationship between erodable materials (e.g., particulate phosphorus) and flow rate - higher flow rates cause erosion of more particulate material than at lower flow rates. The U.S. Army Corps of Engineers (1975) observed similar behaviour between total phosphorus and flow rate for several major U.S. watersheds influent to Lake Erie (e.g., the Maumee, etc.). Similar relationships were sought in this work.

A plot of total phosphorus versus associated flow rate for a typical station (Stn S5) is shown in Figure 4 . It indicates that, above a certain flow rate, a definite relationship exists but below this flow rate, no significant relationship exists. The high variation of concentration at low flows is due to random disturbance of the channel bottom during summer - fall periods. No similar relationship is observed for nitrate. To further analyze this relationship, a chemograph was determined for N1, M2, S2, S4, S7, S9 and the main station (MSN). Samples for total phosphorus and nitrates were taken at 2 - 4 hr. intervals during the fall of the hydrograph at those stations during April 25 to April 28. Figure 3 . shows trends of concentration and flow with time for station S5. These trends are typical for all stations, including tile drains. For all stations, the total phosphorus concentrations show a generally consistent decrease as the flow rate decreases. No such relationship is observed for nitrate. Preliminary plots of mass export of total phosphorus (e.g., gm/day) against the associated flow were made for a few stations (see Figure 6 for a typical graph). These plots show a much stronger relationship between mass flow (export) and discharge than between total phosphorus concentration and discharge since despite relatively high concentrations at low flows (see Figure 4 ), the mass export at low flow rates is small.

Regressions of mass export as a function of flow were sought for each station. Since there is some variation of flow at each station as a function of corresponding flow at the mouth station, regression models were determined relating mass export at each station as a function of flow rate at the main station. The relationships and the predicted export of phosphorus for each station are shown in Table 15 . The annual export was calculated using the daily flow hydrograph at the mouth station and the appropriate station flux - main station discharge relationship. From these values, the mass export for total phosphorus for each operation is calculated and indicated on Table 4 with a summary describing farming management practices.

For total nitrogen, no flow sensitive relationships are observed, hence, fluxes are calculated by using an average seasonal concentration and the associated flow volume for that period. Estimates of export of nitrate for each station are given in Table 3 and for each operation are given in Table 7. Analysis for all forms of nitrogen (nitrate, nitrite, ammonia and total kjeldahl nitrogen) were carried out on all surveys at three stations (S1 a downstream station, S4 a midstream station and S9 a headwater station) and on all stations during four samplings (Feb.17, Feb.20, Mar.22, Apr.11, 1976). For the two year period, ammonia and nitrite are two orders of magnitude smaller than nitrate while kjeldahl nitrogen is one-half to one order of magnitude smaller than nitrate. (Kjeldahl nitrogen is respectively 3%, 13% and 13% of total nitrogen for S9, S4 and S1 on an annual basis). During the 1976 spring runoff, nitrite and ammonia are two orders of magnitude and kjeldahl nitrogen is one order of magnitude smaller than nitrate (kjeldahl nitrogen ranges from 3 to 5% of total nitrogen). Including kjeldahl nitrogen, estimates of total nitrogen export are given in Table 10.

## 5.3 SEASONAL EFFECTS

### 5.3.1 Hydrograph

Hydrographic variations occur with the seasons. Each season has unique features associated with precipitation, temperature and the water table. Four seasons were chosen based on the hydrographic record of the continuous flow monitoring station at the mouth of AG-3. These hydrological stations fitted closely into 3 calendar month periods and hence equilength seasons were defined as follows for the 2 year study:

i) summer - June 1 to August 31 (184 days)
ii) fall - September 1 to November 30 (182 days)
iii) winter - December 1 to February 28/29 (181 days)
iv) spring - March 1 to May 31 (184 days)

This seasonal breakdown reflects the summer base flow period with occasional rainfall, the autumn period with rising discharge due to fall thundershowers, rainfall and the occasional early snowfall/melt, the baseflow winter freeze-up with sporadic mid-winter snowmelts and the break-up, snowmelt and rainshowers of spring that dominates the annual hydrograph.

### 5.3.2 Phosphorus

The seasonal fluxes of phosphorus outlined in Table 7 also demonstrate the effects noted in section 5.3.1 with the spring seasonal flux being the predominant factor in the export of Phosphorus from the basin, export is higher in either spring or winter than summer and fall combined. The dependency of phosphorus concentration upon flow rate augment the effect of season upon transport.

For the mouth station, spring, summer, fall and winter account for 55.9%, 9.3%, 6.7% and 28.1% respectively of the annual basin export. In general, this pattern is mirrored by all other stations with the tile drains showing the most variance (N5, N6, N7, S3). The tremendous spring flux of phosphorus is directly related to the water cycle features of extremely high water, flooding, ground saturation and snowmelt accompanied by rainfall.

Table 9 shows the domination of the spring runoff period where a single day of break-up (March 13/77) has an almost 20 fold increase of any other single day event of any other season.

The seasonal export of phosphorus from each of the main branches is shown in Table 8. Again we can see that the largest branch (north) supplies the largest Phosphorus export during each season as well as over the whole year. The same relative amounts also are apparent for the south and middle branches.

5.3.3 Nitrogen

Seasonal nitrogen flux was determined by calculating a mean seasonal nitrate nitrogen concentration, applying a total seasonal discharge via a linear relationship to produce a mass seasonal export of nitrate - nitrogen. A mean seasonal TKN export was added based on the ratios calculated in Table 10 on the data in Table 1 to produce an export figure for total nitrogen.

Seasonal nitrogen fluxes were calculated for each operation under study and these data appear in Table 7. This table demonstrates the same general patterns as those outlined for phosphorus in section 5.3.2. There is however, for nitrogen, a greater degree of scatter and randomness in the export and flux figures produced and so interpretation of these results must remain as generalizations. Nitrogen fluxes for winter and spring periods appear to be at about the same level for most operations and at a value an order of magnitude larger than nitrogen fluxes for the summer and fall periods. (again these two seasons have generally the same size fluxes). Export of nitrogen from each operation is basically of the order of 50X the phosphorus export season by season.

With relation to individual operations, the same operations with high P export (No's. 2, 3, 10, 18) also have a large value for N export season by season, and probably the same reasons (as outlined in section 4.4) apply.

The enlarged values of nitrogen export for the control operations tend to show that due to widespread inorganic fertilizer application (usually high N content) no direct statement can be made with respect to the effect of livestock upon nitrogen export.

5.4 Correlation With Livestock

The seventeen operations under study fall under four basic categories: beef feedlots, dairy farms, swine producers and cash crop operations; these are summarized in tables 5a and 5b.

Phosphorus fluxes from the agricultural studies have a base varying from 4 to 580 gm./ha./yr.; a figure of 332 gm./ha./yr. was determined as the background flux from agricultural operations where no livestock were involved. This figure is compatible with the 350 gm./ha./yr. determined by Dr. M. Miller from an independent study. If we consider this figure as a flux integral with agriculture and livestock contributions are additional to this figure, they are shown in column 4 of table 5b. Although exact figures are difficult to explain, some conclusions can be drawn with respect to the relationship between flux figures and livestock.

Generally, the presence of livestock creates an additional flux to that caused by crop activity alone. The type of operation does not seem to affect the input of nutrients; however, the management of a livestock set-up has a far greater effect on the input of nutrients and bacteria to surface water. Several problems attributable to livestock have been detected.

Firstly, the accessibility of livestock waste to surface water is an important factor. Several of the livestock facilities are remote from surface water and the areas drained by extensive underground tiling systems (No. 9, 8, 11) or verged by grass buffer zones (No. 1, 5) or forested areas (No. 12). Fluxes from these sections reflect this minimal livestock contribution. The proximity to watercourses of feedlots (No. 3) pastures (No. 10) and barnyards (No. 20, 4) is reflected in higher flux estimates.

Secondly, the application of manure, the incorporation of crop residues and the fall tillage to floodplains which get inundated at spring runoff creates a large flux of nutrient (with sediment) into the surface water (No. 3, 16).

The breakdown of all or some septic systems in even a small residential community may mask the effect of agricultural operations (No. 18).

The access of livestock directly to the watercourse causes an increase in flux noticeable on long-term and drastic on short-term. Some farms have the stream flowing through the middle of their main pasture (No. 10), others have watercourses flowing directly through or within 10m. of barnyards (No. 20).

Some operations, although appearing well managed on the surface have building sewage systems (No. 2) or silage draining systems (No. 8) tied to field drain systems creating extremely high nutrient concentrations in the drain water at select times of the year (cleaning periods).

Winter manure spreading close to a stream also increases the flux from agricultural land (No. 3, 4, 16, 2) during winter snow-melt and spring high water periods especially if this area is below flood level (No. 3, 16).

Livestock density does not seem to be a large factor unless involved with bad management at the same time. A combination of these two increases the nutrient runoff extensively (No. 2) often creating a small drainage area that contributes a much greater flux than a much larger, well-run operation.

## 5.5 Interpretation of Bacteriology

A summary of geometric means for each station is shown in Table 16 for total coliforms, fecal coliforms and fecal streptococci. Proposed swimming standard for total coliforms (1000/100 m ) are well exceeded except for 5 stations (N2, N6, N7, N10, M1). Swimming standards for fecal coliforms (100/100m ) and for fecal streptococci (20/100m ) are also exceeded; fecal streptococci counts are generally lower on the middle branch than on the other two branches. Total coliforms result not only from the intestinal tracts of warm blooded animals (animal and human), but also are ubiquitous in soil. Hence, these data reflect the typical concentrations expected from an intensively farmed area with small to medium sized herds. Fecal coliforms originate from both human and animal sources (livestock, woodchucks etc.,) while fecal streptococci are normally deemed to be attributable to livestock and, to a lesser extent, man. Hence, in the past, a ratio of fecal coliforms/fecal streptococci of greater than 4 has been used as an indicator of human contamination while a ratio of less than 0.7 has been used as an indicator of animal contamination. For AG-3, the ratio is generally 1 to 2; but this ratio is difficult to interpret in this case. Near sources of contamination, the ratio is normally high; one needs to sample somewhere downstream of a source in order to use the ratio. In fact, questions about sampling location now preclude confidence in using such a ratio for interpretation.

For assessing this data, most confidence is placed in using the fecal coliform data because at results from 24-26 samples over two years; less confidence is placed in the fecal streptococci data because it results from 7 - 10 data sets. The total coliform data is used only as confirmation, due to the coliform sources from soil.

Station N5 has the highest concentrations of pathogenic indicators (an order of magnitude greater than the other stations). It is a tile which drains a barnyard after some soil seepage between the cattle manure areas and the tile. There is probably some diminuation of bacteria during seepage through the soil, but it is minimal. The export of phosphorus is also quite high, indicating that the nutrients are due to the farmyard. For a mass balance, stations N4 plus N5 join to flow 50 feet downstream into station N3. The flow data indicate that the effect of high bacteria concentrations in the tile, N5, is not found immediately downstream, due to dilution by the main stream.

Other stations which have somewhat high bacteria concentrations are N9, S5, S6 and S7. Station N9 has beef cattle grazing in adjacent fields with access to the streams. Station S6 is a ditch draining several farmyards (i.e., the farmyard bacteria are diminished and diluted due to overland flow), station S7 drains through pasture land grazed by cattle. Station S5 receives the flow from both S6 and S7. Nutrient concentrations are periodically high at these four stations, but neither the bacteria data nor nutrient data are consistently high to absolutely confirm that the nutrient concentrations are due to livestock management practices. In fact areal phosphorus export from S5, S6 and S7 is the same as export from the whole basin, while the bacterial levels are higher than for the basin.

Station N9 is above a small hamlet, while station N8 is below the hamlet. The bacterial concentrations below the hamlet do not differ significantly from all other station data; hence, no contamination from septic tank seepage is discernable.

Stations N2, N6, N7 and M1 all have low bacterial concentrations. N2 is a ditch draining essentially cereal and row crops for a beef farm (operation no. 1). Cattle access and manure application to areas adjoining the ditch is low. The low bacterial concentrations result from good farm management. Station N6 is a tile drain in a field used exclusively for corn. The low bacterial concentrations represent the absence of livestock and manure applications. Station N7 is a tile drain from an area without any livestock. All stations in the middle branch have relatively low fecal streptococci concentrations. This is attributed to the observation that the entire middle branch has a lower density of livestock than the other branches. There is no consistent correlation between phosphorus export and bacterial concentration. Only N2 and N6 have low phosphorus export rates.

In summary, there is no consistent data relating bacterial contamination to the presence or absence of tile drains. For tiles draining fields not accessable to cattle, lower than normal bacterial concentrations are found. For tiles which directly drain barnyard areas, a significantly higher level is observed. Some surface locations which drain fields in which cattle pasture or have access to the stream have somewhat higher levels of bacteria; but, these levels are not substantially higher than ambient concentrations found in the whole basin. Accordingly, while AG-3 has some bacterial contamination, it is our conclusion that no substantial improvement in bacterial concentrations would result from change in management practices, except for the tile draining the farmyard (station N5, operation No.2). Further, it is our hypothesis that no large idfferences between operations are found because of the medium to small scale of feedlot operations.

## 5.6 Mass Balance on Branches

The annual average runoff from the north middle and south branches is 0.40, 0.11 and 0.42 $m^3$/sec respectively during the study period while that of the whole basin is 1.02 $m^3$/sec. At the point of measurement, the annual average of the three branches is 91 percent of the mouth station while the three branch stations account for 92 percent of the total area of AG-3.

The annual average export of phosphorus from the basin is 2700 kg/yr for P while that from the individual branches is 1200, 400 and 1000 kg/yr for the north, middle and south branches respectively. These stations account for 96 percent of the total export from the area which compares quite favourably with the area represented by these stations.

The annual average export of nitrogen from the basin is 159,000 kg/yr while it is 72,700, 13,600 and 65,000 kg/yr from the north, middle and south branches respectively. These stations account for 95 percent of the total export from the area.

The export from each branch station is compared with the export from the basin for phosphorus and nitrogen for one day during an event in each season (summer, fall, winter and spring). Generally the sum of the three branches is either randomly less than or randomly greater than the basin export- no seasonal effect is apparent. This variation, which is small (±10%), is a measure of error of the mass export estimates on a given sampling day.

5.7 Form of Nutrients in Transport

Investigations into the form in which the nutrients phosphorus and nitrogen were being transported were carried out throughout the period of study in AG-3. Three stations were selected on the south branch, which is the most regular with respect to flow, most diverse with respect to agricultural practices and relatively free from non-agricultural sources. These three stations are: S1 the mouth station of the south branch which monitors 1933 hectares of wholly agricultural mixed farming, S4 a stream station approximately halfway along the south branch with a drainage area of 1638 hectares and S9 a tile drain station where municipal subsurface systems drain 168 hectares of farming area. Over a period of 2 years 24 samples were collected at each of these stations and analysed for total phosphorus dissolved phosphorus, ortho-phosphorus, nitrate, nitrite, ammonia and total kjeldahl nitrogen. Analyses for these parameters is shown in table 1. The occasional sample is omitted due to unavailability. Breakdown of the analyses is shown in Table 10. Concentrations shown are the mean of the individual concentrations; ratios and deviations are the average of individual ratios for each collection.

5.7.1 Phosphorus

The average concentrations of total phosphorus are calculated as .084, .133, .082 for S1,S4 and S9 respectively. The higher value for S4 is probably due to intensive livestock activity above this point which levels out by S1. For surface water locations (S1 and S4) the fraction of phosphorus that is dissolved varies between 60 and 80 percent and the fraction that is reactive is 63 percent in both cases. That is, for the surface water stations, the greatest part of the phosphorus is dissolved and that part is almost wholly reactive.

For the tile drain station (S9), approximately the same concentration of phosphorus is in transit but in this case it is wholly dissolved and reactive (99 percent). (The .80 ratio for dissolved P probably reflects adhesion of dissolved P to the filter as dissolved P $\geq$ ortho P.)

5.7.2 Nitrogen

The three stations S1, S4 and S9 reflect the same levels of nitrogen as most other stations in the AG-3 sub-basin; these estimates are given in Table 10. The surface water stations S1 and S4 show an average concentration of 6.53 and 6.73 ppm of Nitrogen respectively; of this total, approximately 85 percent is in the nitrate form, 13 percent analysed as kjeldahl nitrogen and the remaining 2 percent was split between nitrite and ammonia forms. For the study period, nitrate N is one order of magnitude larger than TKN and two orders of magnitude larger than either nitrite N or ammonia N. For the tile drain station S9, 9.42 ppm of nitrogen was estimated as the average concentration; of this amount, 8.88 ppm or 94 percent is in nitrate form, 5 percent is organic, and amonia N and nitrite N appear in trace quantities.

## 5.8 Subsurface Drainage Systems

The Little Ausable Sub-basin (AG-3),characteristic of the entire Ausable Watershed, is intensively tile drained. Both clay and plastic tile systems feed into corrugated steel header pipes and drain the relatively flat clay fields by percolation to the tile bed and outflow to the surface channels. Tile drainage systems are extensive in the AG-3 sub-basin set in rows ~15m. apart joined by a header and often tied into a longer municipal drain. These subsurface drainage systems allow rapid drying of the fields during the saturation periods and it is generally accepted that over a period of time they carry approximately 20 percent of the water draining that area.

The project 20 investigations were carried out on 26 stations, of which 8 are tile drains or involved with tile drains. These stations are listed in Table 2 designated with * along with flux data for these points.

Flux of phosphorus from these systems ranges from very low (N6) to very high (N5) and there are several reasons for this variation. A well-installed, efficient tile drainage system should be beneficial to a cultivated area in improving the infiltration of water down through the soil and reducing the surface sheet erosion to open-channels. However, tile drainage systems can also be detrimental to water quality when building drainage systems are linked with the field drains and the tile system in fact becomes a flow-through system for sewage, (as exhibited continuously by N5). Problems also arise when silage leachate is introduced to the drains during the siling down period in mid-autumn (station S3 Table 1 - H).

The chemical breakdown of nutrient forms in a tile drainage system is shown by station S9 in Table 10. This table demonstrates that 80 percent of the total phosphorus is both dissolved and reactive and that almost all percent of the nitrogen is in the nitrate form; almost half the normal amount of organic and nitrite nitrogen is present and extremely small concentrations of nitrogen in the ammonia form.

Tile drains are considered by hydrologists to yield approximately 20 percent of the total surface outflow from an area. BEAK did not conduct any studies to confirm or reject this figure. The nitrate flux is approximately the same for tile drains as for surface drains. The phosphorus flux from tile drains is generally lower than from surface stations except for one tile station which drains a barnyard (N5). Except for N5, tiles yield 0.28 Kg/ha/yr while the surface operations yield 0.71 Kg/ha/yr.

## 6.0 RELATIONSHIP OF PROJECT RESULTS TO PLUARG OBJECTIVES

The objective of this study has been the evaluation of the nutrient and bacterial losses from livestock activities upon the surface water in the Little Ausable River (AG-3) Sub-basin.

The flux of the nutrients phosphorus and nitrogen both annually and seasonally has been determined for the various livestock and control operations under study. Variations in flux estimates are indicated along with probable cause for variation and possible mitigating measures.

These fluxes have been broken down to determine the seasonal fluxes and seasonal baseline fluxes of phosphorus and nitrogen. Also, the nutrient export related to seasonal event has been calculated and discussed.

Studies performed on three stations, two surface water and one tile drain location, have been performed to permit the determination of nutrient forms in transport. These data have been calculated and presented in this study.

The influx of pathogenic indicators to surface water has been investigated throughout the study and the results discussed with respect to the relationship with livestock operations. Because of the small to medium scale of feedlots in AG-3 there appears to be little difference between these operations in the bacteriological data.

This study has addressed itself to the effect of drained vs. undrained fields on nutrient and bacteria flux. For tiles draining fields not accessible to livestock, lower than normal exports were found; for tiles draining barnyard areas, significantly higher than normal levels were noted.

This study has addressed the question: from what sources and from what causes are pollutants contributed to surface waters? Information gathered permits conclusions concerning contributions from different types of livestock sources (dairy, beef, swine and cash crop) and contributions due to management practices of manure storage and distance of barnyard from the surface stream for farm sizes typical of southwestern Ontario.

This study permits conclusions concerning the extent of pollutant contributions and unit loadings by season from agricultural land use and typical clay soils to surface waters; conclusions concerning pollutant contributions are not possible for forest or urban land uses, for such land use practices as differentiating between crops such as corn or cereal grains, or for pollutant contributions to ground water.

This study does not specifically attempt to assess the degree to which pollutants are transported from sources to boundary waters but some statements have been made in the report concerning transport of nutrients in headwater areas.

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## TABLES

GLOSSARY OF CHEMICAL PARAMETER UNITS USED IN TABLES 1

pH - standard pH units

Specific Conductance - units are micromhos centimeter$^{-1}$ at 298K

Total Hardness - unit are mg/ℓ as $CaCO_3$

Total Alkalinity - units are mg/ℓ as $CaCO_3$

Total Phosphate - units are mg/ℓ phosphorus

Ortho Phosphate - units are mg/ℓ phosphorus

Dissolved Phosphate - units are mg/ℓ phosphorus

Nitrate Nitrogen - units are mg/ℓ nitrogen

Nitrite Nitrogen - units are mg/ℓ nitrogen

Ammonia Nitrogen - units are mg/ℓ nitrogen

Kjeldahl Nitrogen - units are mg/ℓ nitrogen

Total Coliforms - units are colonies per 100 mℓ

Fecal Coliforms - units are colonies per 100 mℓ

Fecal Streptococci - units are colonies per 100 mℓ

Table 1-A: Analytical Results - Little Ausable Sub-drainage Basins
Survey A, 23 June 1975

| Station | Discharge cfs | pH | Specific Conductance μmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 11.3 | 7.7 | 565 | 210 | 150 | .017 | 6.2 | .098 | 450 | - |
| N1 | 1.1 | 7.6 | 550 | 200 | 150 | .014 | 6.2 | .120 | 1900 | - |
| N2 | 0.11 | 7.3 | 530 | 270 | 220 | .013 | 3.2 | .052 | 30 | - |
| N3 | - | - | - | - | - | - | - | - | - | - |
| N4 | - | - | - | - | - | - | - | - | - | - |
| N5 | <.01 | 6.9 | 750 | 360 | 340 | .510 | 1.3 | .140 | 11000 | - |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | 7.2 | 615 | 210 | 140 | .030 | 11.3 | .002 | 70 | - |
| N8 | 0.4 | 8.1 | 580 | 210 | 170 | .020 | 5.1 | .200 | 720 | - |
| N9 | 0.3 | 7.7 | 600 | 240 | 200 | .058 | 5.1 | .200 | TNTC * | - |
| N10 | <.01 | 6.9 | 700 | 270 | 170 | .021 | 15.7 | .002 | 380 | - |
| N11 | .18 | 7.3 | 585 | 210 | 170 | .042 | 9.8 | .022 | 800 | - |
| M1 | 0.19 | 8.0 | 520 | 200 | 160 | .016 | 2.8 | .044 | 800 | - |
| M2 | 0.17 | 7.6 | 590 | 190 | 160 | .012 | 4.1 | .080 | 4100 | - |
| M3 | .14 | 8.1 | 580 | 200 | 160 | .009 | 5.3 | .074 | 3400 | - |
| M4 | .12 | 8.0 | 590 | 180 | 130 | .011 | 9.2 | .068 | 1400 | - |
| M5 | .09 | 7.1 | 600 | 210 | 150 | .116 | 9.2 | .160 | 00 | - |
| S1 | 8.9 | 8.4 | 485 | 190 | 130 | .016 | 6.6 | .190 | 200 | - |
| S2 | 8.1 | 8.2 | 515 | 240 | 170 | .019 | 6.1 | .180 | 580 | - |
| S3 | <.01 | 7.1 | 650 | 220 | 150 | .124 | 11.8 | .006 | 540 | - |
| S4 | 3.4 | 8.3 | 525 | 230 | 150 | .024 | 6.1 | .190 | 560 | - |
| S5 | 1.9 | 8.1 | 605 | 200 | 170 | .173 | 7.3 | .160 | 9900 | - |
| S6 | - | - | - | - | | | | | | - |
| S7 | 1.5 | 8.1 | 595 | 210 | 150 | .088 | 6.5 | .130 | 5600 | - |
| S8 | 0.8 | 7.8 | 625 | 200 | 170 | .017 | 7.3 | .110 | 440 | - |
| S9 | 0.39 | 7.5 | 690 | 240 | 150 | .041 | 13.6 | .010 | 1030 | - |
| Rep ( - ) | - | - | | - | - | - | - | - | - | - |

* See Station Record

Table 1-B: Analytical Results - Little Ausable Sub-drainage Basins
Survey B, 14 July 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 6.2 | 7.8 | 475 | 270 | 370 | .044 | 6.9 | .102 | 10,000 + | 10,000 + |
| N1 | 0.8 | 7.55 | 535 | 300 | 410 | .006 | 7.3 | .092 | 10,000 + | 0 |
| N2 | 0.07 | 7.8 | 480 | 240 | 390 | .006 | 4.3 | .032 | 50 | 40 |
| N3 | 0.7 | 7.8 | 515 | 270 | 420 | .028 | 4.5 | .070 | 2,000 | 780 |
| N4 | 0.7 | - | - | - | - | - | - | - | - | - |
| N5 | <.01 | 8.3 | 1065 | 290 | 1240 | .170 | 1.3 | .014 | TNTC | 10,000 + |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | 7.65 | 785 | 340 | 490 | .012 | 12.5 | .002 | 400 | 0 |
| N8 | 0.4 | 7.8 | 440 | 230 | 360 | .078 | 8.5 | .068 | TNTC | 1,300 |
| N9 | 0.2 | 7.9 | 490 | 260 | 370 | .019 | 10.0 | .100 | TNTC | 11,700 |
| N10 | <.01 | 7.6 | 530 | 290 | 420 | .014 | 9.5 | .080 | TNTC | 13,100 |
| N11 | .11 | $8.0^{5}$ | 615 | 340 | 490 | .013 | 14.0 | .054 | 10,000 + | 760 |
| M1 | 0.10 | 8.0 | 510 | 290 | 500 | .041 | 0.7 | .016 | 180 | 50 |
| M2 | 0.09 | 7.9 | 560 | 310 | 530 | .020 | 2.3 | .082 | 10,000 + | 300 |
| M3 | 0.06 | $7.7^{5}$ | 520 | 210 | 490 | .014 | 0.8 | .022 | 4,000 | 330 |
| M4 | 0.04 | 7.8 | 475 | 270 | 370 | .014 | 8.1 | .070 | 5,400 | 940 |
| M5 | 0.03 | $7.7^{5}$ | 610 | 350 | 480 | .033 | 11.5 | .014 | 10,000 + | 4,800 |
| S1 | 4.5 | 8.1 | 440 | 220 | 310 | .006 | 2.8 | .080 | TNTC | 490 |
| S2 | 4.0 | $7.9^{5}$ | 430 | 230 | 330 | .022 | 3.1 | .082 | 10,000 + | 2,700 |
| S3 | <.01 | 8.3 | 645 | 380 | 540 | .125 | 9.0 | .004 | 4,500 | 420 |
| S4 | 1.8 | $7.8^{5}$ | 460 | 260 | 350 | .049 | 5.0 | .058 | TNTC | 3,000 |
| S5 | 1.2 | $8.0^{5}$ | 470 | 250 | 360 | .089 | 9.0 | .054 | TNTC | 4,500 |
| S6 | <.01 | 7.8 | 445 | 280 | 480 | .019 | 1.0 | .080 | TNTC | 4,200 |
| S7 | 0.9 | $8.0^{5}$ | 470 | 260 | 360 | .091 | 14.5 | .064 | 10,000 + | 10,000 +* |
| S8 | 0.6 | 8.0 | 535 | 290 | 390 | .080 | 9.0 | .034 | 10,000 + | 1,300 |
| S9 | 0.28 | 7.5 | 635 | 330 | 460 | .026 | 11.0 | .004 | 0 | 130 |
| Rep ( - ) | - | - | - | - | - | - | - | - | - | - |

* See Station Record

* See Station Record

Table 1-C: Analytical Results - Little Ausable Sub-drainage Basins
Survey C, 28 July 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 2.0 | $7.9^{5}$ | 460 | 250 | 190 | .047 | 1.4 | .052 | 1,600 | 920 |
| N1 | 0.3 | 7.7 | 560 | 300 | 230 | .028 | 4.0 | .076 | 1,000 | 40 |
| N2 | .04 | 7.6 | 490 | 280 | 220 | .009 | 2.9 | .006 | 610 | 160 |
| N3 | .2 | - | - | - | - | .028 | - | - | - | - |
| N4 | .2 | 7.9 | 460 | 250 | 220 | .029 | 0.6 | .020 | 880 | 220 |
| N5 | - | - | - | - | - | - | - | - | - | - |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | - | - | - | - | - | - | - | - | - | - |
| N8 | .07 | $8.0^{5}$ | 590 | 320 | 270 | .038 | 2.0 | .026 | 2,100 | 130 |
| N9 | .03 | 7.8 | 570 | 330 | 280 | .040 | 2.8 | .116 | 4,800 | 1,540 |
| N10 | - | - | - | - | - | - | - | - | - | - |
| N11 | .02 | $7.8^{5}$ | 610 | 320 | 270 | .041 | 8.0 | .020 | 490 | 180 |
| M1 | - | - | - | - | - | - | - | - | - | - |
| M2 | .03 | $8.1^{5}$ | 550 | 330 | 280 | .057 | 2.2 | .026 | 6,100 | 1,060 |
| M3 | - | - | - | - | - | - | - | - | - | - |
| M4 | - | - | - | - | - | - | - | - | - | - |
| M5 | - | - | - | - | - | - | - | - | - | - |
| S1 | 0.34 | 8.65 | 330 | 180 | 130 | .034 | 0.8 | .010 | 3,300 | 3,400 |
| S2 | 0.29 | $8.5^{5}$ | 350 | 200 | 250 | .036 | 1.2 | .020 | 1,500 | 260 |
| S3 | - | - | - | - | - | - | - | - | - | - |
| S4 | 0.23 | 8.7 | 360 | 190 | 150 | .054 | 0.5 | .014 | 410 | 60 |
| S5 | 0.15 | 8.4 | 480 | 240 | 210 | .100 | 0.6 | .030 | 350 | 200 |
| S6 | - | - | - | - | - | - | - | - | - | - |
| S7 | 0.14 | 8.0 | 490 | 250 | 200 | .733 | 1.0 | .044 | 990 | 90 |
| S8 | 0.08 | $7.8^{5}$ | 670 | 320 | 250 | .083 | 4.1 | .078 | 19,100 | 6,100 |
| S9 | <.01 | 7.1 | 900 | 380 | 300 | .038 | 9.7 | .004 | 12,100 | 180 |
| Rep ( N4) | 0.2 | 7.9 | 460 | 250 | 220 | .028 | 0.7 | .020 | - | - |

Table 1-D: Analytical Results - Little Ausable Sub-drainage Basins
Survey D, 11 August 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 0.8 | 7.6$^{5}$ | 460 | 230 | 170 | .056 | 0.8 | .042 | 5,400 | 1,070 |
| N1 | 0.3 | 7.4$^{5}$ | 580 | 290 | 210 | .027 | 2.8 | .126 | 2,300 | 460 |
| N2 | 0.03 | 7.3 | 520 | 250 | 220 | .014 | 3.2 | .010 | 5,200 | 1,180 |
| N3 | 0.2 | 7.7 | 460 | 230 | 190 | .076 | 0.7 | .014 | 2,900 | 430 |
| N4 | 0.2 | - | - | - | - | - | - | - | - | - |
| N5 | - | - | - | - | - | - | - | - | - | - |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | 7.6$^{5}$ | 1530 | 400 | 420 | .000 | 2.6 | .004 | 5,600 | 100 |
| N8 | .03 | 7.6$^{5}$ | 550 | 260 | 220 | .100 | 0.7 | .018 | 4,100 | 170 |
| N9 | .01 | 7.6$^{5}$ | 560 | 260 | 250 | .001 | 0.7 | .100 | 16,800 | 7,700 |
| N10 | - | - | - | - | - | - | - | - | - | - |
| N11 | <.01 | 7.3 | 660 | 290 | 290 | .024 | 5.7 | .026 | 7,600 | 280 |
| M1 | - | - | - | - | - | - | - | - | - | - |
| M2 | <.01 | 7.9 | 680 | 340 | 220 | .008 | 3.1 | .020 | 11,100 | 1,790 |
| M3 | - | - | - | - | - | - | - | - | - | - |
| M4 | - | - | - | - | - | - | - | - | - | - |
| M5 | - | - | - | - | - | - | - | - | - | - |
| S1 | 0.3 | 8.0 | 330 | 170 | 130 | .031 | 0.2 | .008 | 5,600 | 1,430 |
| S2 | 0.2 | 8.0 | 360 | 190 | 130 | .037 | 0.4 | .010 | 4,600 | 610 |
| S3 | - | - | - | - | - | - | - | - | - | - |
| S4 | 0.1 | 7.6 | 370 | 160 | 130 | .000 | 0.2 | .008 | 2,200 | 310 |
| S5 | - | 7.45 | 680 | 280 | 220 | 2.300 | 0.5 | .030 | 10000 | 3900 |
| S6 | - | - | - | - | - | - | - | - | - | - |
| S7 | - | 7.5 | 680 | 280 | 220 | 2.27 | 0.5 | .032 | 9,200 | 4,600 |
| S8 | - | 7.9$^{5}$ | 680 | 260 | 200 | .003 | 1.1 | .010 | 4,700 | 2,300 |
| S9 | <.01 | 7.3$^{5}$ | 1670 | 500 | 330 | .059 | 5.9 | .004 | 20,000 + | 200 |
| Rep (MSN) | 0.8 | 7.6$^{5}$ | 450 | 240 | 160 | .049 | 0.8 | .042 | - | - |

Table 1-E: Analytical Results - Little Ausable Sub-drainage Basins
Survey E, 25 August 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 62 | 7.5 | 540 | 280 | 230 | .214 | 4.0 | 1.06 | TNTC | TNTC |
| N1 | 30 | $7.5^5$ | 660 | 360 | 290 | .412 | 0.6 | .004 | TNTC | TNTC |
| N2 | 0.07 | 6.8 | 470 | 250 | 200 | .036 | 3.60 | .012 | 1,170 | 60 |
| N3 | 13 | $7.1^5$ | 630 | 320 | 250 | .294 | 1.99 | .600 | TNTC | TNTC |
| N4 | 13 | 7.1 | 670 | 400 | 270 | .140 | 2.02 | .540 | 20,000 + | |
| N5 | <.01 | 6.9 | 940 | 420 | 260 | .589 | 15.23 | .570 | 14,000 | 9,300 |
| N6 | <.01 | 7.3 | 800 | 440 | 430 | .019 | 0.28 | .000 | 2,600 | 120 |
| N7 | .02 | 7.3 | 710 | 330 | 270 | .037 | 4.92 | .000 | 8,900 | 70 |
| N8 | 4.3 | $7.7^5$ | 670 | 340 | 250 | .216 | 9.82 | .142 | 13,400 | 3,700 |
| N9 | 2.5 | 7.9 | 650 | 330 | 260 | .118 | 8.16 | .084 | 9,700 | 2,100 |
| N10 | <.01 | $7.2^5$ | 630 | 340 | 250 | .052 | 12.86 | .004 | 17,400 | 890 |
| N11 | .07 | $7.4^5$ | 640 | 350 | 280 | .052 | 10.26 | .036 | 14,900 | 470 |
| M1 | 8.05 | 7.6 | 520 | 280 | 200 | .111 | 8.75 | .022 | 20,000 + | 1,260 |
| M2 | 5.33 | $7.6^5$ | 530 | 290 | 210 | .092 | 9.39 | .026 | 15,700 | 840 |
| M3 | 4.40 | $7.5^5$ | 540 | 280 | 220 | .085 | 9.22 | .020 | 18,200 | 1,840 |
| M4 | 3.33 | 7.5 | 520 | 290 | 220 | .095 | 10.52 | .026 | TNTC | 910 |
| M5 | 2.52 | $7.4^5$ | 550 | 290 | 220 | .047 | 10.26 | .008 | 17,100 | 3,000 |
| S1 | 15 | 7.6 | 490 | 240 | 190 | .080 | 8.44 | .056 | TNTC | 7,200 |
| S2 | 13 | 7.6 | 490 | 260 | 200 | .118 | 9.39 | .056 | 1,100 | 1,240 |
| S3 | .05 | 7.3 | 750 | 380 | 280 | .105 | 9.22 | .000 | 11,700 | 6,600 |
| S4 | 12.3 | $7.6^5$ | 490 | 260 | 200 | .131 | 9.22 | .058 | TNTC | 6,000 |
| S5 | 11.2 | $7.5^5$ | 500 | 260 | 200 | .105 | 9.22 | .056 | 14,200 | 3,900 |
| S6 | .05 | 7.4 | 690 | 350 | 240 | .615 | 5.77 | .186 | TNTC | 11,400 |
| S7 | 11 | 7.4 | 500 | 260 | 190 | .080 | 9.56 | .050 | TNTC | 4,700 |
| S8 | 9.6 | $7.4^5$ | 510 | 270 | 190 | .111 | 10.08 | .042 | 20,000 + | 4,100 |
| S9 | 3.5 | $7.1^5$ | 520 | 290 | 220 | .098 | 8.37 | .044 | TNTC | 6,300 |
| Rep (S9) | 3.5 | 7.1 | 550 | 290 | 220 | .020 | 8.35 | .044 | | |

Table 1-F: Analytical Results - Little Ausable Sub-drainage Basins
Survey F, 8 September 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 4.5 | 7.9 | 540 | 320 | 250 | .053 | 3.2 | .078 | 5,400 | 200 |
| N1 | 2.0 | $7.5^5$ | 600 | 360 | 290 | .073 | 3.1 | .118 | 8,000 | 300 |
| N2 | .05 | 7.1 | 440 | 290 | 230 | .017 | 4.6 | .018 | 1,100 | 0 |
| N3 | 0.8 | 7.6 | 620 | 360 | 320 | .097 | 0.7 | .206 | 9,600 | 200 |
| N4 | 0.8 | - | - | - | - | - | - | - | - | - |
| N5 | <.01 | 7.9 | 870 | 240 | 350 | 1.4 | 0.8 | .088 | TNTC | 79,000 |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | 8.0 | 700 | 420 | 310 | .013 | 5.4 | .000 | 900 | 0 |
| N8 | 0.4 | 7.9 | 620 | 360 | 310 | .110 | 2.0 | .004 | 2,700 | 0 |
| N9 | 0.2 | 7.6 | 600 | 350 | 310 | .033 | 3.6 | .010 | 1,800 | 200 |
| N10 | <.01 | 7.3 | 600 | 380 | 310 | .070 | 5.1 | .000 | 800 | 100 |
| N11 | .04 | 7.7 | 610 | 370 | 310 | .060 | 9.1 | .006 | 900 | 100 |
| M1 | 0.35 | 8.0 | 550 | 340 | 290 | .037 | 2.7 | .000 | 2,100 | 0 |
| M2 | 0.29 | 7.75 | 570 | 340 | 290 | .043 | 4.1 | .002 | 4,000 | 0 |
| M3 | 0.23 | 7.85 | 40 | 330 | 280 | .053 | 4.5 | .006 | 1,900 | 300 |
| M4 | 0.12 | 7.9 | 520 | 320 | 260 | .023 | 7.3 | .086 | 1,200 | 100 |
| M5 | 0.09 | 8.2 | 550 | 360 | 290 | .020 | 8.7 | .004 | 1,600 | 0 |
| S1 | 1.7 | 8.0 | 520 | 310 | 250 | .017 | 4.7 | .044 | 1,200 | 100 |
| S2 | 1.0 | 7.8 | 530 | 320 | 260 | .033 | 5.4 | .034 | 3,400 | 100 |
| S3 | <.01 | 8.0 | 700 | 410 | 340 | .33 | 6.5 | .000 | 1,100 | 0 |
| S4 | 0.7 | $7.8^5$ | 530 | 310 | 240 | .047 | 5.1 | .028 | 5,200 | 100 |
| S5 | 0.6 | 7.8 | 610 | 350 | 280 | .050 | 4.9 | .044 | 21,000 | 900 |
| S6 | - | - | - | - | - | - | - | - | - | - |
| S7 | 0.5 | 7.9 | 600 | 350 | 290 | .107 | 5.4 | .042 | 9,600 | 3,100 |
| S8 | 0.3 | 8.0 | 610 | 350 | 300 | .057 | 6.3 | .016 | 4,600 | 0 |
| S9 | 0.04 | 7.7 | 670 | 390 | 310 | .057 | 10.6 | .000 | 4,000 | 0 |
| Rep ( S2) | 1.0 | 8.0 | 540 | 320 | 270 | .013 | 4.7 | .034 | 2,700 | 300 |

Table 1-G: Analytical Results - Little Ausable Sub-drainage Basins
Survey G, 22 September 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 29.2 | 7.9 | 570 | 360 | 300 | .072 | 7.2 | .150 | 200 | 150 |
| N1 | 16 | 7.6 | 580 | 380 | 300 | .065 | 7.4 | .290 | 300 | 40 |
| N2 | 0.07 | 7.2 | 470 | 300 | 240 | .016 | 4.4 | .046 | 5,400 | 140 |
| N3 | 11 | 7.9 | 600 | 370 | 300 | .108 | 5.1 | .330 | - | - |
| N4 | 11 | 7.8 | 590 | 370 | 310 | .124 | 4.9 | .350 | 3,400 | 260 |
| N5 | <.01 | 7.3 | 730 | 440 | 370 | .167 | 12.3 | .360 | 51,000 | 6,000 |
| N6 | <.01 | 7.4 | 600 | 390 | 320 | .085 | 10.6 | .000 | - | - |
| N7 | .05 | 7.4 | 600 | 370 | 300 | .007 | 6.4 | .002 | 2,300 | - |
| N8 | 8.1 | 7.9 | 600 | 360 | 300 | .036 | 8.9 | .008 | 900 | 70 |
| N9 | 6.5 | 7.9 | 590 | 370 | 300 | .042 | 8.8 | .026 | 5,900 | 900 |
| N10 | .03 | 7.1 | 600 | 380 | 300 | .049 | 11.0 | .002 | 1,900 | 240 |
| N11 | .32 | 7.5 | 590 | 370 | 300 | .052 | 7.9 | .016 | 4,600 | 60 |
| M1 | 4.25 | 7.7 | 560 | 360 | 290 | .033 | 5.8 | .004 | 1,900 | 90 |
| M2 | 2.67 | 7.8 | 550 | 350 | 290 | .039 | 5.8 | .004 | 1,100 | 100 |
| M3 | 2.0 | 7.8 | 560 | 350 | 290 | .036 | 6.6 | .004 | 2,700 | 240 |
| M4 | 1.1 | 7.9 | 550 | 360 | 290 | .016 | 8.5 | .006 | 700 | 120 |
| M5 | 0.38 | 7.7 | 550 | 350 | 280 | .033 | 7.8 | .006 | 4,800 | 110 |
| S1 | 6.4 | 7.9 | 580 | 360 | 300 | .023 | 8.2 | .022 | 300 | 230 |
| S2 | 5.7 | 7.9 | 590 | 370 | 300 | .026 | 8.4 | .022 | 2,100 | 250 |
| S3 | 0.04 | 7.4 | 650 | 430 | 320 | .065 | 10.6 | .004 | 5,100 | 1,160 |
| S4 | 4.5 | 7.9 | 600 | 370 | 300 | .052 | 8.6 | .024 | 1,300 | 90 |
| S5 | 3.9 | 7.8 | 600 | 380 | 300 | .052 | 9.7 | .026 | | |
| S6 | 0.05 | 7.8 | 630 | 390 | 310 | .242 | 7.1 | .320 | 1,400 | 270 |
| S7 | 3.3 | 7.9 | 590 | 370 | 300 | .095 | 9.0 | .012 | 1,200 | 110 |
| S8 | 2.1 | 7.5 | 590 | 360 | 300 | .039 | 10.1 | .008 | 3,700 | 110 |
| S9 | 0.18 | 7.5 | 610 | 390 | 310 | .039 | 10.8 | .016 | 700 | 10 |
| Rep ( N2) | 0.07 | 7.3 | 460 | 290 | 240 | .023 | 4.5 | .046 | | |

Table 1-H: Analytical Results - Little Ausable Sub-drainage Basins
Survey H, 6 October 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 3.8 | 7.7 | 530 | 320 | 260 | .069 | 2.1 | .040 | 300 | 0 |
| N1 | 2.2 | $7.5^{5}$ | 540 | 380 | 300 | .141 | 1.9 | .034 | 300 | 20 |
| N2 | .05 | 7.1 | 450 | 290 | 220 | .023 | 6.5 | .016 | 100 | 30 |
| N3 | 1.4 | 7.5 | 600 | 390 | 320 | .346 | 0 | .002 | 3,000 | 30 |
| N4 | 1.4 | $7.5^{5}$ | 600 | 380 | 320 | .346 | 0 | .002 | 2,900 | 440 |
| N5 | <.01 | 7.5 | 880 | 450 | 430 | 2.32 | 8.7 | .188 | TNTC | TNTC |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | 7.6 | 610 | 370 | 290 | .003 | 7.1 | 0 | 600 | 0 |
| N8 | 0.4 | 7.7 | 620 | 370 | 280 | .294 | 4.5 | .080 | 100 | 0 |
| N9 | 0.2 | $7.7^{5}$ | 600 | 370 | 280 | .036 | 7.3 | .052 | 500 | 60 |
| N10 | <.01 | $7.3^{5}$ | 580 | 380 | 330 | .039 | 9.2 | 0 | 1,300 | 30 |
| N11 | .09 | 7.7 | 550 | 380 | 300 | .042 | 11.5 | .004 | 300 | 20 |
| M1 | 0.37 | 7.8 | 500 | 310 | 260 | .016 | 3.0 | 0 | 1,200 | 0 |
| M2 | 0.30 | 7.7 | 490 | 350 | 270 | .029 | 3.3 | .002 | 1,100 | 50 |
| M3 | 0.25 | $7.7^{5}$ | 520 | 340 | 280 | .029 | 4.5 | .004 | 1,200 | 20 |
| M4 | 0.18 | 7.9 | 480 | 340 | 270 | .007 | 6.2 | .050 | 3,200 | 210 |
| M5 | 0.11 | 7.7 | 520 | 310 | 260 | .020 | 8.5 | .026 | 3,800 | 290 |
| S1 | 0.52 | 7.9 | 490 | 310 | 250 | .026 | 3.0 | .096 | 1,900 | 50 |
| S2 | 0.46 | 7.75 | 490 | 320 | 250 | .073 | 4.1 | .150 | 13,400 | 0 |
| S3 | <.01 | 7.4 | 680 | 460 | 400 | 2.09 | 0.5 | 0 | TNTC | 160 |
| S4 | 0.41 | $7.9^{5}$ | 520 | 330 | 260 | .121 | 5.2 | .076 | 200 | 20 |
| S5 | 0.36 | 7.9 | 540 | 350 | 270 | .124 | 5.2 | .064 | 800 | 60 |
| S6 | - | - | - | - | - | - | - | - | - | - |
| S7 | 0.34 | 7.8 | 520 | 310 | 280 | .114 | 5.4 | .054 | 6,900 | 790 |
| S8 | 0.30 | $7.7^{5}$ | 650 | 350 | 270 | .026 | 7.2 | .012 | 800 | 220 |
| S9 | 0.042 | 7.6 | 580 | 370 | 290 | .039 | 12.5 | 0 | 2,900 | 30 |
| Rep ( M5) | 0.11 | 7.7 | 560 | 350 | 260 | .020 | 8.2 | .026 | | |

Table 1-1: Analytical Results - Little Ausable Sub-drainage Basins
Survey I, 20 October 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 2.3 | 7.8 | 510 | 340 | 290 | .297 | 0.7 | .064 | TNTC | 1,520 |
| N1 | 1.0 | 7.7 | 530 | 370 | 300 | .271 | 1.3 | .042 | 5,800 | 640 |
| N2 | 0.04 | 7.3 | 410 | 280 | 220 | .049 | 2.7 | .014 | 2,900 | 240 |
| N3 | 0.8 | 7.6 | 540 | 340 | 330 | 2.08 | 1.6 | .018 | 6,400 | 1,140 |
| N4 | 0.8 | $7.6^5$ | 540 | 340 | 330 | 1.87 | 1.6 | .016 | - | - |
| N5 | <.01 | 7.9 | 790 | 310 | 380 | 2.97 | 2.3 | .146 | TNTC | TNTC |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | <.01 | $8.0^5$ | 620 | 380 | 300 | .017 | 4.3 | .002 | 490 | 410 |
| N8 | 0.2 | 7.8 | 510 | 340 | 280 | .046 | 2.7 | .010 | 6,100 | 59 |
| N9 | 0.1 | 7.9 | 490 | 320 | 270 | .043 | 2.2 | .044 | 5,000 | 2,000 + |
| N10 | <.01 | 7.7 | 550 | 380 | 310 | .073 | 4.8 | .004 | 320 | 55 |
| N11 | .03 | 8.1 | 540 | 370 | 300 | .033 | 6.6 | .004 | 4,300 | 300 |
| M1 | 0.20 | 8.0 | 500 | 340 | 280 | .033 | 1.3 | .004 | 690 | 67 |
| M2 | 0.17 | $7.8^5$ | 500 | 340 | 270 | .065 | 1.6 | .008 | 1,780 | 1,090 |
| M3 | 0.15 | 7.9 | 500 | 330 | 280 | .049 | 1.5 | .008 | 6.200 | 217 |
| M4 | 0.10 | $7.8^5$ | 430 | 290 | 240 | .033 | 3.5 | .062 | 4,600 | 690 |
| M5 | 0.06 | 7.9 | 480 | 330 | 260 | .135 | 4.8 | .100 | 12,900 | 224 |
| S1 | 0.6 | 8.2 | 420 | 300 | 220 | .020 | 0.9 | .026 | 590 | 42 |
| S2 | 0.4 | 8.2 | 440 | 290 | 230 | .069 | 1.3 | .048 | 1,270 | 46 |
| S3 | <.01 | $7.0^5$ | 1,020 | 650 | 300 | 14.3 | 0 | 0 | TNTC | 7,400 |
| S4 | 0.32 | $8.2^5$ | 470 | 310 | 240 | .083 | 1.3 | .022 | 3,200 | 39 |
| S5 | 0.30 | $8.0^5$ | 540 | 340 | 280 | .540 | 1.6 | .122 | 15,700 | 10,200 |
| S6 | <.01 | 7.5 | 770 | 270 | 310 | .825 | 1.7 | .3 | 164,000 | 20,000 + |
| S7 | 0.25 | 7.7 | 530 | 340 | 280 | .215 | 2.1 | .066 | 13,700 | TNTC |
| S8 | 0.19 | 7.8 | 540 | 340 | 280 | .033 | 2.6 | .012 | 8,000 | 1,120 |
| S9 | 0.04 | $8.2^5$ | 570 | 350 | 280 | .168 | 6.7 | .020 | TNTC | 20,000 + |
| Rep (N2 ) | 0.04 | $7.3^5$ | 410 | 280 | 220 | .033 | 3.7 | .012 | - | - |

Table 1-K: Analytical Results - Little Ausable Sub-drainage Basins
Survey K, 17 November 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.5 | 7.7 | 530 | 340 | 240 | .016 | 8.7 | .026 | 2,300 | 50 |
| N1 | 3.7 | 7.6 | 520 | 350 | 270 | .020 | 9.9 | .016 | 1,400 | 0 |
| N2 | 0.05 | 7.2 | 460 | 280 | 230 | .033 | 5.4 | .020 | 3,700 | 0 |
| N3 | 3.1 | 7.9 | 530 | 350 | 270 | .033 | 8.4 | .050 | 2,100 | 10 |
| N4 | 3.1 | - | - | - | - | - | - | - | - | - |
| N5 | <.01 | 7.7 | 780 | 430 | 370 | .588 | 15.1 | .330 | 10,000 | 2,000 |
| N6 | <.01 | 7.8 | 540 | 360 | 290 | .000 | 10.8 | .0 | 1,100 | 10 |
| N7 | .05 | 7.9 | 570 | 360 | 280 | .000 | 9.1 | .0 | 0 | 0 |
| N8 | 0.7 | 8.0 | 550 | 350 | 290 | .023 | 8.5 | .018 | 600 | 20 |
| N9 | 0.3 | $8.0^{5}$ | 540 | 350 | 290 | .036 | 9.6 | .030 | 3,600 | 970 |
| N10 | 0.07 | 7.4 | 530 | 350 | 290 | .026 | 6.8 | 0 | 5,000 | 0 |
| N11 | 0.17 | $7.5^{5}$ | 550 | 360 | 300 | .023 | 10.8 | .004 | 300 | 50 |
| M1 | 0.90 | $7.9^{5}$ | 540 | 350 | 280 | .059 | 6.1 | .004 | 0 | 0 |
| M2 | 0.64 | 8.1 | 530 | 360 | 290 | .023 | 5.9 | .008 | 1,900 | 100 |
| M3 | 0.51 | 8.1 | 530 | 350 | 290 | .016 | 7.1 | .026 | 4,300 | 100 |
| M4 | 0.45 | 8.0 | 520 | 390 | 290 | .121 | 5.4 | .038 | 2,000 | 10 |
| M5 | 0.18 | $7.8^{5}$ | 520 | 330 | 260 | .013 | 8.2 | .034 | 4,000 | 200 |
| S1 | 1.8 | 8.2 | 560 | 340 | 280 | .013 | 8.9 | .022 | 2,200 | 0 |
| S2 | 1.0 | $8.0^{5}$ | 540 | 350 | 270 | .016 | 8.7 | .044 | 2,000 | 10 |
| S3 | 0.04 | 7.5 | 630 | 400 | 320 | .330 | 2.6 | .810 | 17,000 | 0 |
| S4 | 0.92 | $8.0^{5}$ | 550 | 340 | 260 | .023 | 9.4 | .026 | 5,600 | 100 |
| S5 | 0.86 | 8.0 | 560 | 350 | 270 | .026 | 9.7 | .032 | 1,800 | 50 |
| S6 | 0.05 | 7.8 | 580 | 360 | 270 | .154 | 10.3 | .130 | 29,000 | 360 |
| S7 | 0.77 | $7.9^{5}$ | 570 | 370 | 290 | .101 | 9.2 | .026 | 1,600 | 110 |
| S8 | 0.50 | 7.8 | 560 | 360 | 280 | .000 | 9.4 | .024 | 800 | 0 |
| S9 | 0.07 | 7.7 | 620 | 370 | 280 | .016 | 13.9 | .002 | 2,800 | 390 |
| Rep (M4) | 0.45 | 8.0 | 520 | 350 | 290 | .046 | 7.0 | .040 | - | - |

Table 1-L: Analytical Results - Little Ausable Sub-drainage Basins
Survey L, 1 December 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 53.0 | 7.8 | 480 | 340 | 250 | .049 | 7.8 | .040 | 51,000 | 2,800 |
| N1 | 30.0 | 7.8 | 470 | 350 | 250 | .046 | 9.1 | .038 | 4,200 | 8,400 |
| N2 | 0.18 | 7.2 | 430 | 300 | 240 | .033 | 5.6 | .032 | 16,000 | 20 |
| N3 | 24.0 | $7.9^5$ | 530 | 340 | 240 | .056 | 9.5 | .036 | 11,300 | 3,100 |
| N4 | 24.0 | - | - | - | - | - | - | - | - | - |
| N5 | <.01 | 7.3 | 610 | 410 | 330 | .206 | 10.7 | .120 | 35,000 | 13,800 |
| N6 | <.01 | 7.7 | 480 | 370 | 300 | .000 | 5.9 | .002 | 900 | 10 |
| N7 | 0.64 | 7.7 | 470 | 330 | 240 | .023 | 6.7 | .002 | 76,000 | 20 |
| N8 | 10.4 | $8.0^5$ | 520 | 340 | 260 | .056 | 8.6 | .032 | 6,100 | 210 |
| N9 | 7.5 | 8.1 | 530 | 340 | 250 | .042 | 8.6 | .020 | 9,700 | 1,100 |
| N10 | 0.74 | $7.3^5$ | 460 | 340 | 270 | .026 | 7.8 | .006 | 10,200 | 100 |
| N11 | 0.99 | 7.4 | 470 | 340 | 260 | .039 | 7.8 | .014 | 7,900 | 180 |
| M1 | 7.28 | 8.0 | 460 | 340 | 260 | .077 | 5.9 | .016 | 88,000 | 80 |
| M2 | 4.80 | $7.9^5$ | 460 | 330 | 260 | .042 | 5.9 | .016 | 64,000 | 230 |
| M3 | 2.61 | $7.9^5$ | 460 | 340 | 260 | .042 | 5.9 | .014 | 38,000 | 190 |
| M4 | 2.20 | 7.5 | 450 | 340 | 250 | .042 | 6.8 | .016 | 8,600 | 20 |
| M5 | 1.25 | 7.8 | 450 | 330 | 250 | .033 | 5.9 | .016 | 58,000 | 20 |
| S1 | 10.1 | 8.0 | 500 | 360 | 270 | .065 | 6.8 | .026 | 8,900 | 3,500 |
| S2 | 9.3 | 8.0 | 500 | 370 | 270 | .049 | 6.8 | .026 | 8,600 | 4,600 |
| S3 | 0.53 | 7.6 | 530 | 400 | 310 | .075 | 6.3 | .022 | 2,600 | 1,500 |
| S4 | 7.6 | 8.1 | 570 | 360 | 270 | .072 | 7.7 | .026 | 45,000 | 4,700 |
| S5 | 6.5 | 8.1 | 540 | 370 | 270 | .147 | 7.7 | .024 | 49,000 | 4,000 |
| S6 | 0.53 | 8.1 | 600 | 3.80 | 280 | .092 | 8.7 | .036 | 8,500 | 600 |
| S7 | 6.0 | $7.8^5$ | 520 | 360 | 270 | .108 | 6.8 | .022 | 50,000 | 3,900 |
| S8 | 4.3 | $7.7^5$ | 500 | 360 | 270 | .052 | 6.8 | .020 | 4,300 | 4,400 |
| S9 | 1.06 | 7.8 | 500 | 370 | 270 | .023 | 7.8 | .018 | 8,700 | 370 |
| Rep (M2) | 4.80 | 8.0 | 510 | 340 | 250 | .046 | 6.4 | .016 | - | - |

Table 1-M: Analytical Results - Little Ausable Sub-drainagé Basins
Survey M, 15 December 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 213 | $7.2^{5}$ | 390 | 250 | 170 | .222 | 9.7 | .016 | 200,000 + | 9,000 |
| N1 | 137 | 7.4 | 420 | 280 | 180 | .232 | 10.8 | .030 | 83,000 | 15,200 |
| N2 | 1.8 | 7.3 | 510 | 300 | 200 | .033 | 12.9 | .013 | 7,400 | 300 |
| N3 | 106 | $7.3^{5}$ | 440 | 260 | 170 | .284 | 9.6 | .027 | 64,000 | 12,400 |
| N4 | 102 | - | - | - | - | - | - | - | - | - |
| N5 | UNDER WATER | | | | | | | | | |
| N6 | 0.04 | 7.4 | 510 | 350 | 240 | .062 | 10.0 | .007 | 16,700 | 290 |
| N7 | 1.31 | $7.1^{5}$ | 360 | 240 | 130 | .137 | 9.3 | .004 | 14,700 | 1,600 |
| N8 | 42 | $7.3^{5}$ | 430 | 260 | 160 | .206 | 10.6 | .011 | 22,000 | 13,700 |
| N9 | 28 | $7.3^{5}$ | 390 | 260 | 160 | .190 | 9.7 | .008 | 28,000 | 4,700 |
| N10 | 1.24 | $7.3^{5}$ | 390 | 250 | 260 | .255 | 11.2 | .016 | 108,000 | 16,700 |
| N11 | 3.46 | 7.3 | 380 | 250 | 160 | .654 | 8.9 | .012 | 112,000 | 8,400 |
| M1 | 14.7 | $7.3^{5}$ | 340 | 240 | 150 | .222 | 7.4 | .005 | 175,000 | 120 |
| M2 | 10.0 | $7.6^{5}$ | 340 | 230 | 150 | .297 | 7.4 | .009 | 20,000 + | 7,700 |
| M3 | 7.9 | 7.7 | 350 | 230 | 140 | .275 | 7.9 | .007 | 20,000 + | 7,700 |
| M4 | 5.1 | $7.6^{5}$ | 340 | 260 | 150 | .219 | 9.5 | .005 | 20,000 + | 9,900 |
| M5 | 4.1 | 7.1 | 370 | 230 | 140 | .196 | 7.6 | .007 | 12,800 | 4,900 |
| S1 | 34 | 7.6 | 380 | 240 | 160 | .288 | 11.0 | .015 | 20,000 + | 5,000 |
| S2 | 31 | $7.5^{5}$ | 390 | 270 | 160 | .229 | 9.6 | .013 | 20,000 + | 6,000 |
| S3 | UNDER WATER | | | | | | | | | |
| S4 | 25 | 7.3 | 370 | 240 | 150 | .280 | 9.0 | .014 | 15,600 | 270 |
| S5 | 22 | 7.4 | 380 | 250 | 150 | .209 | 10.3 | .012 | 187,000 | 840 |
| S6 | 5.0 | $7.3^{5}$ | 480 | 270 | 160 | .281 | 12.4 | .030 | 200,000 + | 2,400 |
| S7 | 14.6 | 7.5 | 370 | 250 | 150 | .176 | 9.3 | .012 | 173,000 | 2,000 |
| S8 | 13.7 | $7.4^{5}$ | 370 | 240 | 150 | .173 | 10.8 | ,012 | 204,000 | 3,800 |
| S9 | 9.6 | $7.4^{5}$ | 400 | 260 | 160 | .147 | 11.0 | .009 | 140,000 | 8,400 |
| Rep ( N6) | 0.04 | 7.2 | 570 | 340 | 240 | .069 | 9.5 | .007 | - | - |

Table 1-N: Analytical Results - Little Ausable Sub-drainage Basins
Survey N, 29 December 1975

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.0 | 8.1 | 500 | 340 | 250 | .058 | 10.6 | .024 | 300 | 40 |
| N1 | 2.8 | $7.5^{5}$ | 520 | 340 | 250 | .301 | 13.4 | .026 | 1,200 | 0 |
| N2 | 0.14 | 7.7 | 460 | 290 | 220 | .297 | 9.1 | .054 | 300 | 10 |
| N3 | 2.3 | $8.0^{5}$ | 520 | 320 | 250 | .045 | 11.1 | .034 | 1,300 | 120 |
| N4 | 2.1 | - | - | - | - | - | - | - | - | - |
| N5 | BURIED IN SNOWBANK | | | | | | | | | |
| N6 | <.01 | $7.9^{5}$ | 520 | 360 | 260 | .009 | 14.4 | - | 200 | 0 |
| N7 | .05 | 8.0 | 510 | 330 | 240 | .055 | 11.8 | - | 100 | 0 |
| N8 | 0.9 | $8.1^{5}$ | 530 | 340 | 260 | .0 | 10.4 | .033 | 200 | 20 |
| N9 | 0.6 | 8.1 | 520 | 330 | 260 | .0 | 9.6 | .023 | 7,900 | 2,300 |
| N10 | 0.08 | $7.6^{5}$ | 480 | 340 | 280 | .020 | 6.1 | .002 | 100 | 0 |
| N11 | 0.15 | 8.2 | 500 | 340 | 270 | .019 | 11.3 | .006 | 600 | 20 |
| M1 | 0.88 | $8.0^{5}$ | 470 | 320 | 260 | .035 | 7.5 | .015 | 1,000 | 30 |
| M2 | 0.62 | 8.3 | 510 | 340 | 260 | .031 | 7.0 | .014 | 600 | 60 |
| M3 | 0.51 | 8.3 | 520 | 340 | 270 | .028 | 7.8 | .016 | 1,400 | 40 |
| M4 | 0.40 | 8.4 | 480 | 320 | 260 | .025 | 8.7 | .014 | 1,500 | 0 |
| M5 | 0.17 | $8.0^{5}$ | 510 | 350 | 260 | .469 | 9.8 | .020 | 2,600 | 20 |
| S1 | 2.5 | 8.3 | 510 | 340 | 260 | .068 | 10.3 | .025 | 1,100 | 30 |
| S2 | 1.9 | 8.0 | 520 | 350 | 270 | .057 | 10.3 | .027 | 8,700 | 130 |
| S3 | 0.05 | 7.7 | 600 | 390 | 290 | .279 | 13.4 | - | 1,000 | 200 |
| S4 | 1.6 | $8.1^{5}$ | 530 | 350 | 270 | .301 | 9.9 | .027 | 1,500 | 40 |
| S5 | 1.2 | $8.1^{5}$ | 500 | 350 | 270 | .172 | 10.3 | .027 | 5,900 | 220 |
| S6 | FROZEN SOLID | | | | | | | | | |
| S7 | 1.0 | $8.1^{5}$ | 510 | 330 | 270 | .103 | 9.2 | .024 | 600 | 60 |
| S8 | 0.6 | $7.8^{5}$ | 510 | 340 | 270 | .029 | 9.9 | .025 | 600 | 10 |
| S9 | .08 | $7.9^{5}$ | 560 | 370 | 270 | .050 | 13.7 | .012 | 1,700 | 90 |
| Rep (S7) | 1.0 | 8.1 | 540 | 310 | 270 | .096 | 10.3 | .026 | - | - |

Table 1-P: Analytical Results - Little Ausable Sub-drainage Basins
Survey P, 26 January 1976

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 123e | $6.6^5$ | 500 | 280 | 210 | .107 | 6.6 | .035 | 4,200 | 510 |
| N1 | 68.6 | 6.6 | 470 | 300 | 210 | .037 | 7.5 | .042 | 700 | 80 |
| N2 | 0.5 | $6.7^5$ | 420 | 250 | 150 | .030 | 14.3 | .014 | 600 | 0 |
| N3 | - | - | - | - | - | - | - | - | - | - |
| N4 | 54.7 | 6.8 | 410 | 280 | 210 | .056 | 5.3 | .044 | 300 | 20 |
| N5 | - | - | - | - | - | - | - | - | - | - |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | 1.59 | 6.8 | 460 | 260 | 160 | .065 | 7.2 | .008 | 300 | 100 |
| N8 | 23.7 | $6.9^5$ | 360 | 240 | 160 | .041 | 6.9 | .010 | 500 | 160 |
| N9 | 17.1 | 6.8 | 360 | 220 | 170 | .061 | 7.6 | .016 | 1,800 | 210 |
| N10 | - | - | - | - | - | - | - | - | - | - |
| N11 | 6.36 | $6.6^5$ | 390 | 240 | 170 | .095 | 9.7 | .016 | 3,400 | 1,800 |
| M1 | - | - | - | - | - | - | - | - | - | - |
| M2 | - | - | - | - | - | - | - | - | - | - |
| M3 | - | - | - | - | - | - | - | - | - | - |
| M4 | 4.6e | $6.6^5$ | 350 | 240 | 280 | .106 | 6.6 | .019 | 700 | 110 |
| M5 | - | - | - | - | - | - | - | - | - | - |
| S1 | - | - | - | - | - | - | - | - | - | - |
| S2 | 20.0 | 6.4 | 400 | 250 | 190 | .114 | 5.3 | .020 | 2,500 | 2,300 |
| S3 | 0.64 | $6.6^5$ | 540 | 290 | 210 | .171 | 9.1 | .020 | 16,000 | 13,000 |
| S4 | 18.9e | 6.7 | 420 | 250 | 190 | .124 | 5.3 | .024 | 1.700 | 650 |
| S5 | 17.2e | 6.7 | 410 | 240 | 180 | .110 | 6.6 | .024 | 600 | 520 |
| S6 | - | - | - | - | - | - | - | - | - | - |
| S7 | 16.9e | $6.6^5$ | 420 | 250 | 180 | .097 | 6.6 | .024 | 3,100 | 470 |
| S8 | - | - | - | - | - | - | - | - | - | - |
| S9 | 6.0 | 6.8 | 470 | 250 | 170 | .130 | 7.8 | .017 | 1,600 | 340 |
| Rep (MSN) | 123e | 6.8 | 410 | 280 | 210 | .073 | 6.6 | .030 | - | - |

Table 1-Q: Analytical Results - Little Ausable Sub-drainage Basins
Survey Q, 17 February 1976

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 204e | 7.9 | 370 | 270 | 180 | .173 | 8.9 | .031 | 800 | 900 |
| N1 | 76.0e | $7.4^{5}$ | 380 | 280 | 180 | .160 | 10.6 | .035 | 1,900 | 1,300 |
| N2 | 1.3 | 8.1 | 500 | 310 | 190 | .034 | 11.9 | .010 | 200 | 0 |
| N3 | - | - | - | - | - | - | - | - | - | - |
| N4 | 60.8e | 7.8 | 390 | 260 | 180 | .169 | 10.0 | .031 | 1,000 | 800 |
| N5 | 2.0 * | 7.9 | 410 | 280 | 220 | .111 | 5.6 | .036 | 3,100 | 1,400 |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | 2.5 | $7.8^{5}$ | 310 | 260 | 160 | .092 | 10.2 | .017 | 1,700 | 800 |
| N8 | 26.3e | $7.8^{5}$ | 390 | 260 | 180 | .194 | 10.0 | .040 | 1,100 | 1,000 |
| N9 | 19.0e | $7.9^{5}$ | 370 | 260 | 180 | .218 | 9.6 | .034 | 2,300 | 800 |
| N10 | - | - | - | - | - | - | - | - | - | - |
| N11 | 12.0e | 7.4 | 360 | 280 | 180 | .114 | 9.4 | .029 | 3,900 | 3,300 |
| M1 | 17.4e | 7.9 | 330 | 250 | 170 | .117 | 6.8 | .030 | 1,000 | 400 |
| M2 | 11.8e | 7.8 | 330 | 250 | 170 | .186 | 7.3 | .020 | 1,500 | 400 |
| M3 | 9.4 | 7.8 | 330 | 250 | 170 | .167 | 7.1 | .023 | 700 | 400 |
| M4 | 3.12 | $7.4^{5}$ | 350 | 250 | 170 | .195 | 8.3 | .017 | 700 | 100 |
| M5 | 2.15 | 7.9 | 330 | 270 | 160 | .130 | 8.3 | .016 | 600 | 200 |
| S1 | 82.0 | $7.8^{5}$ | 380 | 260 | 180 | .169 | 8.9 | .024 | 1,200 | 800 |
| S2 | 78.0 | $7.8^{5}$ | 370 | 250 | 180 | .176 | 8.7 | .020 | 1,300 | 1,300 |
| S3 | - | - | - | - | - | - | - | - | - | - |
| S4 | 60.3e | 7.8 | 360 | 270 | 170 | .114 | 8.9 | .019 | 1,500 | 800 |
| S5 | 53.1e | 7.8 | 370 | 270 | 170 | .208 | 9.2 | .029 | 2,700 | 1,600 |
| S6 | 12.0e | 7.7 | 370 | 250 | 170 | .232 | 9.6 | .032 | 3,600 | 1,900 |
| S7 | 39.9e | 7.6 | 370 | 260 | 180 | .124 | 8.3 | .017 | 1,200 | 600 |
| S8 | 33.0e | 7.6 | 370 | 260 | 170 | .145 | 8.5 | .019 | 600 | 700 |
| S9 | 23.2e | 7.5 | 370 | 270 | 170 | .113 | 9.4 | .019 | 700 | 700 |
| Rep (S4 ) | 60.3e | $7.7^{5}$ | 390 | 250 | 170 | .124 | 9.2 | .022 | - | - |

* Surface flow

Table 1-R: Analytical Results - Little Ausable Sub-drainage Basins
Survey R, 20 February 1976

| Station | Discharge cfs | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 154e | 7.6 | 300 | 210 | 150 | .158 | 8.7 | .032 | 400 | 100 |
| N1 | 70.0e | 7.5 | 330 | 220 | 160 | .140 | 10.1 | .034 | - | - |
| N2 | 1.7 | $7.4^5$ | 390 | 260 | 170 | .050 | 11.3 | .020 | - | - |
| N3 | - | - | - | - | - | - | - | - | - | - |
| N4 | 56.0e | $7.6^5$ | 370 | 230 | 160 | .125 | 8.7 | .032 | 1,000 | 400 |
| N5 | 2.0 * | 7.4 | 370 | 270 | 210 | .083 | 5.0 | .032 | 17,400 | 300 |
| N6 | - | - | - | - | - | - | - | - | - | - |
| N7 | 2.2 | $7.5^5$ | 290 | 200 | 120 | .100 | 7.2 | .013 | 25,100 | 9,900 |
| N8 | 24.2 | $7.6^5$ | 370 | 230 | 160 | .157 | 8.5 | .036 | 1.000 | - |
| N9 | 17.5 | $7.6^5$ | 330 | 220 | 160 | .133 | 8.3 | .042 | - | - |
| N10 | 3.5e | 7,5 | 300 | 210 | 150 | .338 | 6.7 | .029 | 500 | 200 |
| N11 | 9.0e | 7.5 | 310 | 220 | 160 | .100 | 7.0 | .048 | 5,200 | 300 |
| M1 | 15.2e | $7.6^5$ | 280 | 170 | 140 | .134 | 7.4 | .030 | 0 | 0 |
| M2 | 10.3e | 7.6 | 280 | 190 | 140 | .155 | 5.5 | .027 | - | - |
| M3 | 8.21 | $7.5^5$ | 280 | 200 | 140 | .176 | 5.8 | .026 | 100 | 100 |
| M4 | 3.30 | $7.5^5$ | 310 | 200 | 160 | .172 | 6.8 | .024 | - | - |
| M5 | 2.28 | 7.6 | 280 | 200 | 140 | .127 | 7.4 | .025 | 800 | - |
| S1 | 46.7 | 7.6 | 330 | 220 | 150 | .140 | 7.4 | .026 | 1,200 | 100 |
| S2 | 44.2 | $7.5^5$ | 320 | 230 | 150 | .135 | 7.0 | .027 | - | - |
| S3 | - | - | - | - | - | - | - | - | - | - |
| S4 | 33.0 | 7.7 | 330 | 210 | 150 | .131 | 7.3 | .028 | 200 | 200 |
| S5 | 19.5 | 7.6 | 320 | 220 | 150 | .147 | 6.0 | .028 | 500 | 200 |
| S6 | 8.0e | $7.6^5$ | 360 | 230 | 160 | .203 | 7.8 | .030 | 700 | 500 |
| S7 | 17.7 | 7.6 | 300 | 220 | 150 | .349 | 7.7 | .024 | - | - |
| S8 | 14.6e | 7.6 | 310 | 210 | 150 | .137 | 7.9 | .027 | 0 | 100 |
| S9 | 9.0e | $7.5^5$ | 340 | 220 | 160 | .120 | 8.3 | .024 | 400 | 0 |
| Rep (N7) | 2.2 | 7.6 | 340 | 200 | 120 | .094 | 9.5 | .013 | - | - |

* Surface Runoff

Table 1-S : Analytical Summary
Sample Collection S - Sample Date: 22 March 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.7 | 390 | 220 | 170 | .101 | .060 | 9.32 | .006 | <.02 | <.05 | 300 | 20 |
| N1 | 7.5 | 390 | 240 | 170 | .098 | .047 | 9.77 | .007 | <.02 | .21 | 700 | 130 |
| N2 | 7.15 | 410 | 220 | 160 | .026 | .025 | 7.69 | .003 | <.02 | <.05 | <100 | <10 |
| N3 | 7.65 | 400 | 220 | 170 | .088 | .063 | 8.56 | .010 | <.02 | .21 | 200 | 40 |
| N4 | 7.6 | 400 | 220 | 170 | .092 | | 7.65 | .010 | – | – | – | – |
| N5 | 7.1 | 590 | 300 | 220 | .088 | .070 | 17.40 | .036 | .28 | .43 | 15900 | 14000 |
| N6 | 7.45 | 460 | 280 | 220 | 0 | <.005 | 11.85 | .000 | <.02 | <.05 | <100 | <10 |
| N7 | 7.6 | 380 | 220 | 160 | .033 | .017 | 7.41 | .000 | <.02 | .07 | 200 | 20 |
| N8 | 7.6 | 390 | 210 | 170 | .114 | .084 | 7.10 | .021 | .08 | .07 | 1200 | 120 |
| N9 | 7.6 | 390 | 210 | 170 | .101 | .076 | 7.69 | .018 | .06 | <.05 | 300 | 20 |
| N10 | 7.45 | 320 | 210 | 160 | .199 | .130 | 4.91 | .012 | .19 | .72 | 600 | 520 |
| N11 | 7.4 | 380 | 220 | 170 | .078 | .037 | 9.60 | .012 | .08 | <.05 | 1300 | 730 |
| M1 | 7.6 | 340 | 200 | 160 | .183 | .140 | 5.16 | .002 | <.02 | .57 | 100 | <10 |
| M2 | 7.55 | 330 | 190 | 160 | .092 | .077 | 5.02 | .004 | <.02 | .36 | 100 | 30 |
| M3 | 7.55 | 340 | 200 | 160 | .105 | .077 | 6.10 | .003 | <.02 | .43 | 500 | 30 |
| M4 | 7.45 | 350 | 200 | 160 | .127 | .077 | 6.48 | .001 | <.02 | .43 | <100 | <10 |
| M5 | 7.75 | 370 | 230 | 170 | .092 | .047 | 7.55 | .006 | .04 | <.05 | 500 | 40 |
| S1 | 7.5 | 390 | 220 | 170 | .085 | .047 (.047) | 6.83 | .003 | .10 (.02) | <.05 (<.05) | 100 | 10 |
| S2 | 7.4 | 390 | 230 | 180 | .085 | .053 | 8.07 | .006 | .03 | <.05 | 100 | 20 |
| S3 | 7.4 | 460 | 260 | 210 | .082 | .037 | 10.81 | .003 | .03 | <.05 | 600 | 100 |
| S4 | 7.6 | 410 | 230 | 170 | .072 | .047 (.053) | 7.69 | .007 | .03 (<.02) | .43 (.14) | 300 | 140 |
| S5 | 7.55 | 390 | 230 | 170 | .082 | .037 | 7.34 | .005 | .06 | .36 | 200 | 10 |
| S6 | 7.55 | 400 | 220 | 170 | .085 | .053 | 8.28 | .015 | .03 | <.05 | 100 | 10 |
| S7 | 7.85 | 390 | 220 | 180 | .085 | .037 | 7.76 | .004 | .04 | <.05 | 100 | 20 |
| S8 | 7.55 | 390 | 220 | 170 | .059 | .037 | 7.69 | .002 | <.02 | <.05 | 100 | 40 |
| S9 | 7.8 | 400 | 230 | 180 | .065 | .043 (.047) | 9.22 | .001 | <.02 (.03) | <.05 (<.05) | 100 | 10 |
| Rep ($M^3$) | 7.6 | 350 | 200 | 160 | .111 | – | 5.96 | .003 | – | – | – | – |

Table 1-T : Analytical Summary
Sample Collection T - Sample Date: 11 April 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.35 | 450 | 250 | 200 | .025 | <.005 | 7.69 | .028 | .14 | .14 | 100 | 10 |
| N1 | 8.2 | 470 | 270 | 200 | .021 | <.005 | 8.73 | .025 | <.02 | .72 | 200 | 30 |
| N2 | 8.0 | 480 | 260 | 200 | .015 | <.005 | 7.52 | .017 | <.02 | .14 | <100 | <10 |
| N3 | 8.5 | 450 | 250 | 200 | .024 | <.005 | 6.89 | .030 | .08 | .14 | 300 | <10 |
| N4 | 8.5 | 460 | 260 | 200 | - | <.005 | 7.66 | .031 | .04 | <.05 | 200 | <10 |
| N5 | 7.7 | 690 | 310 | 280 | 1.21 | 1.05 | 26.1 | .104 | 6.15 | 3.65 | 41000 | 6000 |
| N6 | 8.0 | 480 | 290 | 210 | .000 | <.005 | 11.33 | .000 | .02 | <.05 | 100 | <10 |
| N7 | 8.0 | 500 | 270 | 200 | .013 | <.005 | 8.45 | .000 | .08 | .21 | <100 | <10 |
| N8 | 8.85 | 400 | 230 | 170 | .076 | .042 | 7.52 | .023 | .12 | .43 | 200 | 20 |
| N9 | 8.7 | 400 | 220 | 170 | .022 | <.005 | 7.34 | .019 | .04 | .29 | 700 | 30 |
| N10 | 7.7 | 450 | 270 | 230 | .025 | <.005 | 4.57 | .000 | <.02 | .36 | 100 | <10 |
| N11 | 8.0 | 420 | 240 | 200 | .033 | .017 | 7.69 | .014 | .17 | .21 | 100 | 30 |
| M1 | 8.55 | 420 | 240 | 190 | .017 | <.005 | 4.78 | .017 | .04 | .14 | <100 | <10 |
| M2 | 8.6 | 390 | 230 | 180 | .017 | <.005 | 5.33 | .014 | <.02 | .43 | 700 | <10 |
| M3 | 8.6 | 440 | 240 | 180 | .012 | <.005 | 4.85 | .014 | <.02 | .43 | 500 | <10 |
| M4 | 8.3 | 420 | 240 | 190 | .020 | <.005 | 6.31 | .021 | <.02 | .93 | 400 | <10 |
| M5 | 8.2 | 450 | 260 | 210 | .038 | .025 | 7.35 | .051 | .04 | .36 | 4900 | 130 |
| S1 | 8.45 | 360 | 250 | 190 | .023 | <.005 | 7.17 | .025 | <.02 | <.05 | 200 | 10 |
| S2 | 8.3 | 450 | 260 | 200 | .020 | <.005 | 6.89 | .026 | <.02 | <.05 | 300 | <10 |
| S3 | 7.85 | 540 | 310 | 240 | .079 | .058 | 11.85 | .031 | <.02 | .07 | 200 | 10 |
| S4 | 8.55 | 460 | 260 | 200 | .117 | .080 | 7.00 | .031 | <.02 | .21 | 100 | <10 |
| S5 | 8.6 | 450 | 260 | 200 | .018 | <.005 | 6.89 | .032 | .03 | .21 | 100 | <10 |
| S6 | 8.9 | 460 | 250 | 190 | .082 | .050 | 8.63 | .024 | <.02 | .57 | 300 | 10 |
| S7 | 8.5 | 450 | 250 | 200 | .020 | <.005 | 6.41 | .032 | <.02 | .57 | 100 | <10 |
| S8 | 8.4 | 440 | 240 | 190 | .015 | <.005 | 6.72 | .028 | <.02 | <.05 | 200 | 20 |
| S9 | 8.15 | 530 | 280 | 220 | .022 | .025 | 11.85 | .008 | <.02 | .14 | 200 | 40 |
| Rep (N3) | 8.5 | 460 | 250 | 200 | .026 | - | 7.60 | .030 | - | - | - | - |

Table 1-U : Analytical Summary
Sample Collection U - Sample Date: 3 May 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.3 | 560 | 280 | 220 | .011 | – | 6.78 | .024 | – | – | 18100 | 340 |
| N1 | 8.2 | 580 | 280 | 220 | .004 | – | 7.20 | .027 | – | – | 4500 | 140 |
| N2 | 7.9 | 600 | 280 | 220 | .006 | – | 6.02 | .030 | – | – | 80 | 7 |
| N3 | 8.25 | 580 | 270 | 220 | .022 | – | 6.19 | .029 | – | – | – | – |
| N4 | 8.2 | 590 | 280 | 220 | .016 | – | 6.94 | .032 | – | – | 11000 | 36 |
| N5 | 7.75 | 790 | 330 | 240 | .168 | – | 25.8 | .776 | – | – | 15000 | 4700 |
| N6 | 7.8 | 580 | 270 | 210 | .000 | – | 9.94 | .000 | – | – | <10 | 1 |
| N7 | 7.85 | 580 | 270 | 210 | .006 | – | 7.62 | .004 | – | – | 800 | 4 |
| N8 | 8.7 | 520 | 250 | 200 | .055 | – | 6.75 | .033 | – | – | 12900 | 106 |
| N9 | 8.5 | 520 | 260 | 210 | .024 | – | 6.62 | .015 | – | – | 7400 | 90 |
| N10 | 7.65 | 520 | 260 | 230 | .018 | – | 4.64 | .004 | – | – | 490 | 110 |
| N11 | 7.85 | 540 | 260 | 220 | .032 | – | 8.04 | .023 | – | – | 2600 | 230 |
| M1 | 8.4 | 520 | 280 | 220 | .015 | – | 4.22 | .018 | – | – | 360 | 21 |
| M2 | 8.35 | 480 | 260 | 220 | .012 | – | 4.90 | .030 | – | – | 3600 | 110 |
| M3 | 8.35 | 550 | 260 | 220 | .025 | – | 4.56 | .015 | – | – | 2100 | 220 |
| M4 | 8.15 | 540 | 260 | 210 | .034 | – | 6.88 | .015 | – | – | 400 | 21 |
| M5 | 8.05 | 560 | 290 | 220 | .058 | – | 7.50 | .025 | – | – | > 20000 | > 2000 |
| S1 | 8.3 | 580 | 280 | 220 | .028 | .025 | 5.78 | .022 | <.02 | .29 | 10900 | 310 |
| S2 | 8.2 | 560 | 280 | 230 | .024 | – | 5.78 | .019 | – | – | 14300 | 2060 |
| S3 | 7.7 | 640 | 310 | 250 | .104 | – | 9.53 | .023 | – | – | 4200 | 210 |
| S4 | 8.35 | 590 | 280 | 220 | .050 | .050 | 5.31 | .028 | <.02 | .14 | 5300 | 2320 |
| S5 | 8.45 | 580 | 290 | 230 | .028 | – | 5.35 | .021 | – | – | 3700 | 1350 |
| S6 | 8.45 | 630 | 300 | 230 | .050 | – | 5.96 | .025 | – | – | 4800 | 1090 |
| S7 | 8.4 | 550 | 270 | 220 | .019 | – | 5.08 | .017 | – | – | 2200 | 910 |
| S8 | 8.35 | 550 | 270 | 220 | .014 | – | 5.36 | .029 | – | – | 1500 | 780 |
| S9 | 8.0 | 630 | 280 | 230 | .035 | .040 | 8.46 | .010 | .13 | .07 | 3700 | 130 |
| Rep (N1) | 8.25 | 610 | 280 | 210 | .004 | – | 6.98 | .025 | – | – | – | – |

Table 1-V : Analytical Summary
Sample Collection V - Sample Date: 17 May 1976

| Station | pH | Specific Conductance μmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.95 | 550 | 270 | 230 | .043 | – | 6.83 | .081 | – | – | 7400 | 2000 |
| N1 | 7.9 | 560 | 270 | 220 | .043 | – | 7.22 | .097 | – | – | 8200 | 5700 |
| N2 | 7.55 | 570 | 280 | 220 | .009 | | 6.09 | .072 | – | – | <100 | 40 |
| N3 | 7.85 | 560 | 280 | 230 | .048 | – | 6.83 | .091 | – | – | 2900 | 380 |
| N4 | 7.9 | 580 | 280 | 230 | .042 | – | 7.04 | .089 | – | – | 2400 | 320 |
| N5 | 7.5 | 740 | 340 | 250 | .354 | .250 | 23.4 (20.2) | .245 | 1.5 | 2.6 | 40000 | 37000 |
| N6 | 7.6 | 590 | 300 | 230 | .011 | – | 9.74 | .000 | – | – | 1300 | <10 |
| N7 | 7.7 | 620 | 280 | 220 | .018 | – | 7.57 | .000 | – | – | 1000 | 10 |
| N8 | 8.0 | 600 | 280 | 240 | .101 | – | 6.30 | .074 | – | – | 3200 | 560 |
| N9 | 7.95 | 550 | 280 | 230 | .052 | – | 6.78 | .034 | – | – | 7000 | 880 |
| N10 | 7.45 | 540 | 270 | 240 | .085 | – | 3.87 | .007 | – | – | 500 | 150 |
| N11 | 7.75 | 550 | 270 | 230 | .058 | – | 8.04 | .014 | – | – | 7400 | 380 |
| M1 | 7.85 | 520 | 270 | 220 | .065 | – | 4.83 | .064 | – | – | 5000 | 200 |
| M2 | 8.0 | 540 | 270 | 230 | .055 | – | 5.00 | .048 | – | – | 1400 | 200 |
| M3 | 7.95 | 540 | 280 | 230 | .046 | – | 5.17 | .033 | – | – | 2700 | 330 |
| M4 | 8.2 | 520 | 270 | 230 | .035 | – | 6.52 | .029 | – | – | 2800 | 110 |
| M5 | 8.35 | 540 | 270 | 220 | .080 | – | 7.22 | .074 | – | – | 59000 | 2700 |
| S1 | 8.2 | 560 | 280 | 230 | .031 | <.005 | 6.26 | .054 | <.02 | .07 | 57000 | 710 |
| S2 | 8.1 | 570 | 290 | 240 | .035 | – | 6.91 | .057 | – | – | 8000 | 420 |
| S3 | 7.5 | 650 | 330 | 250 | .513 | – | 11.7 | .035 | – | – | 2400 | 90 |
| S4 | 8.05 | 550 | 280 | 240 | .040 | .015 | 6.22 | .061 | <.02 | .14 | 3900 | 300 |
| S5 | 8.05 | 600 | 310 | 250 | .084 | – | 8.09 | .064 | – | – | 5700 | 440 |
| S6 | 8.05 | 570 | 290 | 240 | .042 | – | 5.91 | .066 | – | – | 10000 | 300 |
| S7 | 8.2 | 560 | 290 | 240 | .039 | – | 6.22 | .061 | – | – | 2700 | 640 |
| S8 | 8.05 | 570 | 290 | 240 | .036 | – | 6.04 | .056 | – | – | 400 | 170 |
| S9 | 8.0 | 630 | 290 | 240 | .031 | .035 | 9.87 | .021 | <.02 | <.05 | 7000 | 150 |
| Rep (S1) | 8.15 | 580 | 290 | 240 | .032 | – | 6.48 | .049 | – | – | – | – |

Table 1-W : Analytical Summary
Sample Collection W - Sample Date: 31 May 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.65 | 510 | 250 | 200 | .027 | .000 | 4.26 | .067 | – | – | 4500 | 840 |
| N1 | 7.55 | 520 | 260 | 190 | .030 | .009 | 4.44 | .059 | – | – | 4200 | 2200 |
| N2 | 7.45 | 540 | 250 | 200 | .020 | .000 | 2.38 | .074 | – | – | 25000 | 2800 |
| N3 | 7.7 | 470 | 230 | 190 | .063 | .028 | 3.58 | .085 | – | – | 44000 | 7300 |
| N4 | 7.75 | 480 | 240 | 190 | .063 | .020 | 3.66 | .084 | – | – | – | – |
| N5 | 7.35 | 610 | 250 | 220 | 1.10 | .980 | 11.44 | .226 | – | – | >200000 | 42000 |
| N6 | 7.35 | 590 | 300 | 230 | .085 | .060 | 7.66 | .033 | – | – | 4800 | 80 |
| N7 | 7.55 | 480 | 200 | 160 | .069 | .044 | 3.98 | .011 | – | – | >200000 | 1500 |
| N8 | 7.75 | 490 | 240 | 190 | .101 | .050 | 4.02 | .111 | – | – | 98000 | 7200 |
| N9 | 7.8 | 530 | 260 | 200 | .036 | .001 | 5.24 | .065 | – | – | 57000 | 6700 |
| N10 | 7.4 | 640 | 330 | 250 | .041 | .028 | 9.88 | .002 | – | – | 800 | 10 |
| N11 | 7.4 | 530 | 240 | 190 | .306 | – | 7.34 | .058 | – | – | 112000 | 6100 |
| M1 | 7.75 | 480 | 260 | 200 | .039 | .010 | 2.34 | .052 | – | – | 11700 | 3600 |
| M2 | 7.65 | 500 | 250 | 200 | .101 | .070 | 3.04 | .053 | – | – | 90000 | 18400 |
| M3 | 7.75 | 480 | 240 | 200 | .053 | .011 | 3.94 | .058 | – | – | 43000 | >20000 |
| M4 | 7.9 | 450 | 210 | 170 | .012 | .003 | 4.96 | .052 | – | – | 44000 | 17400 |
| M5 | 7.9 | 450 | 220 | 190 | .016 | .012 | 5.58 | .047 | – | – | 33000 | 1100 |
| S1 | 7.7 | 460 | 220 | 180 | .032 | <.01 | 3.00 | .079 | .16 | .69 | 31000 | 3900 |
| S2 | 7.65 | 460 | 230 | 180 | .036 | .000 | 2.88 | .068 | – | – | 45000 | 3600 |
| S3 | 7.25 | 660 | 320 | 240 | .426 | .395 | 10.90 | .427 | – | – | 19000 | 7000 |
| S4 | 7.8 | 490 | 230 | 190 | .037 | <.01 | 2.58 | .066 | .14 | 1.22 | 8700 | 3900 |
| S5 | 7.75 | 530 | 240 | 200 | .811 | .507 | 2.58 | .247 | – | – | 147000 | 19700 |
| S6 | 7.7 | 540 | 230 | 190 | 1.54 | 1.19 | 0.50 | .593 | – | – | >200000 | >20000 |
| S7 | 7.75 | 500 | 250 | 200 | .107 | .080 | 2.88 | .068 | – | – | 82000 | >20000 |
| S8 | 7.6 | 510 | 260 | 210 | .054 | .000 | 2.62 | .054 | – | – | 36000 | 4300 |
| S9 | 7.55 | 630 | 260 | 190 | .290 | .26 (.376) | 9.26 | .155 | .08 | .85 | 194000 | 16300 |
| Rep (N8) | 7.75 | 500 | 240 | 190 | .095 | .041 | 4.18 | .111 | – | – | – | – |

Table 1-X : Analytical Summary
Sample Collection X - Sample Date: 14 June 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.2 | 470 | 230 | 190 | .027 | .004 | 1.88 | .055 | – | – | 1500 | 100 |
| N1 | 7.8 | 520 | 260 | 200 | .034 | .002 | 2.42 | .066 | – | – | 1600 | 300 |
| N2 | 7.05 | 540 | 270 | 220 | .221 | .148 | 2.78 | .049 | – | – | 1400 | <100 |
| N3 | 8.3 | 390 | 240 | 210 | .042 | .002 | 0.94 | .031 | – | – | 13000 | 9100 |
| N4 | 8.3 | 460 | 240 | 200 | .036 | .000 | 0.46 | .030 | – | – | – | – |
| N5 | 7.0 | 740 | 280 | 260 | 1.45 | 1.35 | 17.08 | 1.25 | – | – | 146000 | 2000 |
| N6 | – | – | – | – | – | – | – | – | – | – | – | – |
| N7 | 7.5 | 690 | 330 | 250 | .040 | .079 | 7.68 | .000 | – | – | 12000 | 100 |
| N8 | 8.3 | 460 | 230 | 210 | .055 | .003 | 0.62 | .111 | – | – | 4000 | <1000 |
| N9 | 8.7 | 470 | 240 | 210 | .029 | .002 | 2.42 | .043 | – | – | 3500 | 100 |
| N10 | 7.35 | 710 | 330 | 290 | .044 | .043 | 9.12 | .000 | – | – | 800 | <100 |
| N11 | 7.95 | 550 | 280 | 230 | .049 | .026 | 6.16 | .016 | – | – | 1000 | <100 |
| M1 | 8.25 | 470 | 240 | 220 | .059 | .014 | 0.14 | .007 | – | – | 6000 | <100 |
| M2 | 7.55 | 440 | 240 | 210 | .056 | .024 | 0.28 | .011 | – | – | 7700 | 3000 |
| M3 | 7.95 | 480 | 240 | 210 | .030 | .000 | 1.44 | .030 | – | – | 5200 | <100 |
| M4 | 8.2 | 550 | 280 | 220 | .165 | .122 | 7.38 | .323 | – | – | 2200 | 1400 |
| M5 | 8.4 | 530 | 270 | 200 | .062 | .052 | 8.88 | .141 | – | – | 4600 | 200 |
| S1 | 8.7 | 350 | 170 | 140 | .053 | .013 (.000) | 0.28 | .049 | 0.19 (0.12) | 0.74 | 800 | 300 |
| S2 | 8.35 | 400 | 210 | 160 | .036 | .000 | 0.68 | .079 | – | – | 6500 | 600 |
| S3 | 7.35 | 720 | 350 | 260 | .686 | .628 | 14.76 | .069 | – | – | 100 | <1000 |
| S4 | 8.65 | 400 | 210 | 170 | .063 | .012 (.005) | 0.22 | .029 | .23 (.18) | 0.76 | 1500 | 300 |
| S5 | 8.25 | 490 | 240 | 210 | .117 | .079 | 0.22 | .046 | – | – | 3400 | 1000 |
| S6 | 8.0 | 400 | 280 | 240 | .265 | .193 | 0.04 | .015 | – | – | 6000 | <1000 |
| S7 | 8.05 | 500 | 240 | 220 | .295 | .258 | 0.22 | .053 | – | – | 10200 | 7000 |
| S8 | 7.7 | 530 | 260 | 230 | .038 | .003 | 1.56 | .041 | – | – | 3800 | 900 |
| S9 | 7.5 | 670 | 310 | 240 | .037 | .023 (.034) | 10.32 | .000 | .14 (.12) | <.02 | 900 | <1000 |
| Rep (MSN) | 8.2 | 480 | 230 | 190 | .025 | .002 | 1.74 | .052 | – | – | – | – |

Table 1-Y: Analytical Summary
Sample Collection Y - Sample Date: 13 September 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.8 | 520 | 250 | 200 | .052 | .007 | 1.71 | .038 | – | – | 4900 | 2700 | 500 |
| N1 | 7.5 | 600 | 290 | 230 | .030 | .008 | 3.53 | .060 | – | – | 2800 | 900 | <100 |
| N2 | 7.3 | 530 | 270 | 220 | .069 | .049 | 2.73 | .067 | – | – | 2500 | 100 | 100 |
| N3 | 7.7 | 520 | 270 | 230 | .050 | .017 | 0.41 | .018 | – | – | 3000 | 1800 | 400 |
| N4 | 7.7 | 520 | 270 | 230 | .050 | .017 | 0.41 | .018 | – | – | 3000 | 1800 | 400 |
| N5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N7 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N8 | 7.6 | 530 | 260 | 270 | .058 | .026 | 0.44 | .023 | – | – | 6000 | 700 | 100 |
| N9 | 7.8 | 570 | 280 | 270 | .068 | .020 | 0.20 | .003 | – | – | 4700 | 2200 | 300 |
| N10 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N11 | 7.7 | 660 | 340 | 290 | .032 | .021 | 6.26 | .000 | – | – | 5100 | 400 | 200 |
| M1 | 7.75 | 580 | 280 | 270 | .042 | .008 | 0.21 | .000 | – | – | 1200 | 100 | 400 |
| M2 | 7.5 | 600 | 300 | 270 | .075 | .040 | 0.73 | .011 | – | – | 2000 | 200 | 400 |
| M3 | 7.6 | 590 | 280 | 260 | .045 | .001 | 0.20 | .005 | – | – | 1600 | 200 | 300 |
| M4 | 7.7 | 350 | 190 | 180 | .054 | .054 | 0.44 | .000 | – | – | 4500 | 1300 | <100 |
| M5 | 8.45 | 480 | 250 | 200 | .040 | .000 | 1.86 | .064 | – | – | 8000 | 300 | 200 |
| S1 | 8.4 | 370 | 200 | 150 | .011 | .000 (<.001) | 0.33 | .036 | 0.23 | 0.63 | 2700 | 300 | 200 |
| S2 | 7.8 | 420 | 200 | 170 | .049 | .000 | 1.18 | .031 | – | – | 1800 | 800 | 600 |
| S3 | 8.2 | 810 | 390 | 340 | 1.76 | 1.85 | 3.73 | .000 | – | – | 3100 | 500 | 500 |
| S4 | 8.15 | 450 | 200 | 170 | .139 | .012 (.033) | 0.20 | .000 | 0.48 | 1.41 | 2100 | 400 | 100 |
| S5 | 8.4 | 530 | 260 | 220 | .77 | .87 | 0.23 | .004 | – | – | 1700 | 300 | 400 |
| S6 | 7.7 | 720 | 340 | 310 | .151 | .295 | 0.35 | .048 | – | – | 4600 | 1000 | 300 |
| S7 | 7.7 | 530 | 250 | 220 | .076 | .100 | 0.18 | .005 | – | – | 3500 | 2800 | <100 |
| S8 | 7.75 | 620 | 280 | 280 | .036 | .069 | 0.26 | .000 | – | – | 5000 | 4100 | 200 |
| S9 | 7.8 | 990 | 360 | 330 | .069 | .137 (0.13) | 2.89 | .001 | 0.17 | 0.52 | 57000 | 8000 | 100 |
| Rep (N3) | 7.65 | 520 | 260 | 220 | .057 | .022 | 0.35 | .018 | – | – | – | – | – |

Table 1-Z : Analytical Summary
Sample Collection Z - Sample Date; 4 October 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.25 | 580 | 280 | 230 | .035 | .009 | 1.669 | 0.016 | – | – | 1300 | 630 | 490 |
| N1 | 8.0 | 600 | 300 | 240 | .027 | .015 | 3.759 | 0.019 | – | – | 2100 | 810 | 420 |
| N2 | 7.65 | 530 | 270 | 220 | .022 | .005 | 2.496 | 0.032 | – | – | 100 | 110 | 20 |
| N3 | 8.2 | 610 | 290 | 260 | .027 | .007 | 0.861 | 0.019 | – | – | – | – | – |
| N4 | 8.2 | 610 | 280 | 250 | .016 | .011 | 0.974 | 0.019 | – | – | 2000 | 490 | 210 |
| N5 | 7.9 | 620 | 210 | 250 | 2.22 | .812 | 2.271 | 1.048 | – | – | 870000 | TNTC | 1600 |
| N6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N7 | 8.1 | 800 | 370 | 320 | .025 | .025 | 2.327 | – | – | – | 300 | <10 | 740 |
| N8 | 8.2 | 690 | 310 | 300 | .031 | .020 | 1.030 | 0.007 | – | – | 3500 | 560 | 130 |
| N9 | 8.25 | 690 | 350 | 300 | .030 | .012 | 1.650 | 0.016 | – | – | 11200 | 2200 | 230 |
| N10 | 7.8 | 670 | 330 | 310 | .071 | .052 | 2.233 | 0.002 | – | – | 900 | 180 | 60 |
| N11 | 8.05 | 700 | 350 | 300 | .039 | .032 | 5.936 | 0.002 | – | – | 5100 | 5800 | 240 |
| M1 | 8.15 | 620 | 300 | 280 | .048 | .032 | 0.504 | 0.002 | – | – | 400 | 30 | 30 |
| M2 | 8.0 | 620 | 320 | 270 | .076 | .055 | 0.692 | 0.003 | – | – | 2100 | 20 | 70 |
| M3 | 8.1 | 630 | 320 | 280 | .075 | .055 | 0.767 | 0.035 | – | – | 3400 | 170 | <10 |
| M4 | 8.4 | 520 | 260 | 210 | .104 | .021 | 0.974 | 0.065 | – | – | 300 | 60 | – |
| M5 | 8.75 | 600 | 300 | 250 | .086 | .067 | 4.188 | 0.078 | – | – | 1200 | 40 | 10 |
| S1 | 8.25 | 610 | 300 | 250 | .019 | .006 (<.01) | 0.955 | 0.021 | 0.29 | 0.49 | 2600 | 770 | 130 |
| S2 | 8.25 | 610 | 300 | 250 | .035 | .023 | 1.237 | 0.026 | – | – | 3700 | 400 | 210 |
| S3 | 7.65 | 780 | 390 | 320 | .780 | .697 | 2.835 | 0.006 | – | – | 800 | 70 | – |
| S4 | 8.4 | 610 | 290 | 250 | .080 | .061 (.005) | 1.086 | 0.021 | 0.29 | 0.56 | 3100 | 750 | 590 |
| S5 | 8.45 | 690 | 340 | 290 | .300 | .264 | 1.143 | 0.012 | – | – | 4900 | 840 | 330 |
| S6 | 8.3 | 710 | 350 | 300 | .101 | .080 | 2.496 | 0.020 | – | – | 15000 | 430 | 220 |
| S7 | 8.35 | 690 | 330 | 280 | .016 | – | 0.992 | 0.011 | – | – | 3800 | 1600 | 120 |
| S8 | 8.2 | 700 | 290 | 290 | .023 | .008 | 1.331 | 0.006 | – | – | 1700 | 390 | 170 |
| S9 | 8.1 | 800 | 370 | 310 | .043 | .041 (0.040) | 4.244 | – | 0.21 | 0.27 | 2200 | 570 | 80 |
| Rep (MSN) | 8.25 | 570 | 280 | 230 | .032 | .009 | 1.632 | 0.017 | – | – | – | – | – |

Table1-AA: Analytical Summary
Sample Collection AA - Sample Date: 25 October 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.1 | 700 | 280 | 230 | .029 | .022 | 4.470 | .015 | – | – | 1300 | 280 | 140 |
| N1 | 8.1 | 700 | 280 | 230 | .022 | .004 | 4.710 | .017 | – | – | 1100 | 130 | 110 |
| N2 | 7.5 | 580 | 280 | 230 | .279 | .267 | 4.950 | .011 | – | – | 1700 | 10 | 30 |
| N3 | 8.15 | 660 | 300 | 240 | .022 | .018 | 4.810 | .013 | – | – | 1400 | – | – |
| N4 | 8.2 | 660 | 290 | 240 | .021 | .017 | 4.810 | .011 | – | – | – | – | – |
| N5 | 7.7 | 740 | 260 | 310 | 2.091 | 1.001 | 6.610 | .533 | – | – | TNTC | 1200 | TNTC |
| N6 | 7.9 | 820 | 380 | 310 | .009 | – | 13.210 | .000 | – | – | 400 | – | – |
| N7 | 7.7 | 810 | 340 | 280 | .007 | – | 3.410 | .000 | – | – | 2500 | – | – |
| N8 | 8.25 | 710 | 320 | 270 | .055 | .054 | 4.970 | .017 | – | – | 3800 | 720 | 180 |
| N9 | 8.2 | 700 | 320 | 280 | .018 | .015 | 5.810 | .010 | – | – | 8200 | 870 | 630 |
| N10 | 8.1 | 710 | 340 | 300 | .088 | .064 | 1.330 | .002 | – | – | 67000 | – | – |
| N11 | 7.9 | 720 | 340 | 290 | .154 | .077 | 7.810 | .033 | – | – | 28000 | 1840 | >2000 |
| M1 | 8.15 | 670 | 310 | 260 | .029 | .014 | 2.210 | .000 | – | – | 300 | 10 | – |
| M2 | 8.0 | 670 | 330 | 280 | .022 | .018 | 3.170 | .000 | – | – | 3500 | – | 70 |
| M3 | 8.0 | 700 | 330 | 290 | .030 | .017 | 2.870 | .008 | – | – | 5400 | – | 170 |
| M4 | 8.4 | 670 | 300 | 250 | .024 | .001 | 4.610 | .057 | – | – | 43000 | – | 30 |
| M5 | 8.15 | 670 | 300 | 250 | .053 | .029 | 4.830 | .026 | – | – | 6300 | – | 70 |
| S1 | 8.1 | 730 | 330 | 290 | .032 | .029 (.038) | 4.810 | .019 | 0.12 | 0.49 | 8400 | 190 | 180 |
| S2 | 8.1 | 730 | 330 | 280 | .027 | .015 | 4.830 | .019 | – | – | 76000 | – | 320 |
| S3 | 8.2 | 770 | 380 | 320 | .439 | .363 | 3.710 | .004 | – | – | 5000 | – | – |
| S4 | 8.3 | 710 | 310 | 240 | .038 | .032 (.044) | 5.610 | .016 | 0.29 | 0.46 | 1100 | 130 | 260 |
| S5 | 8.15 | 740 | 320 | 260 | .079 | .076 | 5.610 | .018 | – | – | 2000 | – | – |
| S6 | 8.2 | 740 | 390 | 300 | .161 | .167 | 6.410 | .038 | – | – | 3100 | 50 | 470 |
| S7 | 8.1 | 750 | 310 | 250 | .056 | .048 | 5.510 | .014 | – | – | 1300 | 1030 | 230 |
| S8 | 8.15 | 740 | 300 | 250 | .017 | .007 | 5.010 | .012 | – | – | 300 | 60 | 120 |
| S9 | 8.0 | 780 | 340 | 280 | .054 | .049 (.057)(.057) | 6.410 | .003 | 0.07 | 0.15 | 2600 | 100 | – |
| Rep (M2) | 8.05 | 660 | 310 | 260 | .023 | .017 | 2.250 | .000 | – | – | – | – | – |

Table 1-BB: Analytical Summary
Sample Collection BB - Sample Date: 29 November 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.8 | 620 | 310 | 230 | .082 | .055 | 9.02 | .019 | – | – | 146000 | 160 | 410 |
| N1 | 7.75 | 630 | 330 | 230 | .066 | .039 | 9.33 | .018 | – | – | 35000 | 480 | 90 |
| N2 | 7.75 | 700 | 330 | 240 | .022 | .018 | 9.75 | .010 | – | – | 8600 | 20 | 10 |
| N3 | 7.8 | 620 | 310 | 230 | .084 | .046 | 7.86 | .018 | – | – | – | – | – |
| N4 | 7.8 | 620 | 280 | 230 | .080 | .045 | 8.60 | .015 | – | – | 37000 | 200 | 140 |
| N5 | 7.6 | 870 | 400 | 320 | .400 | .263 | 12.49 | .315 | – | – | 144000 | 21000 | 2000 |
| N6 | 7.7 | 770 | 390 | 270 | .009 | .009 | 14.17 | .000 | – | – | 9400 | 40 | <10 |
| N7 | 7.75 | 650 | 310 | 220 | .043 | .025 | 7.97 | .007 | – | – | 3000 | 840 | <10 |
| N8 | 7.8 | 630 | 320 | 240 | .100 | .054 | 7.76 | .015 | – | – | 11400 | 1300 | 330 |
| N9 | 7.8 | 630 | 310 | 240 | .072 | .037 | 8.81 | .014 | – | – | 12200 | 2200 | 320 |
| N10 | 7.6 | 620 | 320 | 250 | .001 | – | 5.80 | .001 | – | – | 6200 | 1800 | 350 |
| N11 | 7.75 | 660 | 310 | 230 | .067 | .041 | 9.12 | .005 | – | – | 16700 | 120 | 100 |
| M1 | 7.8 | 590 | 290 | 220 | .092 | .067 | 6.12 | .023 | – | – | 157000 | 120 | 180 |
| M2 | 7.8 | 570 | 290 | 220 | .097 | .066 | 6.41 | .026 | – | – | 2000 | 800 | 260 |
| M3 | 7.8 | 580 | 300 | 220 | .106 | .072 | 6.20 | .026 | – | – | 72000 | 600 | 270 |
| M4 | 7.8 | 590 | 300 | 220 | .077 | .040 | 7.86 | .021 | – | – | 9300 | 420 | 220 |
| M5 | 7.9 | 570 | 290 | 220 | .059 | .037 | 6.92 | .007 | – | – | 12400 | 230 | <10 |
| S1 | 7.8 | 630 | 310 | 230 | .079 | .056 (.042) | 7.76 | .018 | 0.04 | 0.61 | 38000 | 210 | 550 |
| S2 | 7.75 | 630 | 320 | 240 | .090 | .049 | 8.28 | .018 | – | – | 14700 | 500 | 610 |
| S3 | 7.65 | 680 | 350 | 270 | .072 | .047 | 8.07 | .002 | – | – | 16400 | 1900 | 970 |
| S4 | 7.8 | 620 | 310 | 240 | .105 | .060 (.057) | 8.28 | .016 | 0.017 | 0.63 | 67000 | 160 | 350 |
| S5 | 7.8 | 630 | 320 | 230 | .080 | .051 | 7.86 | .019 | – | – | 27000 | 140 | 540 |
| S6 | 7.7 | 630 | 310 | 220 | .103 | .003 | 8.91 | .021 | – | – | 8600 | 130 | 1400 |
| S7 | 7.95 | 630 | 310 | 240 | .065 | .041 | 8.07 | .012 | – | – | 7400 | 900 | 290 |
| S8 | 7.7 | 620 | 310 | 240 | .061 | .045 | 7.23 | .012 | – | – | 35000 | 60 | 390 |
| S9 | 7.95 | 660 | 330 | 240 | .047 | .040 (.032) | 8.49 | .005 | .02 | 0.23 | 14200 | 110 | 110 |
| Rep. (S2) | 7.75 | 620 | 310 | 240 | .285 | .162 | 7.65 | .017 | – | – | | - | - |

Table 1-CC : Analytical Summary
Sample Collection CC - Sample Date: 20 December 1976

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.7 | 690 | 320 | 250 | .060 | .050 | 6.042 | .027 | – | – | 13200 | 1260 | 11300 |
| N1 | 7.65 | 650 | 320 | 250 | .059 | .041 | 6.154 | .029 | – | – | 7900 | 1970 | 290 |
| N2 | 7.5 | 630 | 300 | 230 | .064 | .033 | 7.940 | .068 | – | – | 900 | 80 | 10 |
| N3 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N4 | 7.8 | 630 | 300 | 250 | .079 | .056 | 6.221 | .027 | – | – | 11400 | 7400 | 370 |
| N5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N6 | 7.55 | 780 | 400 | 290 | .000 | .000 | 14.76 | .000 | – | – | 1800 | <10 | <10 |
| N7 | 7.7 | 650 | 320 | 230 | .029 | .013 | 5.797 | .000 | – | – | – | <10 | <10 |
| N8 | 7.7 | 650 | 310 | 240 | .130 | .086 | 5.373 | .027 | – | – | 9800 | 2400 | 3700 |
| N9 | 7.8 | 650 | 310 | 240 | .055 | .049 | 5.998 | .017 | – | – | 5700 | 1900 | 340 |
| N10 | 7.6 | 630 | 340 | 270 | .046 | .015 | 3.855 | .001 | – | – | 5800 | 240 | 180 |
| N11 | 7.7 | 690 | 340 | 250 | .085 | .066 | 8.498 | .012 | – | – | 9700 | 2700 | 1100 |
| M1 | 7.6 | 650 | 320 | 250 | .052 | .038 | 3.833 | .022 | – | – | 900 | 10 | 20 |
| M2 | 7.8 | 630 | 300 | 240 | .056 | .057 | 3.833 | .017 | – | – | 7300 | 50 | 320 |
| M3 | 7.75 | 630 | 300 | 250 | .076 | .064 | 3.922 | .015 | – | – | 11000 | 470 | 340 |
| M4 | 7.9 | 600 | 280 | 220 | .084 | .069 | 6.333 | .013 | – | – | 14200 | 8400 | 260 |
| M5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S1 | 7.8 | 680 | 310 | 250 | .130 | .078 (.060) | 5.373 | .023 | 0.76 | 1.63 | 39000 | 1280 | 18200 |
| S2 | 7.7 | 740 | 320 | 260 | .186 | .115 | 5.596 | .033 | – | – | 43000 | 2000 | 19700 |
| S3 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S4 | 7.7 | 660 | 330 | 270 | .229 | .150 (.105) | 5.150 | .036 | 1.15 | 2.12 | 7600 | 1900 | 18600 |
| S5 | 7.7 | 650 | 310 | 250 | .151 | .093 | 5.261 | .015 | – | – | 9000 | 2100 | 10900 |
| S6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S7 | 7.7 | 660 | 310 | 260 | .132 | .082 | 5.150 | .025 | – | – | 9500 | 1640 | 1470 |
| S8 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S9 | 7.75 | 710 | 320 | 240 | .111 | .101 (.080) | 7.270 | .017 | <.02 | 0.43 | 31000 | 1100 | 1500 |
| Rep. (N4) | 7.8 | 580 | 320 | 250 | .084 | .054 | 6.132 | .023 | – | – | – | – | – |

Table 1-DD: Analytical Summary
Sample Collection DD - Sample Date: 18 February 1977

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.6 | 800 | 320 | 270 | .090 | .061 | 3.65 | .037 | – | – | 3100 | 250 | 370 |
| N1 | 7.6 | 700 | 330 | 260 | .072 | .034 | 4.73 | .059 | – | – | 23000 | 260 | 360 |
| N2 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N3 | 7.6 | 770 | 370 | 310 | .109 | .047 | 6.89 | .090 | – | – | – | – | – |
| N4 | 7.55 | 780 | 350 | 310 | .109 | .046 | 5.74 | .091 | – | – | 2400 | 80 | 330 |
| N5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N7 | 7.45 | 670 | 310 | 260 | .231 | .098 | 4.85 | .073 | – | – | 6100 | 1700 | 1100 |
| N8 | 7.4 | 770 | 340 | 290 | .235 | .102 | 5.62 | .091 | – | – | 6600 | 800 | 720 |
| N9 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N10 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N11 | 7.75 | 710 | 340 | 280 | .055 | .047 | 9.20 | .025 | – | – | 1500 | 100 | <10 |
| M1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| M2 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| M3 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| M4 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| M5 | 7.8 | 670 | 320 | 270 | .048 | .015 | 4.22 | .007 | – | – | 2900 | 140 | 10 |
| S1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S2 | 7.4 | 1480 | 680 | 600 | .245 | .222 | 13.76 | .086 | – | – | 6000 | 140 | 250 |
| S3 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S4 | 7.4 | 780 | 340 | 290 | .263 | .114 | 5.43 | .059 | – | – | 11000 | 780 | 2400 |
| S5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S7 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| S8 | 7.4 | 730 | 330 | 290 | .116 | .051 | 3.14 | .034 | – | – | 1100 | 160 | 100 |
| S9 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Rep. (S2) | 7.4 | 1450 | 720 | 600 | .231 | .208 | 13.05 | .085 | – | – | – | – | |

Table 1 EE: Analytical Summary
Sample Collection EE - Sample Date: 7 March 1977

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.3 | 510 | 240 | 190 | .150 | .107 | 6.51 | .041 | 0.22 | 0.81 | 3800 | - | 230 |
| N1 | 7.35 | 490 | 240 | 180 | .513 | .213 | 8.32 | .018 | - | - | 7400 | - | 630 |
| N2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| N3 | 7.5 | 540 | 270 | 200 | .119 | .076 | 8.01 | .034 | - | - | - | - | - |
| N4 | 7.5 | 540 | 270 | 210 | .126 | .072 | 8.22 | .035 | - | - | 5800 | - | 530 |
| N5 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| N6 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| N7 | 7.3 | 600 | 290 | 210 | .034 | .025 | 9.10 | .033 | - | - | 7200 | 600 | <10 |
| N8 | 7.5 | 600 | 290 | 220 | .205 | .107 | 7.70 | .030 | - | - | 18600 | 7000 | 490 |
| N9 | 7.5 | 610 | 290 | 220 | .137 | .084 | 8.38 | .020 | - | - | 4200 | - | 580 |
| N10 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| N11 | 7.25 | 620 | 300 | 220 | .054 | .044 | 12.88 | .020 | - | - | 10000 | 4000 | 60 |
| M1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| M2 | 7.2 | 530 | 250 | 190 | .134 | .096 | 7.50 | .023 | - | - | 40000 | 15000 | 70 |
| M3 | 7.2 | 530 | 260 | 200 | .121 | .094 | 6.87 | .018 | - | - | 6800 | 9000 | 140 |
| M4 | 7.2 | 570 | 280 | 220 | .147 | .122 | 8.32 | .021 | - | - | 37000 | - | 250 |
| M5 | 7.3 | 540 | 260 | 200 | .099 | .069 | 8.48 | .020 | - | - | 7800 | 1000 | 30 |
| S1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S2 | 7.15 | 570 | 260 | 200 | .205 | .151 | 7.03 | .038 | 0.34 | 0.90 | 6000 | 6000 | 830 |
| S3 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S4 | 7.25 | 510 | 260 | 190 | .188 | .122 | 6.98 | .039 | 0.39 | 1.22 | 6000 | - | 830 |
| S5 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S6 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S7 | 7.2 | 540 | 250 | 190 | .212 | .140 | 7.86 | .041 | - | - | 6400 | - | 470 |
| S8 | 7.2 | 540 | 250 | 190 | .196 | .143 | 8.84 | .035 | - | - | 2200 | - | 340 |
| S9 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Rep. (MSN) | 7.4 | 500 | 260 | 190 | .153 | .113 | 8.12 | .044 | - | - | - | - | - |

Table 1 FF: Analytical Summary
Sample Collection FF - Sample Date; 13 March 1977

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 7.5 | 230 | 110 | 80 | .532 | .122 | 2.74 | .011 | 0.21 | 1.39 | 4000 | – | 630 |
| N1 | 7.4 | 220 | 110 | 80 | .605 | .157 | 3.47 | .008 | 0.07 | 1.87 | 10000 | – | 490 |
| N2 | 7.4 | 260 | 120 | 80 | .184 | .066 | 3.83 | .017 | 0.09 | 0.85 | 8000 | – | 60 |
| N3 | 7.4 | 230 | 110 | 80 | .732 | .155 | 3.36 | .006 | 0.15 | 1.95 | – | – | – |
| N4 | 7.35 | 220 | 110 | 80 | .775 | .160 | 3.36 | .005 | 0.15 | 1.96 | 20000 | – | 970 |
| N5 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N6 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N7 | 7.4 | 250 | 110 | 70 | .110 | .047 | 3.78 | .019 | 0.09 | 0.92 | 17000 | – | 10 |
| N8 | 7.4 | 230 | 110 | 80 | .503 | .129 | 2.38 | .022 | 0.11 | 1.02 | 41000 | – | 180 |
| N9 | 7.4 | 240 | 110 | 80 | .406 | .342 | 3.26 | .025 | 0.12 | 1.06 | 21000 | – | 160 |
| N10 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| N11 | 7.4 | 230 | 110 | 80 | .294 | .093 | 3.42 | .033 | 0.08 | 1.27 | 13000 | – | 120 |
| M1 | 7.5 | 220 | 110 | 80 | .434 | .113 | 2.80 | .010 | 0.11 | 1.40 | 21000 | – | 170 |
| M2 | 7.4 | 220 | 110 | 80 | .458 | .139 | 2.28 | .012 | 0.06 | 1.31 | 14000 | – | 190 |
| M3 | 7.4 | 220 | 110 | 80 | .458 | .116 | 2.02 | .007 | 0.06 | 1.05 | 8500 | – | 150 |
| M4 | 7.4 | 220 | 110 | 80 | .351 | .111 | 2.18 | .005 | 0.08 | 1.01 | 1900 | – | 210 |
| M5 | 7.4 | 220 | 110 | 80 | .261 | .105 | 3.36 | .027 | 0.06 | 1.17 | 3000 | – | – |
| S1 | 7.4 | 230 | 110 | 80 | .337 | .140 | 2.90 | .031 | 0.18 | 1.25 | 15000 | – | 310 |
| S2 | 7.4 | 230 | 120 | 90 | .413 | .124 | 2.49 | .031 | 0.18 | 1.34 | 20000 | – | 210 |
| *S3 | 7.4 | 260 | 120 | 90 | .451 | .236 | 2.38 | .117 | – | – | – | – | – |
| S4 | 7.4 | 240 | 110 | 80 | .338 | .111 | 2.69 | .022 | 0.16 | 1.26 | 20000 | – | 280 |
| S5 | 7.4 | 230 | 110 | 80 | .321 | .122 | 2.59 | .029 | 0.15 | 1.09 | 20000 | – | 320 |
| S6 | 7.4 | 250 | 120 | 90 | .324 | .176 | 3.36 | .033 | 0.25 | 1.09 | 12000 | – | 610 |
| S7 | 7.4 | 240 | 110 | 80 | .303 | .108 | 2.80 | .023 | 0.16 | 1.08 | 18000 | – | 5100 |
| S8 | 7.4 | 230 | 110 | 80 | .260 | .094 | 2.33 | .029 | 0.09 | 1.04 | 24000 | – | 310 |
| S9 | 7.4 | 250 | 110 | 80 | .178 | .064 | 3.83 | .027 | 0.12 | 0.79 | 7000 | – | 90 |
| Rep. (N1) | 7.4 | 220 | 110 | 80 | .636 | .158 | 3.42 | .008 | – | – | – | – | – |

* Surface runoff - not regular tile drain

Table 1 GG : Analytical Summary
Sample Collection GG - Sample Date; 24 March 1977

| Station | pH | Specific Conductance µmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 6.45 | 590 | 280 | 210 | .069 | .052 | 6.692 | .014 | – | – | – | – | – |
| N1 | 6.4 | 550 | 270 | 200 | .058 | .036 | 4.797 | .012 | – | – | – | – | – |
| N2 | 6.6 | 550 | 260 | 190 | .159 | .137 | 8.045 | .010 | – | – | – | – | – |
| N3 | 6.5 | 570 | 270 | 210 | .055 | .037 | 6.286 | .015 | – | – | – | – | – |
| N4 | 6.5 | 540 | 270 | 200 | .059 | .037 | 7.639 | .016 | – | – | – | – | – |
| N5 | 6.45 | 650 | 310 | 230 | .292 | .141 | 13.233 | .145 | – | – | – | – | – |
| N6 | 6.1 | 650 | 290 | 220 | .000 | .000 | 14.590 | .002 | – | – | – | – | – |
| N7 | 6.1 | 620 | 270 | 200 | .014 | .009 | 8.135 | .003 | – | – | – | – | – |
| N8 | 6.45 | 540 | 280 | 210 | .105 | .070 | 7.233 | .020 | – | – | – | – | – |
| N9 | 6.55 | 540 | 270 | 200 | .030 | .026 | 7.053 | .012 | – | – | – | – | – |
| N10 | 6.2 | 570 | 270 | 200 | .040 | .025 | 5.338 | .003 | – | – | – | – | – |
| N11 | 6.35 | 520 | 270 | 190 | .024 | .031 | 6.917 | .008 | – | – | – | – | – |
| M1 | 6.5 | 540 | 270 | 200 | .033 | .020 | 5.203 | .011 | – | – | – | – | – |
| M2 | 6.7 | 540 | 270 | 200 | .036 | .027 | 4.211 | .006 | – | – | – | – | – |
| M3 | 6.7 | 540 | 270 | 200 | .046 | .033 | 5.203 | .007 | – | – | – | – | – |
| M4 | 6.55 | 540 | 270 | 200 | .021 | .030 | 5.699 | .008 | – | – | – | – | – |
| M5 | 6.4 | 550 | 280 | 210 | .012 | .013 | 6.917 | .005 | – | – | – | – | – |
| S1 | 6.8 | 590 | 290 | 220 | .081 | .049 | 6.782 | .013 | – | – | – | – | – |
| S2 | 6.8 | 590 | 290 | 220 | .060 | .036 | 5.835 | .012 | – | – | – | – | – |
| S3 | 6.25 | 690 | 310 | 220 | .109 | .078 | 5.925 | .007 | – | – | – | – | – |
| S4 | 6.55 | 550 | 290 | 220 | .044 | .031 | 6.466 | .013 | – | – | – | – | – |
| S5 | 6.5 | 570 | 290 | 220 | .074 | .036 | 6.060 | .016 | – | – | – | – | – |
| S6 | 6.45 | 570 | 270 | 210 | .141 | .083 | 5.880 | .024 | – | – | – | – | – |
| S7 | 6.6 | 570 | 300 | 220 | .032 | .023 | 5.203 | .009 | – | – | – | – | – |
| S8 | 6.5 | 570 | 290 | 220 | .027 | .027 | 5.880 | .009 | – | – | – | – | – |
| S9 | 6.6 | 620 | 280 | 210 | .027 | .028 | 7.955 | .007 | – | – | – | – | – |
| Rep. (N6) | 6.1 | 650 | 290 | 220 | .001 | .000 | 12.556 | .000 | – | – | | | |

Table 1 HH : Analytical Summary
Sample Collection HH - Sample Date: 11 April 1977

| Station | pH | Specific Conductance μmhos | Total Hardness mg/ℓ | Total Alkalinity mg/ℓ | Total Phosphate ppm | Ortho-Phosphate ppm | Nitrate N ppm | Nitrite N ppm | Ammonia N ppm | Kjeldahl N ppm | Total Coliforms #/100 mℓ | Fecal Coliforms #/100 mℓ | Fecal Strep. #/100 mℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSN | 8.0 | 530 | 270 | 200 | .022 | .006 | 1.19 | .019 | – | – | 200 | <10 | <10 |
| N1 | 8.1 | 530 | 280 | 210 | .016 | .003 | 5.88 | .018 | – | – | 600 | <10 | 30 |
| N2 | 7.8 | 540 | 270 | 200 | .158 | .146 | 5.77 | .017 | – | – | 200 | <10 | <10 |
| N3 | 8.1 | 510 | 270 | 190 | .019 | .004 | 4.79 | .020 | – | – | 100 | 10 | 30 |
| N4 | 8.05 | 510 | 260 | 190 | .016 | .008 | 5.66 | .020 | – | – | – | – | – |
| N5 | 7.6 | 670 | 330 | 260 | .093 | .069 | 11.32 | .050 | – | – | 13000 | 210 | 170 |
| N6 | 7.2 | 670 | 340 | 220 | .001 | – | 9.25 | – | – | – | <100 | <10 | <10 |
| N7 | 7.35 | 680 | 320 | 230 | .004 | – | 6.09 | .004 | – | – | 100 | <10 | <10 |
| N8 | 8.2 | 450 | 240 | 170 | .063 | .020 | 4.90 | .030 | – | – | 2000 | 30 | 20 |
| N9 | 8.0 | 470 | 250 | 170 | .044 | .010 | 6.04 | .017 | – | – | 5200 | 90 | 30 |
| N10 | 7.25 | 550 | 290 | 230 | .033 | .025 | 4.13 | .007 | – | – | 300 | <10 | 40 |
| N11 | 7.7 | 580 | 290 | 220 | .028 | .023 | 9.96 | .007 | – | – | 700 | 60 | 20 |
| M1 | 8.1 | 440 | 220 | 160 | .021 | – | 3.26 | .012 | – | – | <100 | <10 | <10 |
| M2 | 8.6 | 440 | 240 | 160 | .019 | – | 4.13 | .010 | – | – | 400 | <10 | <10 |
| M3 | 8.55 | 460 | 240 | 170 | .024 | – | 4.03 | .011 | – | – | 900 | 30 | 10 |
| M4 | 8.15 | 470 | 260 | 190 | .014 | .004 | 5.17 | .010 | – | – | 200000+ | 60 | <10 |
| M5 | 7.85 | 550 | 290 | 210 | .002 | .010 | 6.58 | .010 | – | – | 2900 | 10 | <10 |
| S1 | 8.4 | 540 | 270 | 200 | .035 | .006 | 5.01 | .019 | – | – | 2400 | <10 | 20 |
| S2 | 8.4 | 550 | 290 | 220 | .055 | .023 | 4.84 | .022 | – | – | 4900 | <10 | <10 |
| S3 | 7.4 | 660 | 340 | 270 | .078 | .063 | 5.77 | .009 | – | – | 600 | 20 | 40 |
| S4 | 8.1 | 520 | 260 | 190 | .036 | .005 | 4.73 | .024 | – | – | 3000 | 20 | 60 |
| S5 | 8.15 | 510 | 260 | 190 | .103 | .066 | 5.11 | .025 | – | – | 1800 | 40 | 170 |
| S6 | 8.4 | 510 | 270 | 190 | .150 | .082 | 6.69 | .043 | – | – | 3700 | 20 | 1290 |
| S7 | 8.15 | 510 | 260 | 190 | .047 | .023 | 4.62 | .018 | – | – | 400 | <10 | <10 |
| S8 | 8.2 | 500 | 260 | 190 | .044 | .005 | 4.52 | .018 | – | – | 1000 | 20 | 10 |
| S9 | 7.5 | 640 | 300 | 220 | .030 | .022 | 7.24 | .012 | – | – | 500 | 20 | 10 |
| Rep. (S5) | 8.25 | 510 | 260 | 190 | .098 | .064 | 4.30 | .023 | – | – | | – | |

Table 2 : Phosphorus export data

| Station | Area (ha.) | Total Export (gm/yr) | Station Yield (gm/ha/yr) | Area % AG-3 | Export % AG-3 |
|---|---|---|---|---|---|
| MSN | 5670 | 2709889. | 478 | 100 | 100 |
| N1 | 2410 | 1219158. | 506 | 42.5 | 45.0 |
| N2 | 93.4 | 5489. | 59 | 1.7 | 0.2 |
| N3 | 1758 | 866109. | 493 | 31.0 | 32.0 |
| N4 | 1749 | 844547. | 483 | 30.9 | 31.2 |
| N5 * | 9.0 | 10150. | 1128 | 0.2 | 0.4 |
| N6 * | 14.9 | 65.3 | 4.4 | 0.3 | .002 |
| N7 * | 58.7 | 8729. | 149 | 1.0 | 0.3 |
| N8 | 480 | 694283. | 1448 | 8.5 | 25.6 |
| N9 | 410 | 533530. | 1302 | 7.2 | 19.7 |
| N10 * | 56.9 | 19113. | 336 | 1.0 | 0.7 |
| N11 * | 173 | 45982. | 266 | 3.1 | 1.7 |
| M1 | 884 | 396342. | 449 | 15.6 | 14.6 |
| M2 | 775 | 290798. | 375 | 13.7 | 10.7 |
| M3 | 686 | 238857. | 348 | 12.1 | 8.8 |
| M4 | 320 | 150371. | 470 | 5.7 | 5.5 |
| M5 * | 129 | 62762. | 488 | 2.3 | 2.3 |
| S1 | 1933 | 1003860. | 519 | 34.1 | 37.0 |
| S2 | 1819 | 883821. | 486 | 32.1 | 32.6 |
| S3 * | 55.6 | 27709. | 498 | 1.0 | 1.0 |
| S4 | 1638 | 736819. | 450 | 28.9 | 27.2 |
| S5 | 1520 | 668202. | 440 | 26.8 | 24.7 |
| S6 | 223 | 159474. | 716 | 3.9 | 5.9 |
| S7 | 1291 | 402178. | 312 | 22.8 | 14.8 |
| S8 | 1150 | 225490. | 196 | 20.3 | 8.3 |
| S9 * | 168 | 74249. | 443 | 3.0 | 2.7 |
| MSN-Σ(M+N+S) | 443 | 90529. | 204 | 7.8 | 3.3 |

* tile affected stations

Table 3: Nitrogen export data

| Station | Area (ha.) | $NO_3^-$ N Export (Kg/yr) | Average Nitrate N Conc. ppm | Total N Export (Kg/yr) | Total N Flux Kg/ha/yr |
|---|---|---|---|---|---|
| MSN | 5670. | 286254 | 5.33 | 323467 | 56.95 |
| N1 | 2410. | 131679 | 6.23 | 148797 | 61.74 |
| N2 | 93.4 | 4077 | 6.13 | 4607 | 49.33 |
| N3 | 1758. | 80111 | 5.01 | 90525 | 51.49 |
| N4 | 1749. | 77856 | 4.93 | 87977 | 50.30 |
| N5 | 9.0 | 745 | 11.01 | 767 | 85.22 |
| N6 | 14.9 | 273 | 10.53 | 281 | 18.86 |
| N7 | 58.7 | 3929 | 7.01 | 4047 | 68.94 |
| N8 | 480. | 51351 | 5.86 | 58027 | 120.89 |
| N9 | 410. | 37851 | 6.29 | 42772 | 104.32 |
| N10 | 56.9 | 2360 | 6.93 | 2431 | 47.72 |
| N11 | 173. | 10167 | 8.58 | 11489 | 66.41 |
| M1 | 884. | 24872 | 4.14 | 28105 | 31.79 |
| M2 | 775. | 20513 | 4.38 | 23180 | 29.91 |
| M3 | 686. | 16635 | 4.72 | 18798 | 27.40 |
| M4 | 320. | 14487 | 6.19 | 16370 | 51.16 |
| M5 | 129. | 10108 | 7.12 | 11422 | 88.54 |
| S1 | 1933. | 115040 | 5.24 | 129995 | 67.25 |
| S2 | 1819. | 104623 | 5.69 | 118224 | 64.99 |
| S3 | 55.6 | 2578 | 2.54 | 2655 | 47.75 |
| S4 | 1638. | 77684 | 5.54 | 87783 | 53.59 |
| S5 | 1520. | 64799 | 5.74 | 73223 | 48.17 |
| S6 | 223. | 6913 | 5.80 | 7812 | 35.02 |
| S7 | 1291. | 53153 | 5.81 | 60063 | 46.52 |
| S8 | 1150. | 35525 | 5.99 | 40143 | 34.91 |
| S9 | 168. | 14994 | 8.95 | 15444 | 91.93 |

Table 4: Pluarg Project 20 AG-3 Operation Fluxes

| Operation | Type | Area (ha.) | Phosphorus Flux gm/ha/yr | Distance Barn From Stream (m.) | Manure Storage: type | storage | distance | slope | applied | proximity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Y-yes | N-no |
| 1 | B-100 | 93.4 | 58.77 | 250 | S | B | D | F | Y | N |
| 2 | B-200 | 9.0 | 1127.79 | 100 | S | B | C | M | Y | Y |
| 3 | B-220 | 114.6 | 1047.46 | 10 | S | B | A | F | Y | Y |
| 4 | S-120 | 89.2 | 582.30 | 20 | S/L | P | B | F | Y | Y |
| 5 | B-52 | 191.6 | 457.25 | 280 | S | P | D | F | Y | N |
| 6 | C-0 | 173.2 | 266.49 | 830 | N | N | N | G | N | N |
| 7 | mass balance | 2409.7 | 505.94 | N/A | N | N | N | N | N | N |
| 8 | D-90 | 55.6 | 498.36 | 1000 | S | P | D | F | Y | N |
| 9 | D-78 | 56.9 | 335.91 | 350 | S | B | D | F | Y | N |
| 10 | D-66 | 142.0 | 1244.28 | 100 | S | P | C | G | Y | N |
| 11 | B-230 | 167.7 | 442.75 | 1700 | S | B | D | S | Y | N |
| 12 | S-300 | 128.5 | 488.42 | 1000 | L | V | D | G | N | N |
| 13 | C-0 | 58.7 | 148.71 | 200 | L | V | D | S | N | N |
| 14 | mouth station | 5680. | 477.94 | N/A | N | N | N | N | N | N |
| 15 | C-0 | 14.9 | 4.38 | no barn | N | N | N | M | N | N |
| 16 | B-35 | 108.4 | 973.66 | 380 | S | P | D | F | Y | N |
| 17 | C-0 | 118.1 | 581.01 | 120 | N | N | N | G | N | N |
| 18 | S-342 | 69.5 | 2313.00 | 100 | L/S | P | C | S | Y | Y |
| 20 | S-2420 | 222.6 | 716.42 | <10m | L/S | V/P | A | S | Y | Y |

**Type:**
- B - beef cattle
- S - swine
- D - dairy cattle
- C - non-livestock controls

(numbers indicate # head)

**Storage Type:**
- S - solid
- L - liquid
- N - no cattle

**Storage:**
- B - bunker (containment)
- P - pile (open)
- V - vat (enclosed)
- N - no storage

**Distance:** (from watercourse)
- A - <10m
- B - 10-30m
- C - 30-100m
- D - >100m
- N - not applicable

**Slope:**
- F - flat (no evident slope)
- S - slight (small mounds & depressions)
- G - gradual (slight gradient ∼ 2%)
- M - moderate (gradient ∼ 5%)
- N - not applicable

Table 5a: Summary of farm operations investigated

| Operation | Area (ha.) | Livestock No. | Livestock Density | Crop (% Area) Primary | Secondary | Tertiary | Drainage Type |
|---|---|---|---|---|---|---|---|
| Beef | | | | | | | |
| No. 1 | 93.4 | 100 | 1.07 | B-36 | C-16 | H-11 | ditch |
| 2 | 9.0 | 200 | 22.2 | C-42 | G-25 | H-18 | tile |
| 3 | 114.6 | 220 | 1.92 | C-67 | B-17 | H-8 | stream |
| 5 | 191.6 | 52 | .27 | H-38 | C-29 | G-28 | stream/tile |
| 11 | 167.7 | 230 | 1.37 | C-54 | H-21 | G-11 | tile |
| 16 | 108.4 | 35 | 0.32 | S-36 | W-29 | G-25 | stream |
| Average | 114.1 | 139.5 | 1.22 | | | | |
| Dairy | | | | | | | |
| No. 8 | 55.6 | 90 | 1.62 | H-25 | C-23 | G-22 | tile |
| 9 | 56.9 | 78 | 1.37 | H-34 | G-24 | C-22 | tile |
| 10 | 142.0 | 66 | .46 | C-33 | G-31 | H-18 | stream |
| Average | 84.8 | 78.0 | .92 | | | | |
| Swine | | | | | | | |
| No. 4 | 89.2 | 128 | 1.43 | W-26 | G-24 | B-18 | stream |
| 12 | 128.5 | 300 | 2.33 | G-64 | S-34 | - | tile |
| 18 | 69.5 | 342 | 4.92 | G-64 | S-34 | - | stream |
| 20 | 222.6 | 2420 | 10.87 | C-51 | H-20 | M-13 | ditch |
| Average | 127.4 | 797.5 | 6.26 | | | | |
| Control | | | | | | | |
| No. 6 | 173.2 | 0 | 0 | C-23 | B-17 | W-16 | tile |
| 13 | 58.7 | 0 | 0 | S-34 | B-23 | W-19 | tile |
| 15 | 14.9 | 0 | 0 | S-34 | C-20 | H-10 | tile |
| 17 | 118.1 | 0 | 0 | C-47 | S-25 | B-15 | stream |
| Average | 91.2 | | | | | | |
| AG-3 Average | 59 | 34.2 A.U.*/farm | 0.58 A.U.*/ha | C-32 | G-16 | S-12 | |

Legend: Crops: C- Corn, G- Mixed Grain, H- Hay/Pasture, W- Fall Wheat, B- Barley, S- Soybeans

* A.U.= Animal Units (Reference 1)

Table 5b : Pluarg Project 20 Livestock Operations

| Operation | Livestock | Annual Flux (gm P/ha) | Corrected Flux* gm P/ha/yr |
|---|---|---|---|
| Beef | | | |
| 1 | 100(400-950 lb. gain) Beef Feeders | 58.77 | - |
| 2 | 100(400-1100 lb. gain) Beef Feeders | - | - |
| | 50(400-750 lb. gain) Beef Feeders | 1127.79 | 795.72 |
| | 50(750-1100 lb. gain) Beef Feeders | - | - |
| 3 | 220(400-1100 lb. gain) Beef Feeders | 1047.46 | 715.39 |
| 5 | 40(400-1100 lb. gain) Beef Feeders | 457.25 | 125.18 |
| | 12/12 Beef Cow/Calf | | |
| 11 | 230(400-1100 lb. gain) Beef Feeders | 442.75 | 110.68 |
| 16 | 35(400-1100 lb. gain) Beef Feeders | 973.66 | 641.59 |
| Dairy | | | |
| 8 | 40 Milkers | - | - |
| | 40 Followers | 498.36 | 166.29 |
| | 10(calf-1100 lb. gain) Beef Feeders | - | - |
| 9 | 35 Milkers | - | - |
| | 35 Followers | 335.91 | 3.84 |
| | 8(400-750 lb. gain) Beef Feeders | - | - |
| 10 | 48 Milkers | - | - |
| | 6 Followers | 1244.28 | 912.21 |
| | 12(400-1100 lb. gain) Beef Feeders | - | - |
| Swine | | | |
| 4 | 120 Feeder Hogs | 582.30 | 250.23 |
| | 8 Farrowing Boars/Sows | | |
| 12 | 300 Feeder Hogs | 488.42 | 156.35 |
| 18 | 300 Weiners | - | - |
| | 42 Farrowing Boars/Sows | 2313.00 | 1980.93 |
| 20 | 2302 Feeder Hogs | - | - |
| | 116 Farrowing Boars/Sows | 716.42 | 384.35 |
| | 18 Cows | - | - |
| | 30 (400-1100 lb. gain) Beef Feeders | - | - |

* Background of 332 gm./ha./yr deleted from each operation.

Table 6 : Relationship between operations and stations

| OPERATION | TYPE OF DRAINAGE | STATIONS | METHOD OF CALCULATION |
|---|---|---|---|
| 1 | Ditch | N2 | Direct Measurement (M/M) |
| 2 | Tile Drain | N5 | Direct M/M of Tile Outflow* |
| 3 † | Stream | S1, S2 | By Difference Calculation (S1-S2) |
| 4 | Stream | M2, M3 | By Difference (M2-M3) |
| 5 † | Stream | M4, M5 | By Difference (M4-M5) |
| 6 | Tile/Ditch | N11 | Direct M/M |
| 7 @ | Stream | N1 | Direct M/M |
| 8 | Tile Drain | S3 | Direct M/M of Tile Outflow* |
| 9 | Tile Drain | N10 | Direct M/M of Tile Outflow* |
| 10 | Stream | S7, S8 | By Difference (S7-S8) |
| 11 | Tile Drain | S9 | Direct M/M of Tile Outflow* |
| 12 | Tile/Ditch | M5 | Direct M/M |
| 13 | Tile Drain | N7 | Direct M/M of Tile Outflow* |
| 14 @ | Stream | MSN | Direct M/M (also ≃N1+M1+S1) |
| 15 | Tile Drain | N6 | Direct M/M of Tile Outflow* |
| 16 | Stream | M1, M2 | By Difference (M1-M2) |
| 17 | Stream | S4, S5 | By Difference (S4-S5) |
| 18 | Stream | N8, N9 | By Difference (N8-N9) |
| 19 | Stream | N3, N4 | By Difference (N3-N4) |
| 20 | Ditch | S6 | Direct M/M |

† operation also extensively tiled

@ large area operations involving many drainage types

* tile drain samples may not reflect total output flux of the area

Table 7: Seasonal export of nutrients from operations

| Operation | Summer P | Summer N | Fall P | Fall N | Winter P | Winter N | Spring P | Spring N | Annual P | Annual N |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nutrient Fluxes gm/ha/day | | | | | | | | | |
| Mass Bal. | | | | | | | | | | |
| 14 | 0.483 | 19.01 | 0.353 | 21.42 | 1.481 | 132.4 | 2.902 | 173.3 | 1.308 | 77.90 |
| 7 | 0.478 | 23.32 | 0.347 | 22.39 | 1.547 | 143.1 | 3.158 | 184.5 | 1.384 | 84.46 |
| Beef | | | | | | | | | | |
| 1 | 0.093 | 16.24 | 0.079 | 18.01 | 0.188 | 133.9 | 0.282 | 133.4 | 0.160 | 67.48 |
| 2 | 1.049 | 41.06 | 0.764 | 27.04 | 3.431 | 87.9 | 7.076 | 398.7 | 3.078 | 116.58 |
| 3 | 0.174 | 35.43 | 0.061 | 34.57 | 2.602 | 436.7 | 8.598 | 448.9 | 2.866 | 140.02 |
| 5 | 0.343 | 27.12 | 0.246 | 7.81 | 1.315 | 70.8 | 3.092 | 67.9 | 1.252 | 35.33 |
| 11 | 0.441 | 61.15 | 0.323 | 40.56 | 1.370 | 153.3 | 2.707 | 244.0 | 1.211 | 125.76 |
| 16 | 0.729 | 12.24 | 0.526 | 10.14 | 2.779 | 168.1 | 6.603 | 86.2 | 2.665 | 75.53 |
| Dairy | | | | | | | | | | |
| 8 | 0.630 | 42.89 | 0.491 | 12.52 | 1.597 | 97.0 | 2.734 | 152.7 | 1.364 | 65.32 |
| 9 | 0.271 | 43.98 | 0.197 | 16.51 | 0.978 | 70.1 | 2.234 | 92.1 | 0.919 | 58.45 |
| 10 | 1.935 | 79.19 | 1.555 | 52.12 | 4.155 | 289.6 | 5.951 | 371.4 | 3.404 | 191.90 |
| Swine | | | | | | | | | | |
| 4 | 0.652 | 14.87 | 0.471 | 18.37 | 1.895 | 125.7 | 3.342 | 170.4 | 1.594 | 67.20 |
| 12 | 0.476 | 50.18 | 0.347 | 35.85 | 1.503 | 143.4 | 3.011 | 235.3 | 1.337 | 121.13 |
| 18 | 3.929 | 96.23 | 2.879 | 58.07 | 8.735 | 551.3 | 9.783 | 611.1 | 6.328 | 300.27 |
| 20 | 0.739 | 8.31 | 0.543 | 14.87 | 2.232 | 92.9 | 4.315 | 95.7 | 1.960 | 47.92 |
| Control | | | | | | | | | | |
| 6 | 0.285 | 42.06 | 0.212 | 29.82 | 0.829 | 110.7 | 1.571 | 177.8 | 0.726 | 90.85 |
| 13 | 0.166 | 46.44 | 0.125 | 26.13 | 0.470 | 123.8 | 0.864 | 190.3 | 0.408 | 94.31 |
| 15 | 0.009 | 0.30 | 0.008 | 10.26 | 0.013 | 32.4 | 0.017 | 53.8 | 0.013 | 25.80 |
| 17 | 0.271 | 35.67 | 0.127 | 53.20 | 1.685 | 209.2 | 4.299 | 409.5 | 1.590 | 168.65 |

Summer: June 1 - August 31 (1975,1976) (184 days)
Fall: September 1 - November 30 (1975,1976) (182 days)
Winter: December 1 - February 29 (1975 - 1977) (181 days)
Spring: March 1 - May 31 (1976, 1977) (184 days)
Annual: June 1 1975 - May 31, 1977 (731 days)

Table 8: Export of nutrients by branch (Kg/day) June 1975 - May 1977

| Station and Location | Spring P | Spring N | Summer P | Summer N | Autumn P | Autumn N | Winter P | Winter N | Annual Average P | Annual Average N |
|---|---|---|---|---|---|---|---|---|---|---|
| M1 (middle branch) | 2.573 | 77 | .337 | 13 | .244 | 10 | 1.176 | 70 | 1.084 | 38.45 |
| N1 (north branch) | 7.609 | 445 | 1.151 | 56 | .836 | 54 | 3.725 | 345 | 3.336 | 203.55 |
| S1 (south branch) | 6.332 | 380 | .922 | 48 | .669 | 50 | 3.046 | 328 | 2.747 | 177.83 |
| Sum of branches | 16.514 | 902 | 2.410 | 117 | 1.749 | 114 | 7.947 | 743 | 7.167 | 419.83 |
| MSN (mouth station) | 16.469 | 983 | 2.735 | 108 | 2.003 | 121 | 8.406 | 751 | 7.414 | 442.50 |
| % SUM/MSN | 100.3 | 91.8 | 88.1 | 108.3 | 87.3 | 94.2 | 94.5 | 98.9 | 96.5 | |

Spring - Mean of 184 days
Summer - Mean of 184 days
Fall - Mean of 182 days
Winter - Mean of 181 days
Annual - Mean of 731 days
Area - M1 + N1 + S1 = 92.2% MSN

NOTE: Export is calculated through the full two year period; although no sampling was done in May 1977, the flow record for May 1977 was used in the regression relationships already established to produce a full two year record.

Table 9: Export of nutrients during seasonal events (Kg/day)

| Station and Location | Summer (E) August 25/75 P | N | Fall (BB) November 29/76 P | N | Winter (Q) February 13/76 P | N | Spring (FF) March 13/77 P | N |
|---|---|---|---|---|---|---|---|---|
| M1 (middle branch) | 3.26 | 263 | 2.77 | 190 | 4.35 | 273 | 78 | 772 |
| N1 (north branch) | 27.02 | 42 | 5.04 | 714 | 20.12 | 1354 | 666 | 5968 |
| S1 (south branch) | 3.56 | 378 | 6.65 | 655 | 33.91 | 1962 | 313 | 3734 |
| Sum of branches | 33.83 | 683 | 14.46 | 1559 | 58.38 | 3589 | 1057 | 10474 |
| MSN (mouth station) | 32.88 | 778 | 16.21 | 1787 | 65.19 | 3410 | 1207 | 9867 |
| MSN (seasonal mean) | 2.74 | 108 | 2.00 | 122 | 8.41 | 751 | 16.47 | 983 |

Events:
E - Severe thundershowers August 24/75 pptn 42 mm
BB - Rainshowers November 26-28/76 pptn 24 mm
Q - Light rainfall February 15-22/76 pptn 49 mm accompanying thaw
FF - Spring breakup thaw accompanying rainfall pptn 14 mm

Table 10: Form of nutrients in transport

| Nutrient | S1 Average concentration (ppm) | S1 Ratio of concentration to total concentration: mean ratio | S1 standard deviation | S4 Average concentration (ppm) | S4 Ratio of concentration to total concentration: mean ratio | S4 standard deviation | S9 Average concentration (ppm) | S9 Ratio of concentration to total concentration: mean ratio | S9 standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| **Phosphorus** | | | | | | | | | |
| Total P. | .084 | 1.0 | 0 | .133 | 1.0 | 0 | .082 | 1.0 | 0 |
| Dissolved P. | .054 | .84 | .63 | .093 | .62 | .24 | .061 | .80 | .28 |
| Ortho P. | .047 | .63 | .72 | .060 | .63 | .44 | .063 | .99 | .51 |
| **Nitrogen** | | | | | | | | | |
| Total N. | | 1.0 | - | - | 1.0 | - | - | 1.0 | - |
| Nitrate N. | 5.70 | - | - | 5.81 | - | - | 8.88 | - | - |
| Nitrite N. | .03 | - | - | .03 | - | - | .02 | - | - |
| Total Kjeldahl N | .69 | .13 | - | .75 | .13 | - | .46 | .03 | - |
| Ammonia N | .11 | - | - | .14 | - | - | .06 | - | - |

NOTE: Concentrations are the mean of the individual concentrations while ratios and deviations are the average of individual ratios for each collection period.

Table 11: AG-3 groundwater analyses

| Sample | pH | Cond. µmhos | Total Hardness mg/ℓ $CaCO_3$ | Total Alkalinity mg/ℓ $CaCO_3$ | Total Phosphate ppm as P | Ortho Phosphate ppm as P | Nitrate N ppm as N | Nitrite N ppm as N | Ammonia N ppm as N | TKN ppm as N |
|---|---|---|---|---|---|---|---|---|---|---|
| GW1 | 7.4 | 600 | 270 | 200 | .213 | 0.20 | 1.5 | 0 | <.02 | <.05 |
| GW2 | 7.55 | 510 | 250 | 240 | .022 | <.005 | 1.9 | .001 | <.02 | .07 |
| GW3 | 7.55 | 560 | 270 | 260 | .010 | <.005 | 9.4 | 0 | <.02 | .07 |
| GW4 | 7.65 | 550 | 290 | 220 | .022 | <.005 | 6.6 | 0 | <.02 | 0.5 |
| GW5 | 8.2 | 300 | 110 | 160 | .016 | <.005 | 0.2 | 0 | <.02 | 0.21 |
| GW6 | 8.2 | 590 | 340 | 250 | .048 | .017 | 4.2 | 0 | <.02 | 0.14 |
| GW6b | 8.1 | 580 | 320 | 280 | .024 | <.005 | 4.2 | .059 | <.02 | 0.43 |
| GW7 | 8.15 | 320 | 170 | 130 | .012 | <.005 | 1.8 | .012 | <.02 | 0.36 |

Table 12: Little Ausable River Basin - Chemograph Study - Mass Export (gm/hr)

| Collection Time (hrs.) | Collection # | MSN P | MSN N | N1 P | N1 N | M2 P | M2 N | S2 P | S2 N | S4 P | S4 N | S7 P | S7 N | S9 P | S9 N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | 1 | 34.39 | 5278 | 8.72 | 2849 | 4.62 | 555 | 16.52 | 1814 | 13.99 | 1568 | 3.18 | 609 | 0.41 | 124 |
| t + 2 | 2 | 34.49 | 5788 | 11.42 | 2145 | 4.07 | 437 | 15.50 | 1170 | 15.87 | 1131 | 4.42 | 358 | 0.99 | 124 |
| t + 4 | 3 | 36.66 | 5430 | 5.93 | 2408 | 4.57 | 519 | 15.88 | 1693 | 11.24 | 1318 | 3.89 | 327 | 1.37 | 112 |
| t + 6 | 4 | 36.61 | 5475 | 14.97 | 1732 | 4.71 | 415 | 16.15 | 1295 | 14.04 | 1050 | 4.32 | 328 | 0.90 | 141 |
| t + 7 | 5 | 32.54 | 5543 | 22.27 | 2441 | 4.99 | 528 | 12.11 | 1084 | 12.46 | 1308 | 2.97 | 375 | 0.65 | 136 |
| t + 8 | 6 | 29.42 | 5656 | 9.74 | 2071 | 7.20 | 501 | 11.61 | 1068 | 12.40 | 827 | 4.07 | 386 | 0.89 | 112 |
| t + 9 | 7 | 27.27 | 5817 | 6.33 | 1866 | 3.58 | 371 | 11.10 | 1124 | 11.76 | 1199 | 2.81 | 346 | 0.71 | 92.5 |
| t + 11 | 8 | 25.20 | 5549 | 7.02 | 2178 | 3.59 | 494 | 11.42 | 1330 | 10.75 | 960 | 2.84 | 383 | 0.43 | 84.6 |
| t + 13 | 9 | 18.35 | 5241 | 6.97 | 2423 | 2.24 | 430 | 9.62 | 1226 | 6.40 | 1113 | 2.44 | 329 | 0.47 | 105 |
| t + 15 | 10 | 17.13 | 4634 | 6.31 | 2043 | 2.23 | 348 | 7.84 | 854 | 7.85 | 928 | 3.23 | 360 | 0.38 | 116 |
| t + 17 | 11 | 16.24 | 3661 | 5.70 | 2022 | 2.62 | 383 | 6.71 | 751 | 9.43 | 946 | 2.50 | 323 | 0.35 | 59.9 |
| t + 19 | 12 | 16.22 | 3439 | 6.04 | 2116 | 2.75 | 481 | 12.80 | 1278 | 5.17 | 823 | 2.08 | 326 | 0.31 | 53.9 |
| t + 22 | 13 | 24.97 | 3198 | 8.67 | 1820 | 2.54 | 379 | 8.35 | 978 | 8.49 | 889 | 2.34 | 270 | 0.34 | 58.7 |
| t + 25 | 14 | 17.86 | 2865 | 7.40 | 1670 | 1.68 | 352 | 5.99 | 864 | 4.10 | 737 | 2.18 | 251 | 0.26 | 57.2 |
| t + 28 | 15 | 27.48 | - | 8.18 | 1510 | 2.20 | 305 | 8.92 | 691 | 10.79 | 676 | 1.24 | 192 | 0.20 | 50.0 |
| t + 31 | 16 | 23.22 | - | 6.48 | 1404 | 3.05 | 442 | 8.28 | 1074 | 3.40 | 1118 | 2.43 | 214 | 0.28 | 44.2 |
| t + 37 | 17 | 14.22 | - | 6.20 | 1536 | 1.95 | 367 | 5.46 | 688 | 4.23 | 653 | 0.85 | 278 | 0.16 | 27.8 |
| t + 43 | 18 | 8.57 | 2521 | 3.12 | 1596 | 0.62 | 432 | 7.59 | 931 | 1.71 | 544 | 0.49 | 196 | 0.11 | 30.7 |
| t + 49 | 19 | 7.43 | - | 2.94 | - | 0.50 | - | 4.59 | - | 2.80 | - | 0.75 | - | 0.05 | - |
| t + 55 | 20 | 7.54 | - | 2.57 | - | 0.50 | - | 5.23 | - | 2.72 | - | 0.49 | - | 0.06 | - |
| t + 61 | 21 | 6.12 | - | 2.04 | - | 0.32 | - | 3.12 | - | 1.60 | - | 0.26 | - | 0.018 | - |
| t + 67 | 22 | 3.85 | - | 1.28 | - | 0.17 | - | 2.28 | - | 2.25 | - | 0.23 | - | 0.019 | - |

Table 13 : Log - log model

| Station | Slope (m´) | Intercept (b´) | Determination Coefficient ($r^2$) |
|---|---|---|---|
| N1 | 1.023 | -.43 | .974 |
| M1 | 1.066 | -1.03 | .952 |
| M5 | 1.054 | -1.64 | .935 |
| S1 | 0.931 | -0.32 | .975 |

regression equation employed:

$$\log Qi = m' \log Qmsn + b'$$

Table 14: Linear flow model $Q_i$ = mQmsn

| Station | Slope (m) | Determination Coefficients ($r^2$) |
|---|---|---|
| N1 | .393 | .974 |
| N2 | .0114 | .334 |
| N3 | .297 | .960 |
| N4 | .294 | .958 |
| N5 | .0010 | .489 |
| N6 | .0064 | - |
| N7 | .0078 | .644 |
| N8 | .163 | .948 |
| N9 | .112 | .937 |
| N10 | .0041 | .691 |
| N11 | .0216 | .775 |
| M1 | .112 | .949 |
| M2 | .0819 | .924 |
| M3 | .0655 | .934 |
| M4 | .0436 | .926 |
| M5 | .0264 | .933 |
| S1 | .468 | .969 |
| S2 | .342 | .967 |
| S3 | .0052 | .807 |
| S4 | .261 | .966 |
| S5 | .210 | .960 |
| S6 | .0204 | .775 |
| S7 | .170 | .943 |
| S8 | .110 | .934 |
| S9 | .0273 | .840 |

Table 15 : Flux - flow relationship

| Station | Regression $a(x10^{-3})$ | Coefficients b | Annual Mass P Export Kg/yr |
|---|---|---|---|
| MSN | 7.863 | 1.200 | 2710 |
| N1 | 1.353 | 1.274 | 1220 |
| N2 | 7.598 | 0.703 | 5.49 |
| N3 | 6.661 | 1.124 | 866 |
| N4 | 6.470 | 1.125 | 845 |
| N5 | 0.009 | 1.289 | 10.2 |
| N6 | 1.765 | 0.443 | .065 |
| N7 | 0.109 | 1.087 | 8.73 |
| N8 | 1.521 | 1.222 | 694 |
| N9 | 0.034 | 1.491 | 534 |
| N10 | 0.002 | 1.454 | 19.1 |
| N11 | 0.325 | 1.131 | 46.0 |
| M1 | 0.094 | 1.391 | 396 |
| M2 | 0.134 | 1.341 | 291 |
| M3 | 0.045 | 1.409 | 239 |
| M4 | 0.031 | 1.401 | 150 |
| M5 | 0.110 | 1.239 | 62.8 |
| S1 | 0.746 | 1.305 | 1000 |
| S2 | 3.004 | 1.188 | 884 |
| S3 | 1.918 | 0.950 | 27.7 |
| S4 | 7.528 | 1.102 | 736 |
| S5 | 15.160 | 1.039 | 668 |
| S6 | 0.611 | 1.179 | 159 |
| S7 | 21.112 | 0.973 | 402 |
| S8 | 0.517 | 1.218 | 206 |
| S9 | 0.180 | 1.214 | 74.2 |

This table displays the relationship between daily phosphorus export at a station and the corresponding flow at the main station based on the equation: $E=aQmsn^{b}$, where E is the daily [P] and Qmsn is the daily flow at the main station.

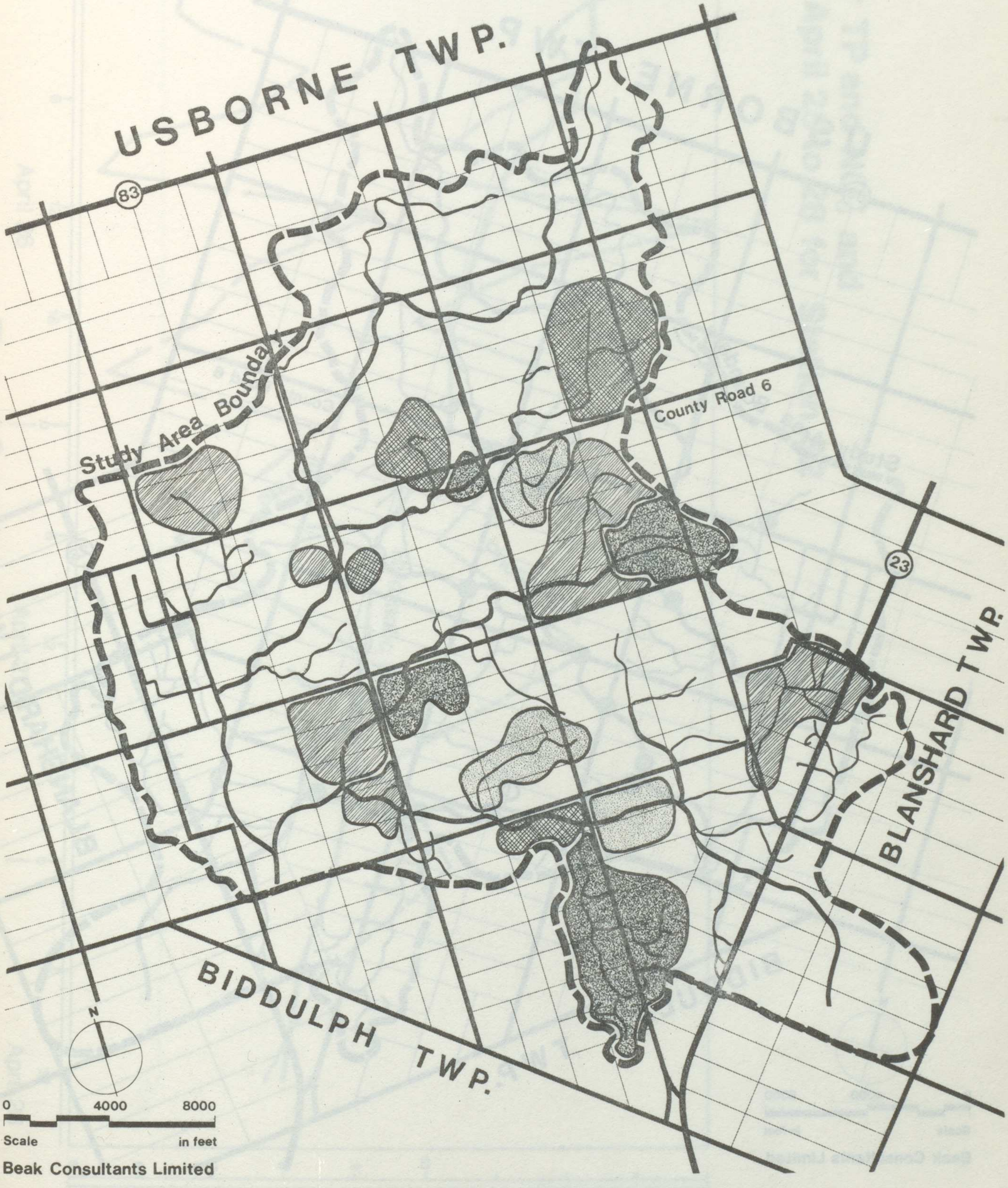
Table 16: Geometric means of bacterial data

| Station | Total Coliforms (No./100mℓ) | Fecal Coliforms (No./100mℓ) | Fecal Streptococci (No./100mℓ) |
|---|---|---|---|
| MSN | 2500 | 340 | 260 |
| N1 | 3000 | 210 | 180 |
| N2 | 750 | 32 | 21 |
| N3 | 3300 | 410 | - |
| N4 | 3200 | 280 | 260 |
| N5 | 1800 | 8100 | 1130 |
| N6 | 290 | 9 | 5 |
| N7 | 1100 | 34 | 24 |
| N8 | 3300 | 240 | 250 |
| N9 | 5900 | 760 | 250 |
| N10 | 1400 | 100 | 110 |
| N11 | 3600 | 340 | 110 |
| M1 | 1000 | 34 | 58 |
| M2 | 3800 | 220 | 100 |
| M3 | 3300 | 240 | 92 |
| M4 | 3500 | 160 | 81 |
| M5 | 4100 | 210 | 19 |
| S1 | 3500 | 240 | 220 |
| S2 | 4700 | 380 | 280 |
| S3 | 3700 | 230 | 270 |
| S4 | 3200 | 270 | 410 |
| S5 | 4800 | 510 | 420 |
| S6 | 8000 | 530 | 570 |
| S7 | 4300 | 710 | 230 |
| S8 | 2500 | 250 | 140 |
| S9 | 3900 | 230 | 100 |

FIGURES

# Livestock Operations · Fig. 1

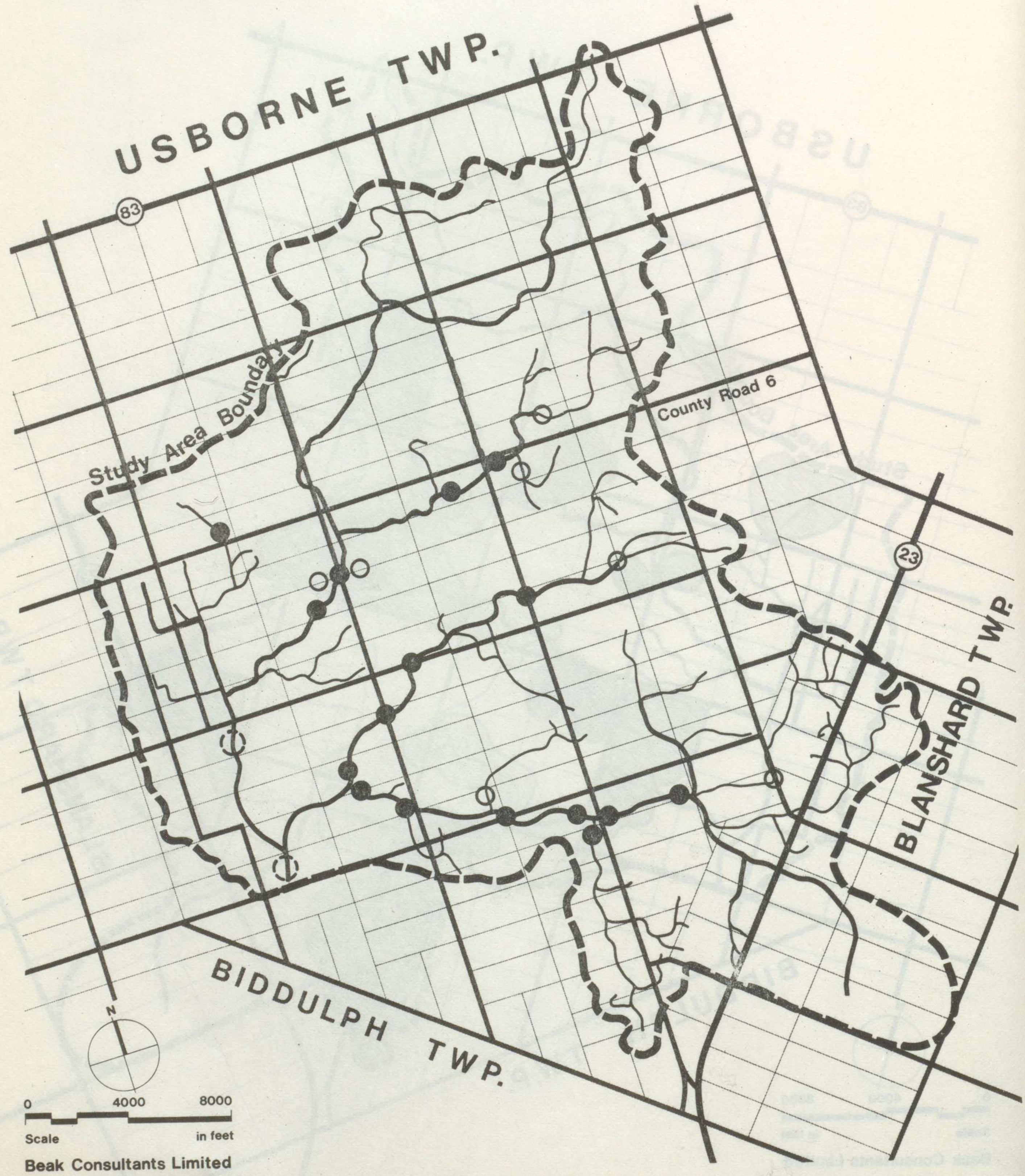
- Beef Operations
- Dairy Operations
- Swine Operations
- No Livestock Controls




Beak Consultants Limited

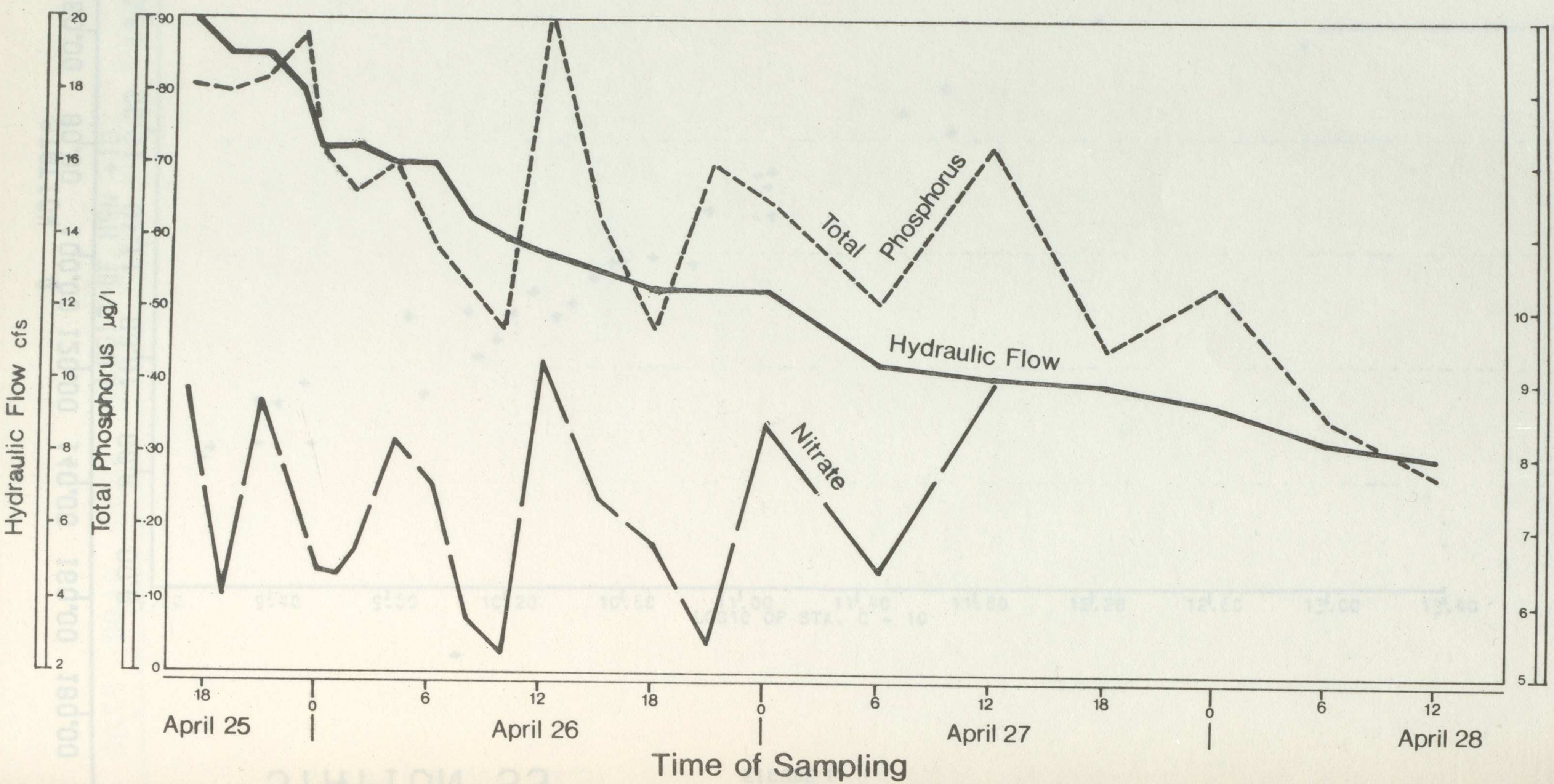
# Sampling Stations · Fig. 2

- ● Surface Water Stations
- ○ Tile Sample Stations
- ◌ Stations N1 and MSN
  Mass Balance Station



## Figure 3

**Chemograph for TP and $NO_3^-$ and Hydrograph for April 25 to 28 for Station S2**



STATION S5

FIGURE 4

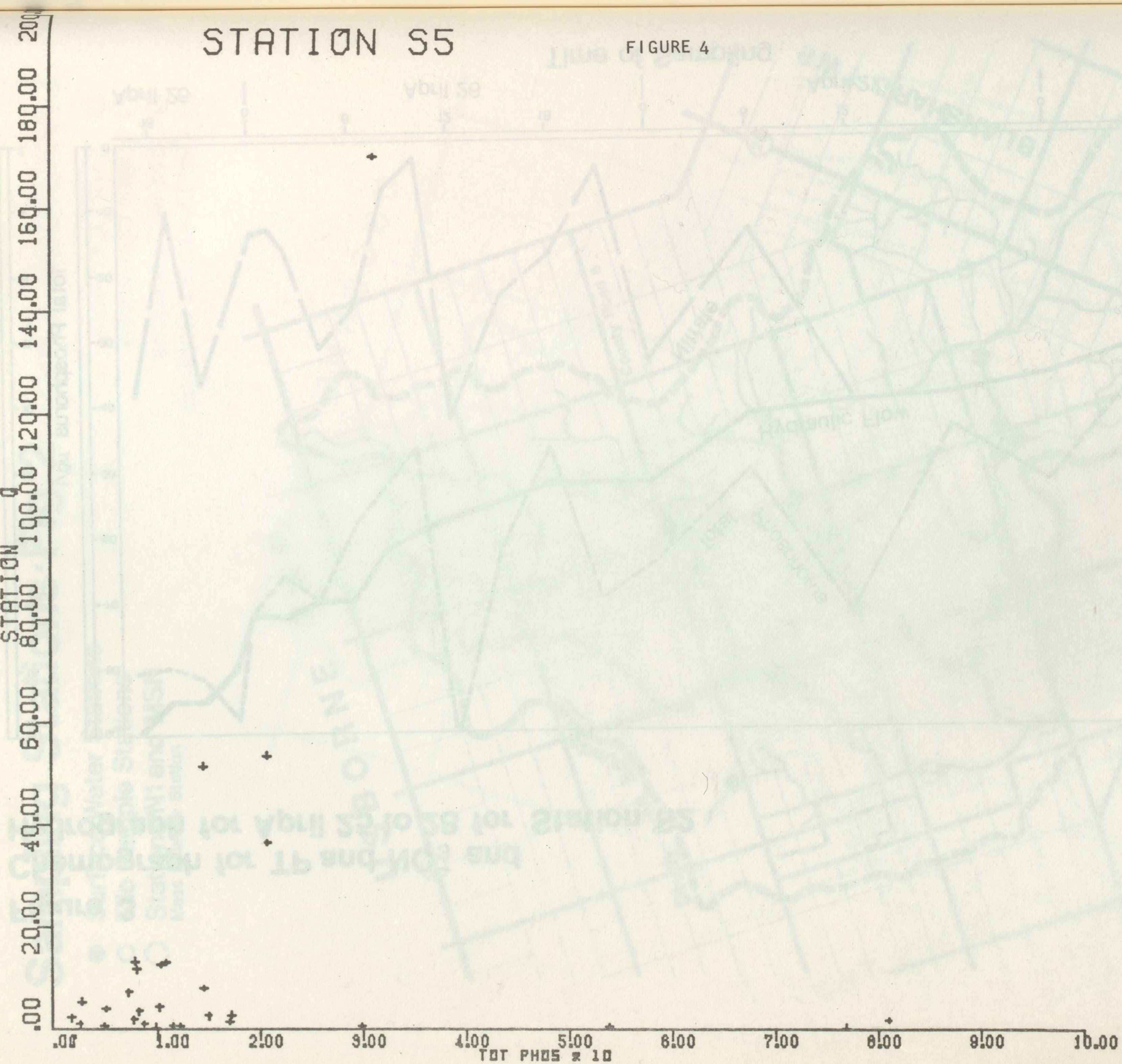
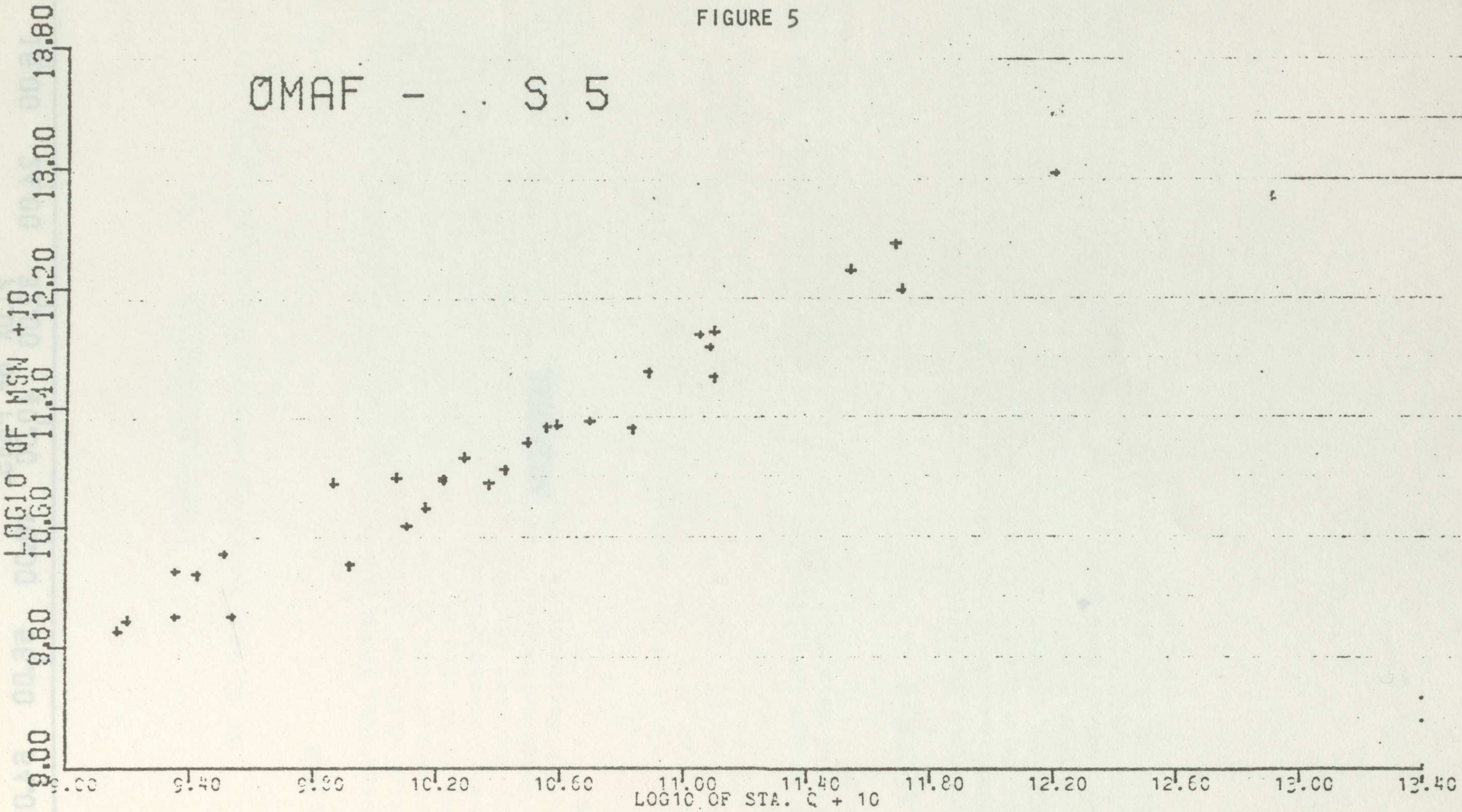
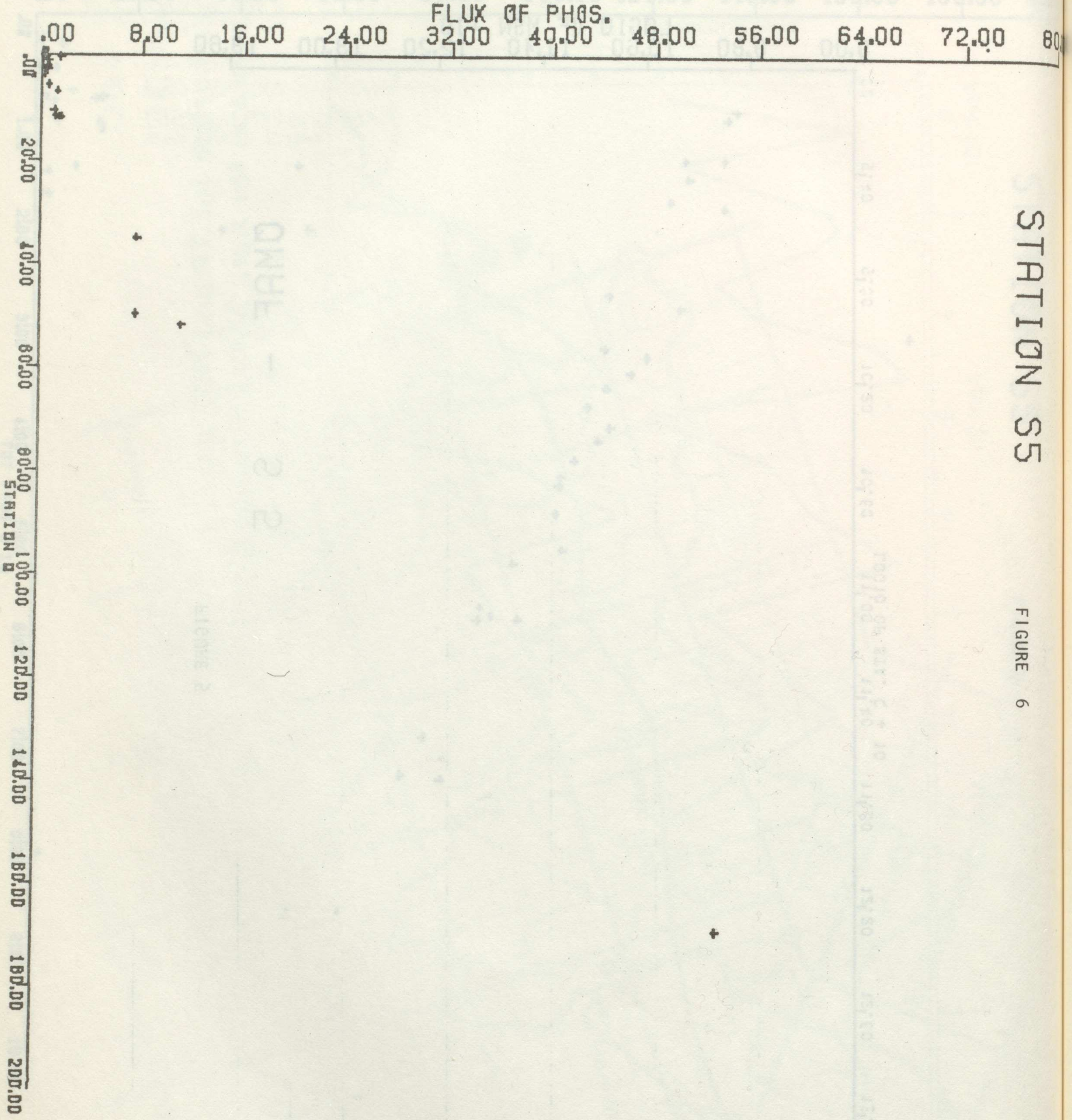


FIGURE 5


ØMAF - . S 5
LOG10 OF MSW +10
9.00
9.80
10.60
11.40
12.20
13.00
13.80
LOG10 OF STA. Q + 10
9.00
9.40
9.80
10.20
10.60
11.00
11.40
11.80
12.20
12.60
13.00
13.40




STATION S5

FIGURE 6

# APPENDICES

# METHODS OF ANALYSIS

To Be Used In The Agricultural Watershed Studies

## INTRODUCTION

Beak Consultants is to determine a number of analytical parameters in conjunction with the Agricultural Watershed Studies. The analysis is to be conducted both in the field using Beak mobile laboratory facilities and in Toronto at the Beak chemistry laboratories. Realizing that mobile laboratory conditions may be somewhat limiting and the necessity for very low sensitivity and high accuracy and precision, certain modifications will be required in the standard analytical techniques. The following is a detailed description of the methods to be employed.

## PHOSPHATE ANALYSIS

### Scope

This method is applicable to the analysis of receiving waters and is capable of measuring total phosphate concentration down to at least 2 ppb as P.

### Summary of Method

This method is essentially the same as that given in Standard Methods (1) using potassium persulphate digestion coupled with stannous chloride molybdate colorimetric finish. Because low sensitivity is essential a predigestion concentration step is included and a modification of reagent volumes added. Standards and spikes carried out using distilled water and samples gave good results. No particular problems were observed with color or turbidity interference but a filtration step can be included if turbidity does occur.

Procedure

1) All glassware is to be acid washed and rinsed several times with distilled water. Glassware blanks must be completely eliminated.

2) Take 300 ml of sample or standard and put into 400 ml tall form beakers. Add 0.3 ml $H_2SO_4$ (50%) and evaporate on hotplates to about 50 ml.

3) Next add 5 ml $K_2S_2O_8$ (5%) and boil for about 90 minutes, keeping the volume about 30 ml.

4) Cool and neutralize (6N NaOH) to phenolphthalein pink. Reacidify (1N $H_2SO_4$) to just remove the color. Then make up to 50 ml final volume. At this point total dissolved solids should be about the same in all standards and samples for best subsequent color development and reproducibility.

5) Take a portion of the 50 ml solution and read the background at $\lambda$=690 mμ. This will compensate for modest color and turbidity interference. Return the used portion to remake the 50 ml volume.

6) Color development is carried out as follows:

   To the 50 ml aliquots add 2.0 ml molybdate reagent. After having added this to all samples being reacted, add exactly 5 drops of stannous chloride reducing reagent at one minute intervals to the solutions. Let the color develop and make the photometric color measurement after 10 minutes but before 12 minutes, employing the same specific interval for all determinations. The reason for the interrupted stannous chloride addition is to make the subsequent 10-12 minute interval limit for each determination much easier to achieve without rushing the readings. The wavelength setting is 690 mμ

7) Subtract appropriate sample blanks.

8) Make appropriate plots and calculations.

## NITRATE ANALYSIS

### Scope

This method is applicable to the analysis of nitrate in receiving waters with a detection limit of 50 ppb.

### Summary

This method is based upon the reaction of the nitrate ion with brucine sulphate in concentrated sulphuric acid solution at a temperature of about 100°C. This method has only limited modifications to that outlined in standard procedures (1,2,3 ). Color and turbidity interferences are removed by reading sample blanks prior to reaction with brucine, or after reaction but without brucine.

### Procedure

1) Add 10 ml of sulphuric acid solution to 10 ml aliquot of sample or standard in test tube. Mix well and cool for 5 minutes in cold water. Add 1 ml of brucine solution and mix well.

2) Place in boiling water for exactly 20 minutes. Make sure water is boiling at the start of this time. If the water is cooled considerably by addition of many test tubes, lower absorbance readings will be obtained. By increasing the length of boiling time this can be improved.

3) Remove the reacted tubes from the boiling water and place into cold water for 15 minutes. Make sure the water remains cold, then let stand in the rack for about 5 minutes exposed to room temperature so that equilibrium is established.

4) Read the developed color at 410 mμ, subtract appropriate blanks, plot standards and perform required calculation.

## Standards

Temperature and time are very important to the reproducibility of standards and samples. Since absolute control of temperature is not practical in different batch reactions, standards must be run with every batch processed. The standard curve plotted using these standards is to be used for determining the nitrate concentration in the samples carried through the reaction in the same bath.

## BACTERIOLOGICAL ANALYSIS

### Scope

The method of analysis is applicable to receiving waters.

### Summary of Method

Total and fecal coliforms are determined by the membrane filter procedure (1,4). A known volume of sample is filtered through a 0.45 µm cellulose acetate filter that has been presterilized. The filters are incubated at 35°C (Total Coliforms) and 44.5°C (Fecal Coliforms) using appropriate nutrient media. Equipment and media are supplied by Millipore Ltd.

### Procedure

1) All equipment used in the tests must be washed and sterilized. Filtration equipment is sterilized by placing in boiling water for at least 10 minutes. Volumetric flasks, graduate cylinders, pipettes and forceps are washed with chromic acid. Blanks are run to assure contamination free equipment.

2) Set up the filtration apparatus using glassware that is cool (after sterilization). Wash the filter with a small volume of buffer solution.

3) Shake the sample well and pour it into the funnel making sure that no suction is applied to the apparatus. Filter the sample and wash with buffer solution. If small sample volumes are necessary then place a small amount of buffer solution into the funnel prior to sample addition. This will aid in dispersing the sample on the filter uniformly.

4) Make all necessary dilutions with boiled distilled water.

5) Prepare the petri dishes by placing the absorbent pads on the bottom then adding the nutrient media. For total coliforms use the M-Endo Broth and for fecal coliforms use the MFC Broth. Take the respective ampoules, break them and saturate the pads. Place the filters from the filtartion step onto the pads and close the dishes. Incubate the total coliform dishes at 35 ± .5°C and the fecal coliform dishes at 44.5 ± .2°C for 24 hours.

Procedure (continued)

6) Each test is to be run in duplicate or triplicate with or without volume dilution.

7) Make appropriate counts and calculations. Report counts per 100 ml.

Nutrient Media

The nutrient media used for the above tests will be that supplied by Millipore Ltd., prepared in 2 ml ampoules. Tests will also be conducted using the dehydrated M-Endo and MFC broths as well as Les-Endo Agar for total coliforms to confirm potency of the preprepared media.

Additional Methods

The other parameters to be determined in this study will be analyzed using standard techniques (1,2,5,6)

## REFERENCES


1) Standard Methods for the Examination of Water and Wastewater 13th. edition APHA 1971.

2) Methods for Chemical Analysis of Water and Wastes (Manual of) U.S. E.P.A. 1974.

3) Brucine Method for Determination of Nitrate in Ocean, Estuarine, and Fresh Waters, by D. Jenkins and L. L. Medsker Anal. Chem. Volume 36, No. 3 March 1964.

4) Biological Analysis of Water and Wastewater Application Manual AM 302 Millipore Ltd. 1973.

5) Methods of Analysis of the Association of Official Analytical Chemists. 12th. Edition AOAC 1975.

6) Analytical Methods Manual
Inland Waters Directorate
Water Quality Branch
1974.

# QUALITY CONTROL PROGRAM

BEAK participated in several quality control programs througout the PLUARG study.

## Interlab Duplicate Samples Program for Task C (Canadian) Analysts

Duplicate samples were collected regularly, one analyzed by BEAK the other by the Central Laboratory of the Ontario Ministry of the Environment, Toronto.

BEAK laboratory was found to be in good agreement with O.M.E. Toronto for all parameters except Total Kjeldahl Nitrogen and Ammonium where little data existed. These were not priority parameters for our laboratory and the difficulties were mainly associated with variable blanks.

## Intercomparison Evaluation Minerals and Nutrients

BEAK participated in three studies from 1975 to 1977. Although generally results showed good precision and accuracy, certain parameters in each of the studies showed inconsistencies, though not severe. It was obvious that TKN, ammonia and nitrate values showed bias as a result of blank problems.

## In-Lab Duplicate Analysis of Blind Replicates

BEAK carried out duplicate analyses on "blind" separately collected (not split) samples from 1975 to 1977. The data is useful in assessing the additional effect of field activities and sample type on precision.

## Pluarg Microbiology Interlaboratory Comparison

The quality control study was undertaken in order to evaluate the microbiological data generated by BEAK, M.O.E. Toronto and M.O.E. London. The aim was to compare recovery rates for Total Coliforms, Fecal Coliforms and Fecal Streptococci. Statistical analysis showed that although absolute numbers differed, the data generated by the three laboratories was comparable and interpretation of numbers in the data base would produce similar conclusions as to water quality.