1978-08-01

Pollution Potential of Cattle Feedlots and Manure Storages in the Canadian Great Lakes Basin: Agricultural Watershed Studies, Project 21: Final Report

International Reference Group on Great Lakes Pollution from Land Use Activities

Canada. Department of Agriculture

D. R. Coote

F. R. Hore

INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL JOINT COMMISSION

POLLUTION POTENTIAL OF CATTLE FEEDLOTS AND MANURE STORAGES IN THE CANADIAN GREAT LAKES BASIN

AGRICULTURAL WATERSHED STUDIES

PROJECT 21 - FINAL REPORT

POLLUTION POTENTIAL OF CATTLE FEEDLOTS AND MANURE STORAGES IN THE CANADIAN GREAT LAKES BASIN

PART I - RUNOFF CHARACTERISTICS AND POLLUTION POTENTIAL

PART II - GROUNDWATER CONTAMINATION FROM AN UNPAVED FEEDLOT

D.R. COOTE
LAND RESOURCE RESEARCH INSTITUTE,

AND

F.R. HORE
ENGINEERING AND STATISTICAL RESEARCH INSTITUTE,
AGRICULTURE CANADA, OTTAWA, ONTARIO K1A 0C6

AUGUST, 1978

DISCLAIMER

The study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-U.S. Great Lakes Water Quality Agreement of 1972. Findings and conclusions are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of the following: Mr. John Gall, Engineering and Statistical Research Institute, Agriculture Canada, who assisted with the initial installations; Dr. David Glutek of the Laboratories of the Ontario Ministry of the Environment at London; Mr. Eric Leggatt of the Ontario Ministry of the Environment Microbiology Section in Toronto; Dr. Brian Derbyshire of the Ontario Veterinary College; and the five farmers without whose facilities and cooperation this project would not have been possible.

The authors wish to thank Mr. Michael Binns, Engineering and Statistical Research Institute, Agriculture Canada, who assisted with statistical analyses; Mr. Rod Leuty, Land Resource Research Institute, Agriculture Canada, who assisted with field work; Mr. Ron DeHaan and Mrs. Mabel Cole, Engineering and Statistical Research Institute, Agriculture Canada, who assisted with field work and the preparation of this report, respectively.

Also acknowledged is the assistance of Mr. C.G.E. Downing, former Director, Engineering Research Service, Agriculture Canada, who acted as Scientific Authority for Contracts OSW4-0085 and OSW5-0007, of which this study forms a part.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE		PAGE

FOREWORD

This report covers the period from the fall of 1973 to the summer of 1977 during which time a variety of research and monitoring activities were taking place under the auspices of the I.J.C. Pollution from Land Use Activities Reference Group (PLUARG), Task C, Agricultural Watershed Studies. Two distinct studies were undertaken on the topic of the environmental impact of feedlots and manure storages. They were carried out consecutively, - the first was concerned with surface water; the second with groundwater. The reports of these two studies are presented in this volume as two separate sections. Only the discussion of implications for remedial measures and the list of references are common to the two studies, and these appear at the end of the document.

1.0 RUNOFF CHARACTERISTICS AND POLLUTION POTENTIAL

1.1 SUMMARY AND CONCLUSIONS

This report presents the results of a two-year study of runoff quality and quantity from two beef feedlots and two manure storage areas in Southern Ontario. One of the feedlots was paved, while the other had an unpaved soil surface. One of the manure storages held solid (with bedding) manure, the other held semi-solid manure - both were paved.

Runoff quantities were fairly predictable, being approximately 60% of the rainfall, with a mean amount withheld before runoff occurs varying from .15 cm for a paved area to .71 cm for a dry soil surfaced feedlot. Most runoff at the manure storages occurred when these were mainly empty in the summer. Runoff from the feedlots was about the same in summer and winter when expressed as a percentage of the precipitation.

Very large degrees of variability were observed in runoff water quality on a sample to sample basis. However, when analysed statistically it was found that significant differences existed between the different sites and between summer and winter for most parameters. Suspended solids increased with increasing rate (depth) of flow. BOD, total solids, Kjeldahl nitrogen and phosphorus were all significantly affected by the suspended solids concentration. A predictive equation was developed for runoff water quality from analysis of variance of concentration data depending on season, site, flow level and suspended solids concentration.

The study permitted the estimation of the pollutant loadings that feedlots and manure storages may yield in runoff. Data collected in an earlier air-photo survey of livestock operations in the Canadian Lower Great Lakes Basin were used to estimate the impact of runoff from feedlots and manure storages in the basin. It was concluded that the contribution of Total Phosphorus from livestock operations probably falls between 0.5% and 13% of the total Great Lakes Basin loadings of this pollutant now coming from agricultural areas.

1.2 INTRODUCTION

During the winter of 1972-73, an Ad Hoc Task Force was established by Agriculture Canada to assess the relationship between agriculture and water quality as a first step towards the implementation of the 1972 Canada-U.S. Great Lakes Water Quality Agreement. Section II of the Task Force Report (Hore and MacLean, 1973) reported on the potential problems which exist when effluents from livestock operations are allowed to enter water courses. The Task Force reviewed the literature and available data on this potential problem and concluded that, among other recommendations, " ..... surveillance of runoff from open feedlots and manure storages should commence as soon as possible to quantify this source of pollution". In addition to measuring the quantity and quality of runoff from these areas, further objectives listed were to provide information from which to develop control facility design requirements and runoff prediction equations.

The project described in the following pages was initiated soon after the Task Force made its report. It was designed to investigate a small number of sites in South Western Ontario (i.e. in the Great Lakes Drainage Basin) which were representative of a range of livestock feedlots and manure storage conditions found in the area. It was not anticipated that the solutions would be provided for specific problems, but rather that an indication of potential problems and meaningful relationships would be obtained. The project was commenced in the fall and winter of 1973, and field observations ceased after 2 complete years at each site.

Shortly after the initiation of the project, the International Joint Commission established a Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG). A significant portion of the field studies funded under the Task Group C of PLUARG deal with the examination and quantification of the effect of agricultural activities on Great Lakes water quality. The project described in this report was subsequently incorporated into the Detailed Study Phase of the PLUARG Task C Agricultural Watershed Study, and constitutes Project No.21 in the Detailed Study Plan, 1975-76. (I.J.C., PLUARG, October 1975).

During the initial 6-month period, funding for this project was provided by the Interdepartmental Committee on Water of the Federal Government, through Agriculture Canada and Environment Canada, in support of the 1972 Canada-U.S. Water Quality Agreement. Since April 1974, the operating costs of the project have been covered by the Engineering Research Service, Agriculture Canada, with funds provided by the Treasury Board in support of the I.J.C. PLUARG programme. The project was initiated by Mr. F.R. Hore of the Engineering Research Service, Agriculture Canada, who remains as a Project Leader in the PLUARG programme. Responsibility for the operation and analysis of the study was assumed by D.R. Coote first under the terms of Contract No. OSW4-0085, and later under the requirements of Contract No. OSW5-0007, both with the Engineering Research Service through the Department of Supply and Services. In February 1974, a detailed progress report was presented to the Engineering Research Service describing the progress of this study in the first year of operation.

This final report describes the background and nature of the Feedlot and Manure Storage Runoff Study, and presents an analysis of results and conclusions drawn at the end of two years' work.

1.3 REVIEW OF LITERATURE

General

There have recently been three excellent reviews made of literature pertaining to the problem of livestock wastes. In 1971, McQuitty et al conducted a literature review on feedlots as a source of pollution. The Task Force Report (Hore and MacLean, 1973) on the Implementation of the Great Lakes Water Quality Agreement took an overview approach to the problem on the Canadian side of the Great Lakes Drainage Basin. The following year, Task A of the International Reference Group on Great Lakes Pollution from Land Use Activities prepared a U.S. report (Loehr, 1974) which reviewed over one hundred documents on this subject.

McQuitty et al reviewed a large number of papers identifying feedlots as sources of pollution and fish kills in receiving streams. They showed the need for the establishment of some criteria on the acceptable pollutant loading from individual feedlots in terms of annual B.O.D. (biochemical oxygen demand) or some other appropriate parameter. They also recognize the problem of determining the proportion of feedlot runoff which actually enters a receiving body of water. McQuitty et al (1971) also stressed the need for additional information on runoff volumes from feedlots for predictive purposes and for establishing the relative significance of these pollution sources compared to other sources.

Hore and MacLean (1973) considered the situation in Ontario, including the legislative options for control of serious livestock pollution problems. They pointed out the need to anticipate runoff storage requirements for pollution control, and the present lack of information on which to base design criteria. Their discussion divided the animal waste problem into three areas of concern -- i) nutrients; ii) Biochemical Oxygen Demand; and iii) pathogenic organisms. They reviewed the chemical, transport and control processes in some detail prior to making their recommendations.

Loehr (1974) followed a similar procedure in his review of the situation relative to the U.S. portion of the Great Lakes Basin. He recommended a number of measures which should be undertaken to meet identified information needs including the following which are related to feedlots and manure storage -- i) studies of runoff and pollutant loss relationships; ii) studies of groundwater contamination from leachates originating in these areas.

Ontario

Literature which is more specific to the situation and conditions which are found in Ontario is somewhat sparse. Townshend et al (1969) reviewed conditions in Ontario at that time, emphasizing the trend towards fewer farms and larger sizes of remaining operations. Especially noticeable was the rise in numbers of beef cattle in the Province since 1948 -- a rise which was not observed for other livestock types. The data presented in their paper relative to the magnitude of the disposal problem were based on U.S. data and Ontario livestock population statistics. They presented the results of a survey of liquid manure disposal systems in the Province. They concluded that the problems with livestock waste disposal were increasing, that more information on waste properties and quantities was needed, and that disposal should be aimed at return to the soil and not to discharge to water courses. In a later paper, Townshend, Janse and Black (1969) discussed the beef feedlot problem in Ontario in more detail. They showed that in 1969 there were 100,000 head of beef cattle in feedlots in Ontario, with an average of about 150 animals per feedlot. The waste loading from these confined beef cattle was equivalent to about 1 million people in terms of B.O.D. However, the total cattle population, all of which are confined at some period during the year in Ontario exceeded 3 million (Townshend et al, 1969). It was suggested that about 6 months storage must be provided for wastes from confined cattle in Ontario.

Jensen (1972), indicated that only if a feedlot or other confinement area was located near a water course should a water pollution problem arise. However, runoff control was a major concern of a survey of feedlot pollution problems which he conducted for his report.

In 1973, MacDonald examined the effects of 17 feedlots on streams draining to Lake Ontario. He concluded that runoff caused pollution only during the spring runoff when it was most likely to reach a receiving stream. Either short distances or the presence of drainage tile between the feedlot area and the stream contributed to observed incidences of pollution. In most cases gross pollution was negligible and well below "permissible limits" set by Ontario Ministry of the Environment. He also concluded that the actual pollution of receiving streams from these sources is far less than the potential often indicated in the literature.

In 1974, Irwin and Robinson reported on a study of runoff from a feedlot to a holding pond. They were able to estimate runoff based on a 15-day period, but not on a storm-event basis.

Other Areas

There is a large volume of data in the literature describing conditions observed around feedlots and manure storages throughout North America and other continents. It serves little purpose to discuss the comparability of these situations with those found in Ontario at this stage of this report. Rather, in the section on Results and Discussion, reference will be made to relevant observations in other areas, emphasizing differences in local conditions and identifying common trends.

It will be seen from the foregoing that there has been in general, a need identified for additional information on the volumes, overall quality and pollutant loadings of runoff from cattle feedlots and manure storage areas in the Ontario portion of the Great Lakes Drainage Basin. The study described in this report was initiated with this need in mind, and contributes significantly to a better understanding of the problems associated with controlling pollution from these sources. It should be noted that a parallel and complimentary study, under the auspices of the I.J.C. - PLUARG Programme on Agricultural Watersheds, has been conducted by BEAK Consultants Ltd. (Detailed Study Plan, 1975). The study has estimated the effect of a number of livestock operations on a small study basin in the Ausable River watershed.

1.4 METHODS AND MATERIALS

The objective of the study was to characterize the quality and quantity of runoff to be expected from feedlots and manure storage areas in Southern Ontario. The sites which were to be studied, therefore, had to be fairly representative of livestock operations in the Province. It was determined at the outset of the project that, in order to cover the most common potential sources of polluted runoff, at least four distinct conditions should be covered:

1) A beef feedlot on a paved surface.
2) A beef feedlot on an unpaved (soil) surface.
3) A manure storage area, paved, but where the manure is mixed with large quantities of bedding - such as with a conventional tie-stall type dairy barn.
4) A manure storage area, paved, but where manure is essentially unaltered by bedding additives, such as might be the case with a free stall confinement housing area, with cattle sleeping in cubicles.

A suitable beef feedlot on a paved surface was readily identified from existing information. The remaining 3 sites proved more difficult to locate. The Ontario Ministry of Agriculture and Food (O.M.A.F.) Agricultural Representative (livestock) in Waterloo County, Mr. Lance Warren, assisted in the identification of sites for consideration, as did Mr. Martin Wrubleski, O.M.A.F., Engineering Extension Specialist at the University of Guelph*. The senior author and Mr. John Gall of Engineering Research Service, Agriculture Canada, Ottawa, visited a number of farms and three additional sites were selected.

Arrangements were made, at the outset of the project, to have the Ontario Ministry of the Environment (O.M.O.E.) Laboratories at London, Ontario, conduct analyses on samples collected from the feedlot and manure runoff sites. These laboratories are under the direction of Dr. David Glutek, whose assistance and cooperation is deeply appreciated. Laboratory analyses were conducted on the raw runoff samples as follows:

---

*Now Agricultural Engineering Research Specialist, Saskatchewan Department of Agriculture, Regina.

5-day Biochemical Oxygen Demand (BOD_5)
Suspended Solids
Total Solids
Free Ammonia
Kjeldahl Nitrogen
Nitrite (NO_2^-)
Nitrate (NO_3^-)
Total Phosphorus
Soluble Phosphorus

Samples were collected by the farmers after each runoff event, and shipped (unfiltered and unrefrigerated) as rapidly as possible (to arrive within 48 hours) to the O.M.O.E. Laboratories in London.

The laboratory analyses performed by the Ontario Ministry of the Environment at London, Ontario, were by the methods described below:

B.O.D., Total Solids, Suspended Solids: Five day, 20°C B.O.D., total solids and suspended solids were analysed according to "Standard Methods" (1965) with suspended solids being determined with a Reeve Angel fiber-glass filter. (approximately 1 - 2μ).

Free Ammonia: Free ammonia was determined, following filtration, by colour development with alkaline phenol hypochloride, and spectrophotometry by autoanalyser.

Total Kjeldahl Nitrogen: Total Kjeldahl nitrogen was determined by standard Kjeldahl distillation after digestion with sulphuric acid and potassium persulphate.

Nitrite Nitrogen: Nitrite nitrogen was determined by colour development with sulphanilic acid and naphthylamine hydrochloride, with photometry by autoanalyser.

Nitrate Nitrogen: Nitrate was catalytically converted to nitrite by passage over granular metallic cadmium, then the nitrite was determined as above.

Soluble Phosphorus: Soluble P was determined after filtration, by phosphomolybdate colour development after treatment with ammonium molybdate and stannous chloride. Measurement of colour was achieved with the autoanalyser.

Total Phosphorus: Total P was determined by digesting unfiltered samples with sulphuric acid and potassium persulphate (as for pre-treatment of samples for Kjeldahl distillation), followed by measurement of phosphate as described above.

For the study of the presence of infectious bovine enteroviruses, 4 litre samples were collected in clean, (new) glass bottles and shipped directly (less than 3 hours) to the laboratory of the Department of Veterinary Microbiology, Ontario Veterinary College, Guelph University for analysis under the direction of Dr. J. Brian Derbyshire. The method employed was to pool the sample bottles, concentrate by talc-celite adsorption and then passage both the original pool and the concentrates in embryonic bovine kidney cell cultures.

1.4.1. STUDY SITES

Figure 1. indicates the approximate location of the four sites within the region of Southwestern Ontario.**

Runoff Site 1: The paved feedlot was part of a beef raising complex in Kent County, near the Town of Chatham. The feedlot housed approximately 500-600 beef cattle, ranging in size from about 800 to 1200 pounds. They were fed a non-commercial mix of grain and silage made from sweet corn processing plant waste.

Roof runoff from the covered portion of the feedlot entered an underground tile directly via eavetroughs and down pipes, and was thus excluded from the feedlot runoff. The slope of the concrete paved area was gentle, being less than 1%. The area was approximately 2,446 square metres (26,350 ft^2). The feedlot runoff passed through a shallow "settling basin" (of approximately 4.3 m^3 capacity) and then into a 10" diameter clay tile pipe which conducted it a distance of approximately 750 metres (2,500 ft) through an area of imperfectly drained Tuscola fine sandy loam soils, to a stream. Gauging and sample collection was done at the outlet from the settling basin to the discharge pipe. The surface of the feedlot was mechanically scraped regularly with a determined effort being shown by the operator to scrape prior to any anticipated rainfall event. The solids which collected in the shallow settling basin were removed by a front-end loader after each runoff event whenever possible.

Cooperation on the part of the feedlot operator was good, contributing to reliable results at this site. Samples were shipped to the London M.O.E. Laboratories by C.N. Express from Chatham the day of collection. The site was equipped with runoff measuring and sampling devices, and a recording raingauge, in August, 1973, after constructing a concrete block retaining wall on which to mount the flume.

Figure 2 shows a sketch of the layout of the feedlot and the monitoring area.

** For the purpose of this report, the owner and operator of any facilities studied will not be identified, as cooperation on the part of the farmer is dependent on anonymity.

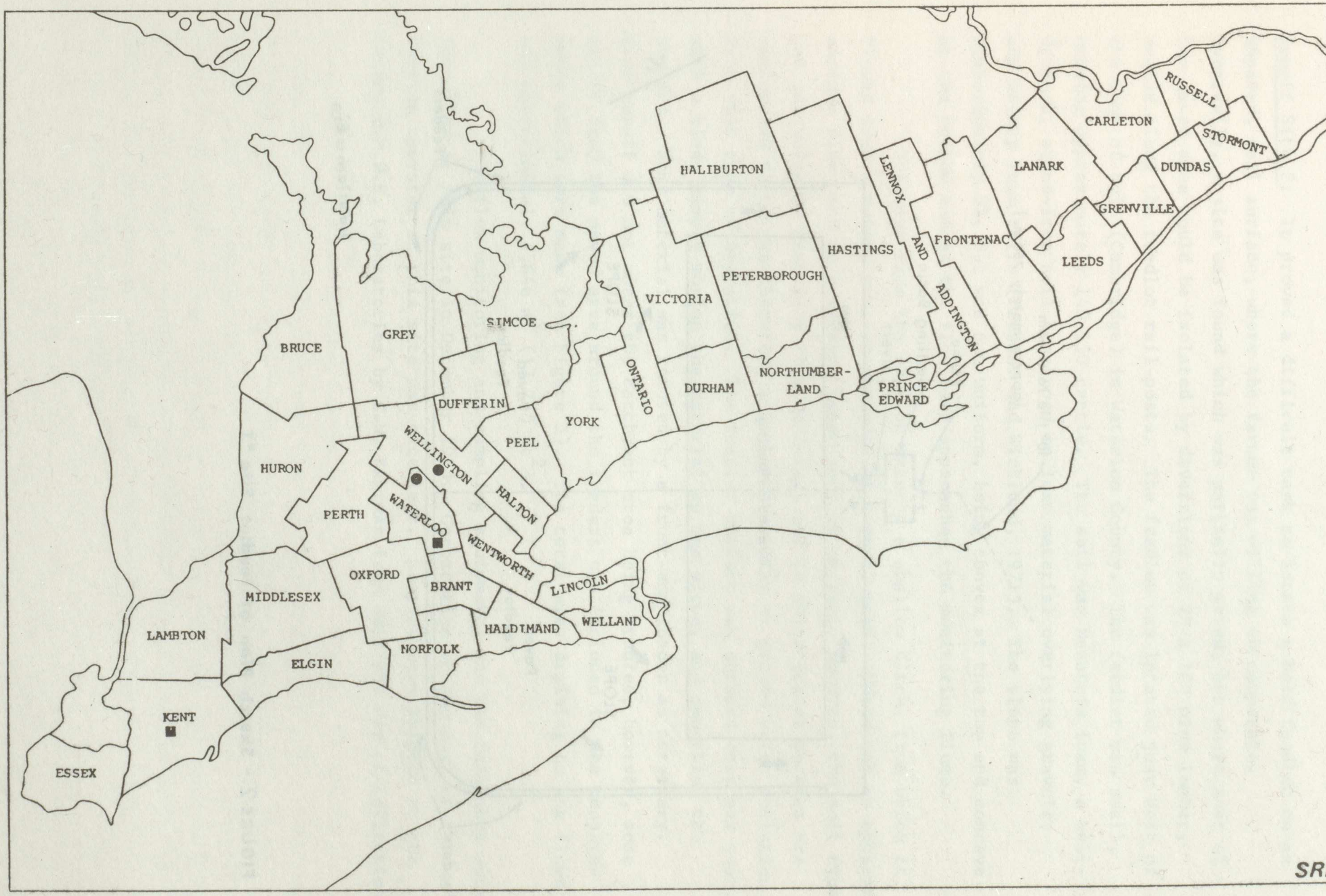

Figure 1. Location of the two feedlots (■) and two manure storage areas (●).

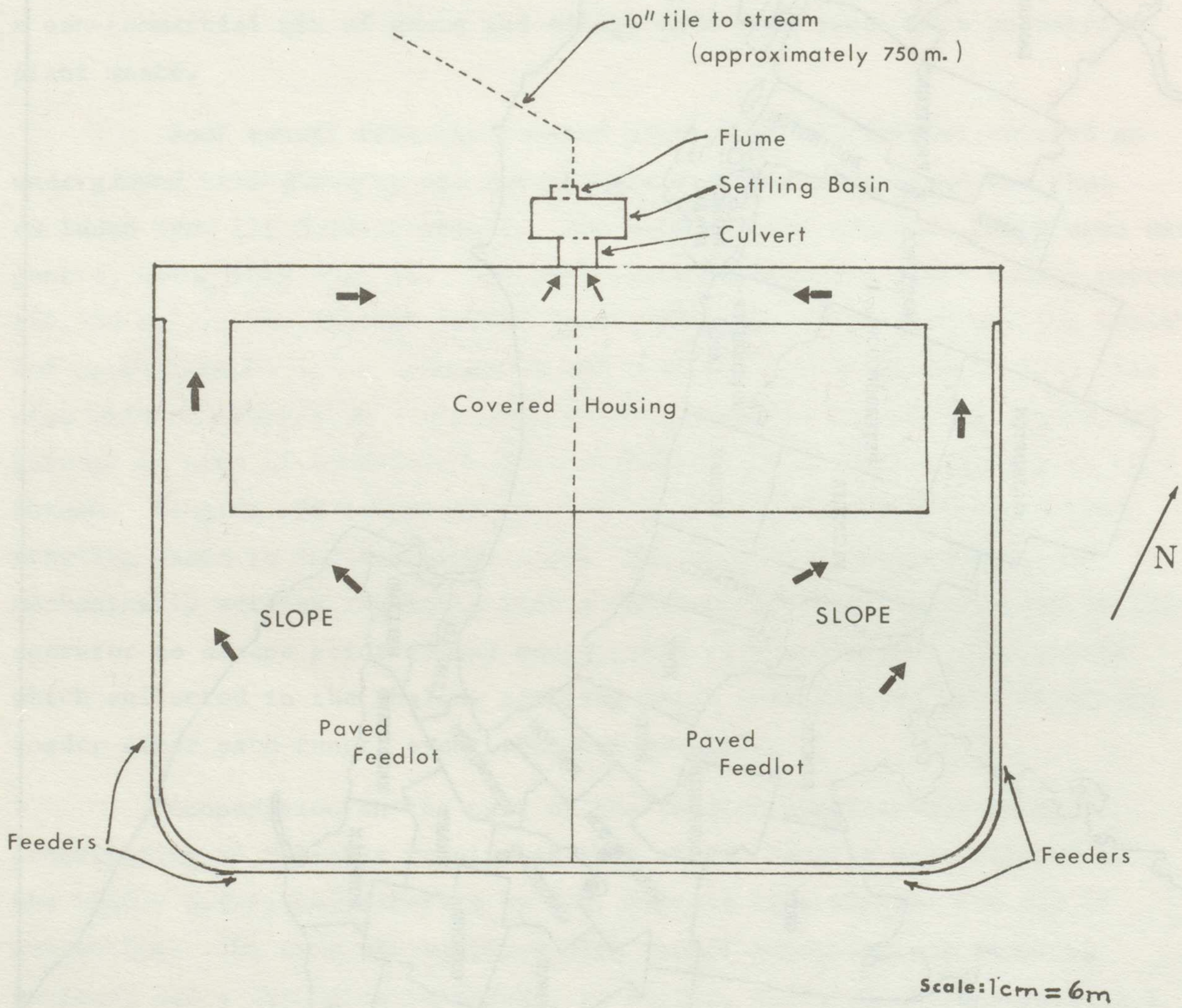

FIGURE 2 - Sketch Plan of Feedlot, Site #1

Runoff Site 2: It proved a difficult task to locate a beef feedlot on an unpaved, soil surface, where the farmer was willing to cooperate. Eventually, a site was found which was partially paved, but where most of the paved area could be isolated by diversions of 2" x 10" pine lumber, nailed along the feedlot rail-posts. The feedlot was located just West of the Town of Galt (Cambridge) in Waterloo County. The feedlot was small, housing approximately 140-150 cattle. The soil was Mannheim loam, a well-drained, stone-free soil developed on loam material overlying gravelly and stoney loam tills (Presant and Wicklund, 1971). The slope was approximately 3%, but was not uniform, being convex at the top and concave at the bottom end as the flow path approaches the monitoring flume.

Drainage from the feedlot entered a shallow ditch, from which it flowed into a marshy area at the edge of a small wood. There was no apparent surface flow path to a surface water body or stream. However, the soil type was one which is generally free draining, and in which gravel pockets are common and there was therefore a high probability of ground water pollution from this type of operation. The feedlot surface was scraped once per year, with a blade simply moving the material up the slope, and smoothing the surface. Some material was removed by a front-end loader as necessary. Roof runoff did not enter the catchment area being studied; however, some runoff from the paved area around the feeders was included in the measurements which were made (see Figure 3). The total area draining to the flume was approximately 1,646 m^2 (17,735 ft^2).

The flow monitoring and sampling equipment, and the raingauge were installed at this site in December 1973. Cooperation on the part of the feedlot operator at this site was excellent. Samples were shipped to the London O.M.O.E. Laboratories by C.N. Express from Galt the day of collection.

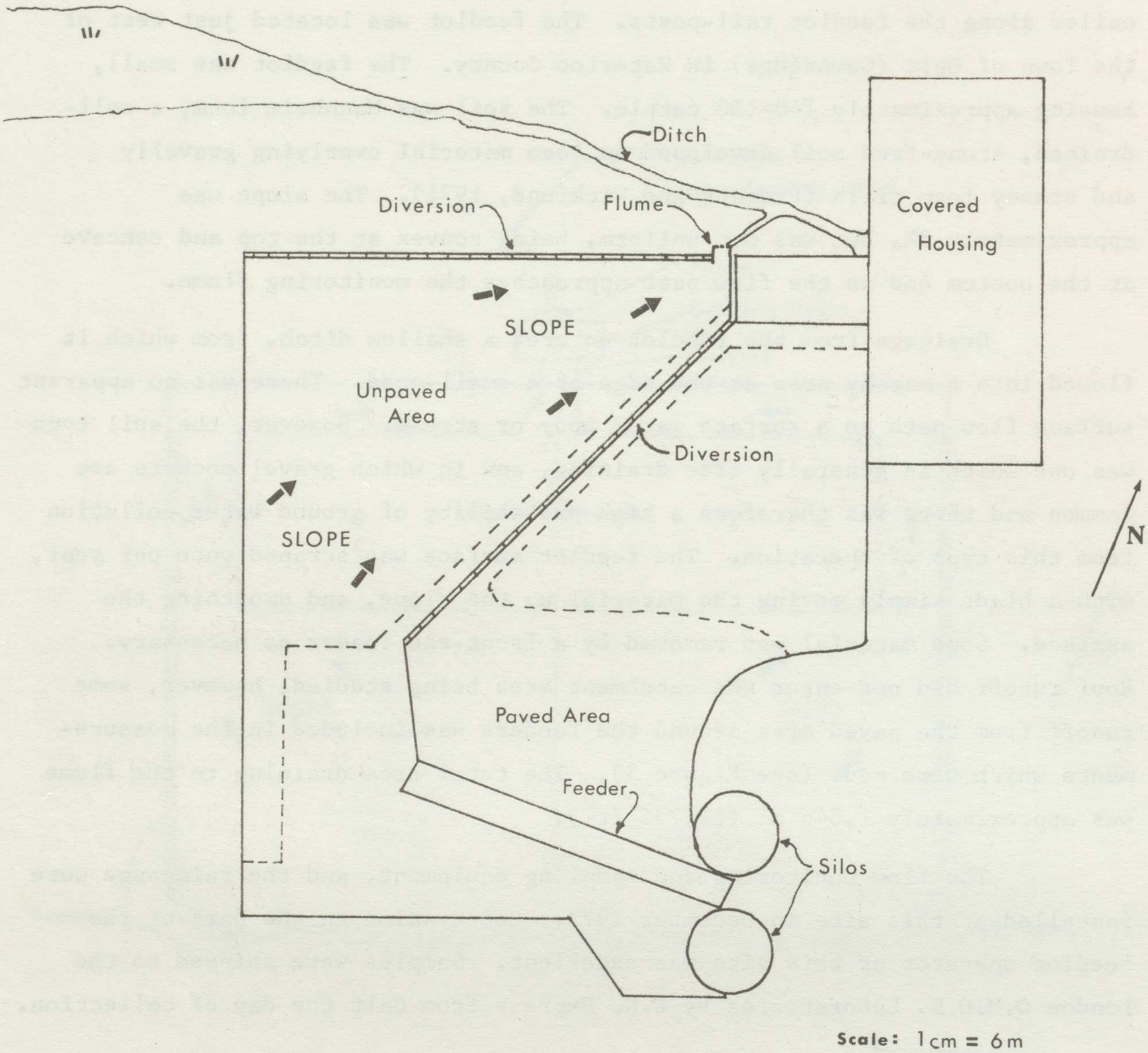

FIGURE 3 - Sketch Plan of Feedlot, Site # 2

Runoff Site 3: The third runoff monitoring site was located near Elmira and consisted of a manure storage area adjacent to a dairy barn at the top of a slope leading directly to a branch of the Canagagigue Creek. The area was used to store the manure and used bedding material from approximately 40 dairy cows and 60 young stock and calves, for periods of up to 4 months. Maximum storage occurred in March and early April, with removal started as soon as weather conditions permitted in late April and in May. The soil was Burford gravelly loam on a slope of about 3%, dropping off steeply to 6-12% below the manure storage area. About two-thirds of the total area of approximately 502 square metres (5,400 ft^2) was paved with concrete. Roof runoff from the barn was directed out of the catchment area by eavestrough down pipes which conveyed this water to the slope to the east of the silos (Figure 4). Farmer cooperation was excellent at this site.

Runoff Site 4: The fourth site was a manure storage area associated with a confined housing dairy operation. Approximately 100 dairy cows were housed in a free-stall barn, with manure being scraped daily to a centrally located gutter cleaner which conveyed this material to the manure storage area. This area was entirely paved with a retaining wall on two of the downslope sides. On the third downslope side, a metal and plywood retaining wall was constructed to confine runoff and to facilitate the mounting of the H-flume. Manure was removed from this area regularly throughout the summer, and in winter a small dyke of bedding material from the calf pens was placed between the semi-solid manure and the outlet. This had the effect of holding back the manure and retaining runoff. The runoff from the area spread out over a cultivated field with a flow path of at least 3,000 ft. to the nearest intermittant stream course (see Figure 5). Roof runoff from the free-stall barn was not diverted from the manure storage area. However, a sod strip approximately 20 ft. wide separated the barn from the concrete manure storage pad, and little, if any, roof runoff ever reached the concrete pad. Some difficulties were encountered with maintenance of the monitoring installation. However, the nature of the site and the runoff pattern was such that in 1974, practically no runoff occurred, and in 1975 most runoff occurred during the summer when satisfactory alternative arrangements were made for chart changing and sample collection.

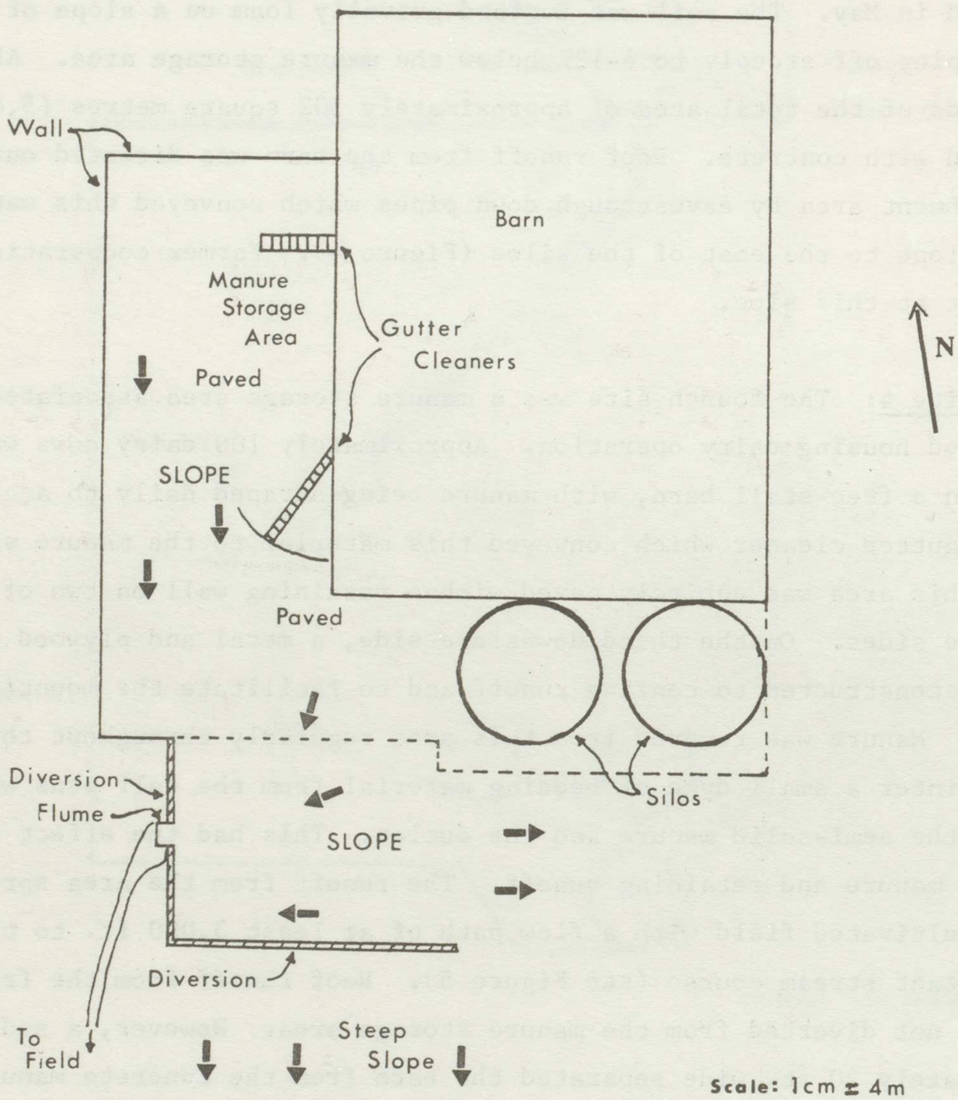

FIGURE 4 - Sketch Plan of Manure Storage, Site #3

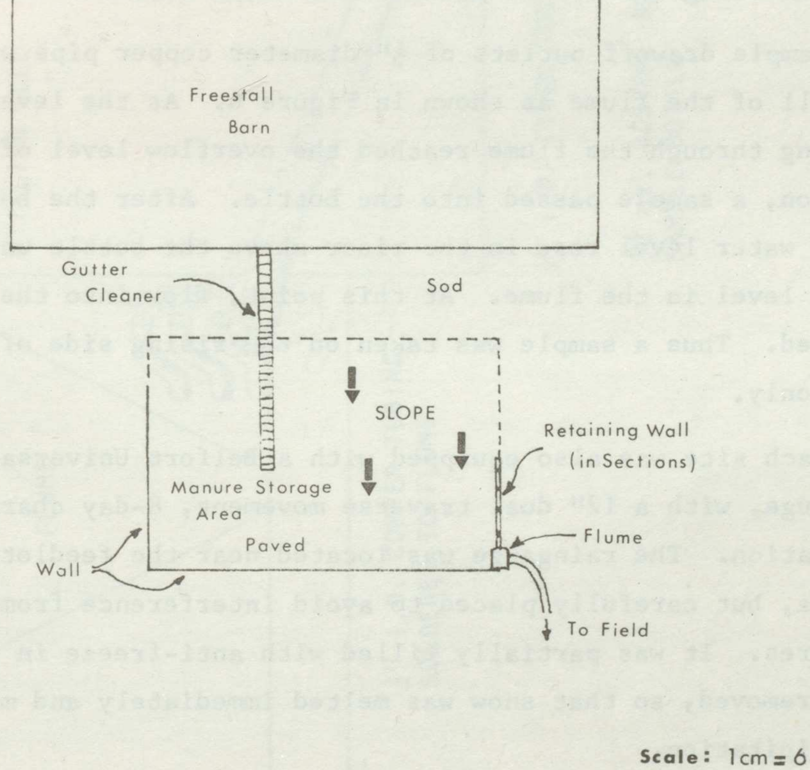

FIGURE 5 - Sketch Plan of Manure Storage, Site # 4

1.4.2. MONITORING EQUIPMENT

Each site was equipped as follows:

A 0.75 ft. (22.9 cm) "H"-flume was installed at the outlet of each site. The flumes were constructed to conform to U.S. Department of Agriculture Drawing No. P-2145* and were of stainless steel type 304-2B. The flumes were constructed by Alexander Metal Products, Ltd., of Ottawa. Each flume was fitted with a Belfort FW-1 Portable Liquid Recorder, equipped with 8-day chart drive and 24-hour rotation. A drain valve was fitted to the stilling well/float chamber to facilitate washing the equipment after a runoff event, and to allow the draining of the float chamber in freezing weather to protect the float from ice damage.

Sample drawoff outlets of ½" diameter copper pipe were soldered into the wall of the flume as shown in Figure 6. As the level of the water passing through the flume reached the overflow level of the outlet configuration, a sample passed into the bottle. After the bottle was filled, the water level rose in the riser above the bottle until it reached the level in the flume. At this point, flow into the sample bottle ceased. Thus a sample was taken on the rising side of the flow hydrograph only.

Each site was also equipped with a Belfort Universal Weighing type Raingauge, with a 12" dual traverse movement, 8-day chart drive and 24-hour rotation. The raingauge was located near the feedlot or manure storage area, but carefully placed to avoid interference from objects and structures. It was partially filled with anti-freeze in winter, and the funnel removed, so that snow was melted immediately and measured as liquid precipitation.

---

*Harrold, L.L. and D.B. Krimgold, 1943; Runoff Measuring Devices. Soil Conservation Research, Water Conservation and Disposal Practices Division, S.C.S. - Research, U.S.D.A. p.24.

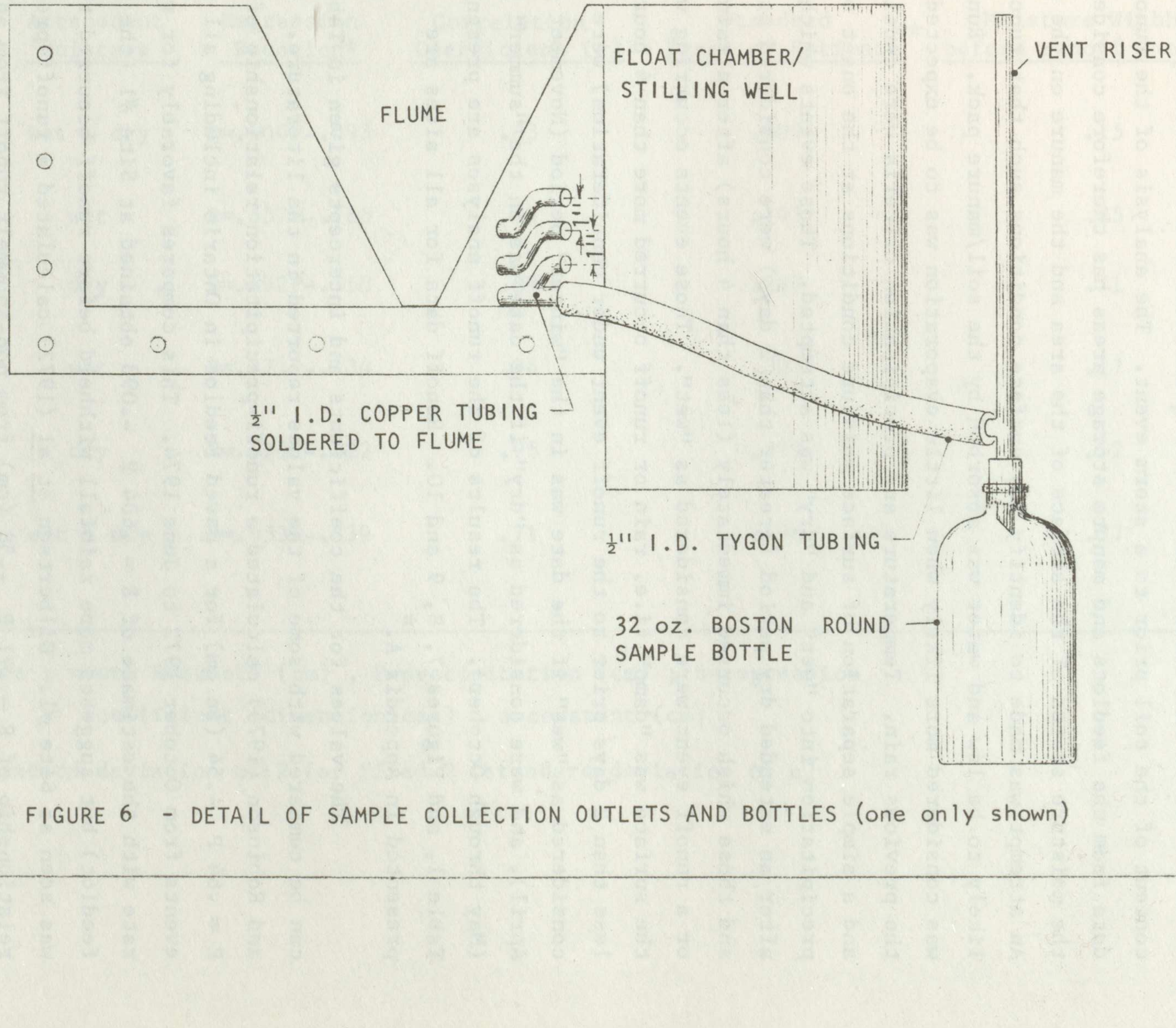

FIGURE 6 - DETAIL OF SAMPLE COLLECTION OUTLETS AND BOTTLES (one only shown)

1.5 RESULTS AND DISCUSSION

1.5.1. RUNOFF

It is well known that runoff quantities are affected by the moisture content of the soil prior to a storm event. The analysis of the runoff event data from the feedlots and manure storage areas has therefore considered the moisture status of the surface of the area and the manure on the area. An attempt was made to identify dry surface conditions such that runoff was likely to be low and water was absorbed by the soil/manure pack. Runoff was considered more likely when little evaporation was to be expected since the previous rain. Temperature and precipitation criteria were considered and a simple separation of surface moisture conditions at the onset of precipitation into "wet" and "dry" was attempted. Those events which occurred after an extended dry period (greater than 2 days) were considered as "dry", and those which occurred immediately (less than 4 hours) after a rainfall or a runoff event were considered as "wet". Those events occurring when the surface was "damp" (i.e. rain or runoff occurred more than 4 hours but less than 2 days prior to the runoff event under consideration) were considered as "wet" if the date was in the "winter" period (November through April), and were considered as "dry" if the date was in the "summer" period (May through October). The results of the runoff analyses are presented in Table 1, and Figures 7, 8, 9 and 10. Runoff data for all sites are presented in Appendix A.*

The values for the coefficients and intercepts given in Table 1 can be compared with some of the values reported in the literature. Irwin and Robinson (1975) calculated a runoff-precipitation relationship of $R = .64 P - .54$ (in cm) for a paved feedlot in Ontario including all runoff events from October 1972 to June 1974. This compares favorably for runoff rate with the estimate of $R = .604 P - .093$ obtained at Site #1 (the paved feedlot) but suggests more rainfall withheld before runoff occurred than was seen at Site #1. Gilbertson et al (1972) calculated a runoff precipitation relationship of $R = .71 P - .58$ (cm) from non-snowmelt runoff from an unpaved feedlot in Nebraska. This compares reasonably well with the equation $R = .657 P - .165$ obtained at the unpaved feedlot in this study (Site #2) for events preceded by wet conditions but again represents more withheld rainfall before runoff occurred. The runoff rate appears to be higher than the prediction $R = .492 P - .350$ obtained at Site #2 for dry antecedent moisture conditions.

---

*A computer programme was written by the senior author to convert flow hydrographs to volumetric discharges. The programme is not listed here, but details may be obtained from the author on request.

TABLE 1: Runoff Prediction by Linear Regression of Runoff vs Precipitation (in cm) by Events, 1973-75

Site No.	Antecedent Moisture	Regression Equation*	Correlation Coefficient (r)	Standard Error of Estimate**	Moisture Withheld before runoff (mean) cm
1	wet & dry	R=.604P-.093	.83	.309	.15
2	wet	R=.657P-.165	.88	.197	.25
	dry	R=.492P-.350	.89	.287	.71
3	wet	R=.771P-.134	.96	.301	.17
	dry	R=.625P-.322	.95	.299	.52
4	wet & dry	R=.653P-.239	.71	.496	.37

*R=bP+a ; where R=runoff (cm) , P=precipitation (cm) ; b=regression coefficient (dimensionless) , a=constant (cm)

** Standard deviation of R for fixed P (standard deviation of a)

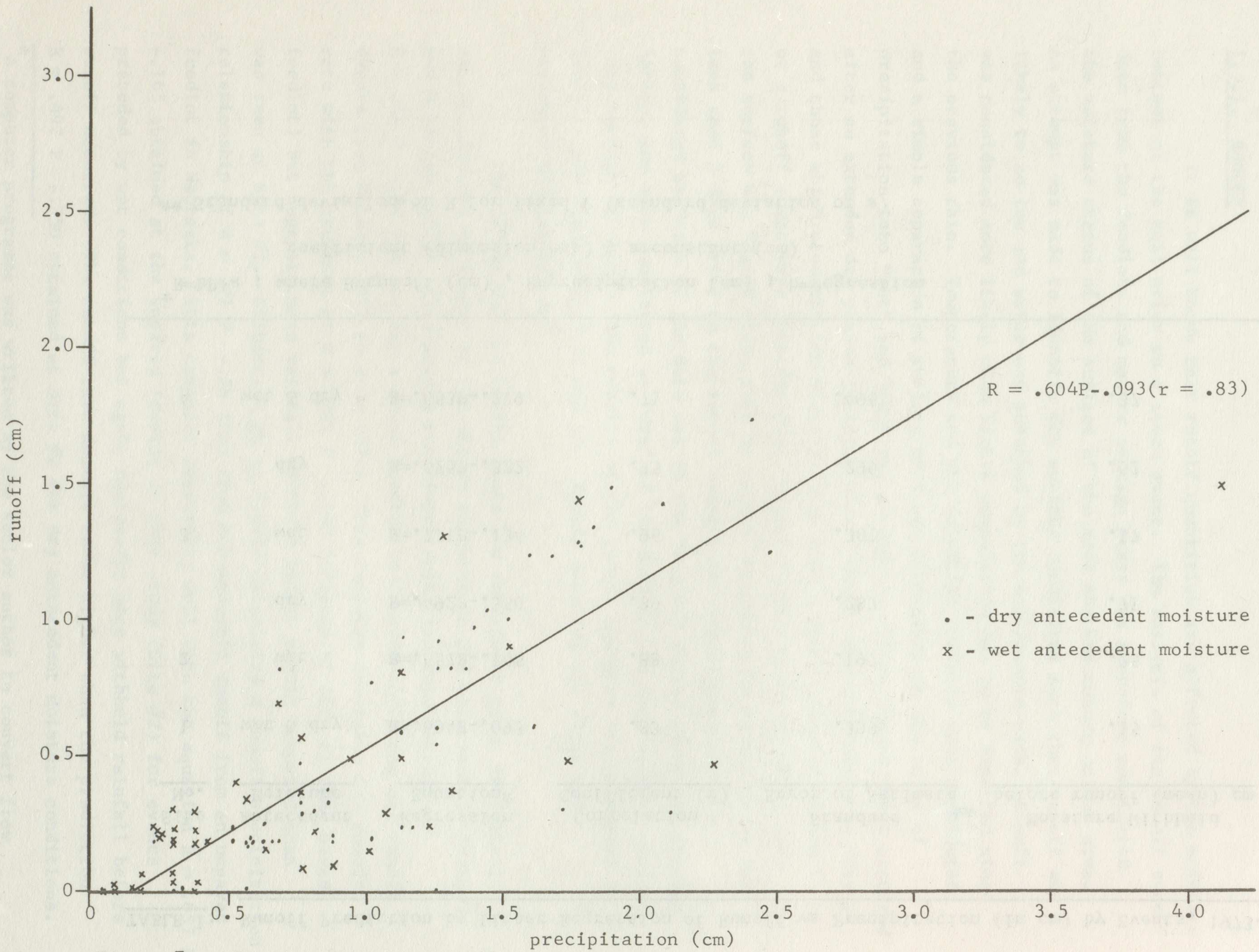

Figure 7 : Precipitation vs Runoff -
Site #1 (paved feedlot), 1973-75.

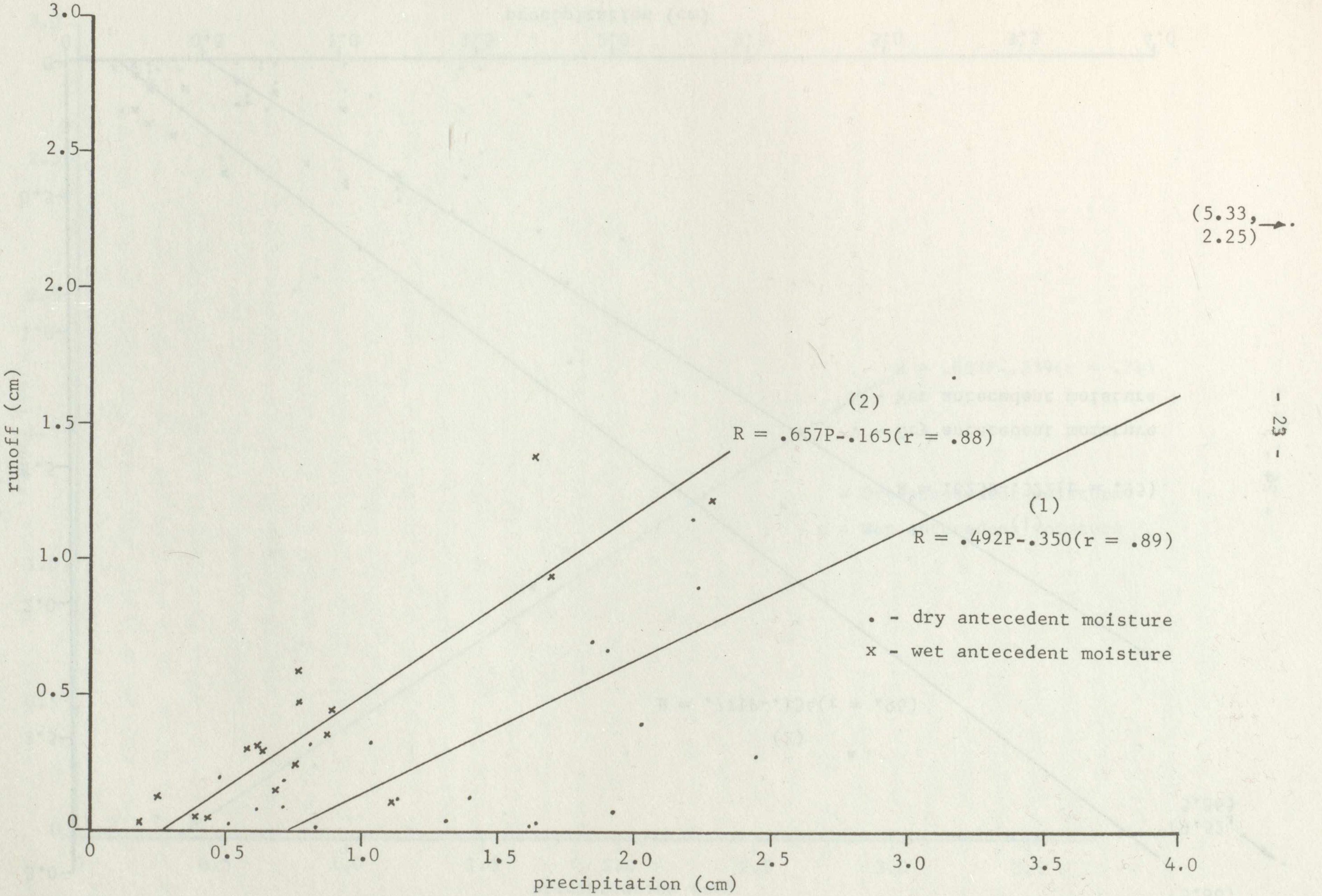

Figure 8 : Precipitation vs Runoff - antecedent moisture conditions dry (1) and wet (2) - Site #2 (unpaved feedlot), 1973-75.

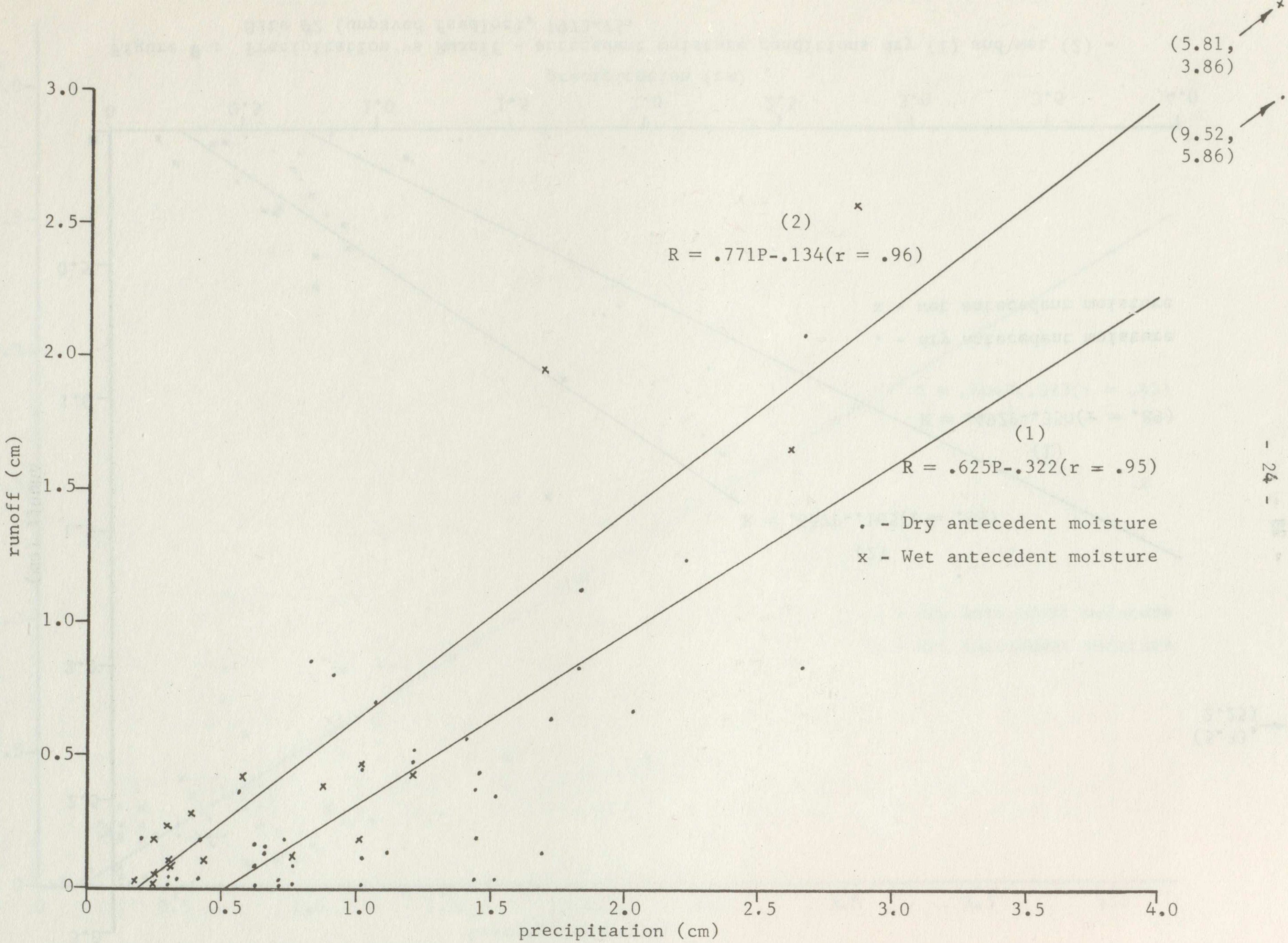

Figure 9 : Precipitation vs Runoff - antecedent moisture conditions dry (1) and wet (2), Site #3 (solid manure storage), 1973-75.

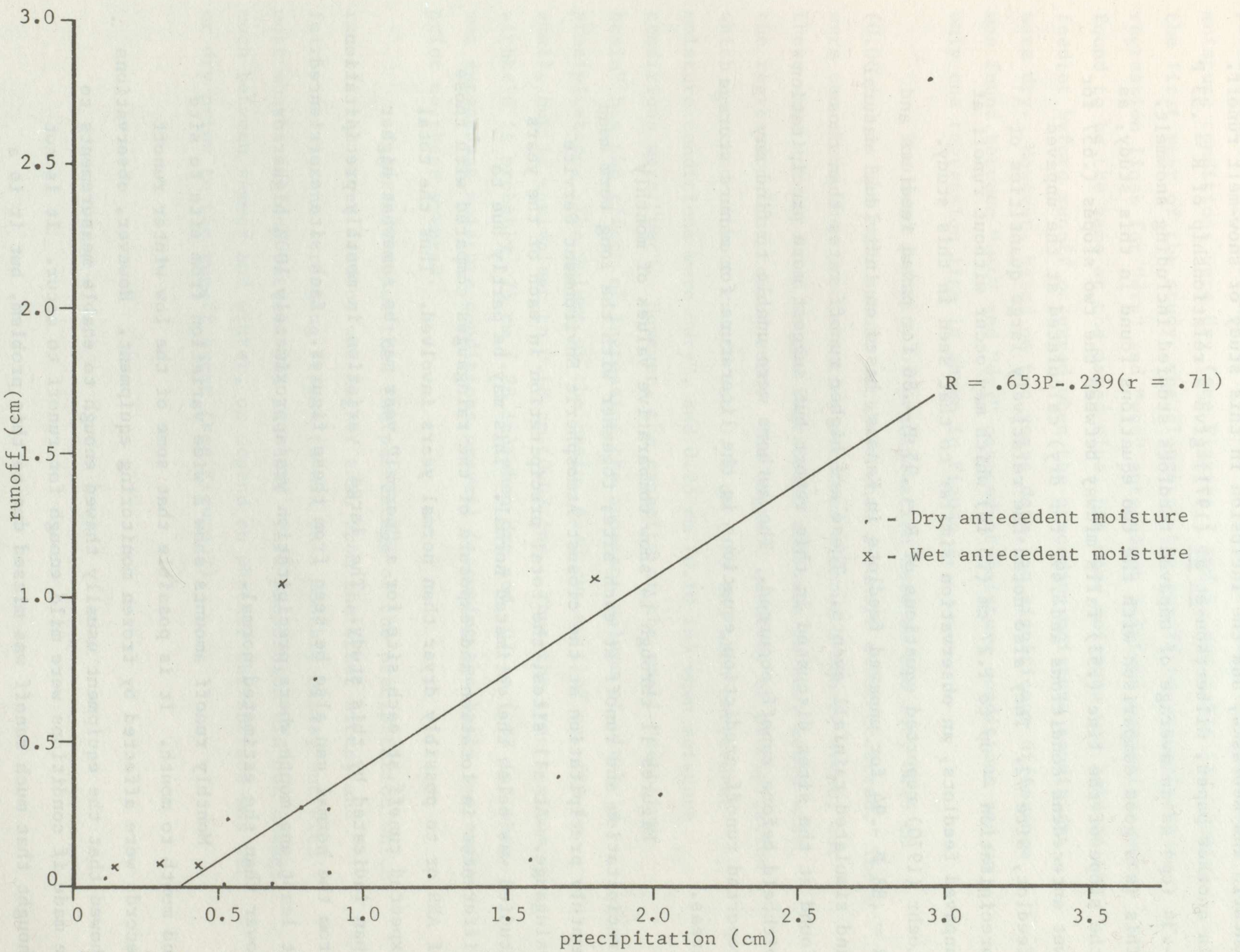

Figure 10: Precipitation vs Runoff - Site #4 (semi-solid manure storage), 1973-75.

This probably reflects differences in the rainfall characteristics between Ontario and Nebraska, and the inclusion in this study of snow-melt runoff. In another paper, Gilbertson et al (1971) give a relationship of R = .53 P -.34 (cm) as an average of unpaved feedlots studied including snowmelt. This is a good comparison with the two equations found in this study, as the slope of the line (.53) falls midway between the two slopes (.657 for wet antecedent conditions and .492 for dry) calculated at the unpaved feedlot, Site #2. They also noted the relatively large quantities of precipitation -- up to 1.27 cm (.5 in) which may occur without runoff at unpaved feedlots, an observation similar to that seen in this study. Loehr (1970) reported equations of R = .95 P -.86 for paved feedlots and R = .88 P -.94 for unpaved feedlots in Kansas, based on individual natural and simulated rainfall events. These are higher runoff rates than those found at the sites discussed in this report but suggest more precipitation withheld before runoff occurred. The authors were unable to find any reported runoff prediction equations in the literature for manure storage areas.

Figures 11 through 14 show comparative values of monthly precipitation and runoff at each site, together with the long term mean monthly precipitation at the closest Atmospheric Environment Service raingauge. At all sites, the total precipitation in each of the years studied was below the estimated normal. This may be partly due to differences in location and exposure of the raingauges compared with those of AES or to possibly dryer than normal years involved. Thus the total expected runoff at each site for a "normal" year may be somewhat higher than indicated by this study. The large variation in monthly precipitation from the normal can also be seen from these figures. Each site experienced at least one month where precipitation was approximately 100% higher or lower than the estimated normal.

Monthly runoff amounts show a wide variation from site to site and month to month. It is possible that some of the low winter runoff records were affected by frozen monitoring equipment. However, observations showed that the equipment usually thawed enough to enable measurements to be made if conditions were mild enough for runoff to occur. It is not thought that much runoff was missed due to this problem, but it is a consideration which must not be overlooked.

Site #1: The paved feedlot of Site #1 had a higher ratio of runoff to precipitation than the unpaved feedlot of Site #2 where the antecedent moisture conditions were dry (see Figures 7 and 8, and Table 1). During the first year of the study, the slopes of the runoff to precipitation regression lines for "dry" and "wet" antecedent moisture conditions were found to be the same at the paved site, but more moisture was held on the feedlot before runoff occurred when the preceding moisture conditions were dry. However, based on two years data, no significant difference was found between "wet" and "dry" antecedent moisture conditions and so only one regression line is shown in Figure 7.

The mean quantity of precipitation held on the lot, 0.15 cm (0.06 in) is the mean amount withheld when a runoff event occurred. There were occasions when precipitation occurred without a runoff event, but these were not included in the regression analysis as they would bias the regression line toward zero. The highest quantity of precipitation which occurred without runoff was 0.91 cm (.35 in) when antecedent moisture conditions were "dry", and 0.25 cm (0.10 in) when moisture conditions were "wet". However, the capacity of the small "settling basin" has the effect of increasing the apparent volume of withheld precipitation. The volume of the basin, 4.30 cu. m, (152 cu. ft) is small, but is equivalent to 0.18 cm (0.07 in). Thus the true maximum withheld is probably .73 cm (.28 in) when dry and .07 cm (.03 in) when wet antecedent moisture conditions prevail (assuming the basin was empty prior to these events).

Figure 11 shows that the percentage of the precipitation which ran off the paved feedlot was higher than from the other sites, and fairly consistent - ranging from 6 to 83% on a monthly basis, but with most months falling between 40% and 60%. This proportion did not change much between summer and winter, or depend on whether the surface was wet or dry prior to the runoff event (see Figure 7).

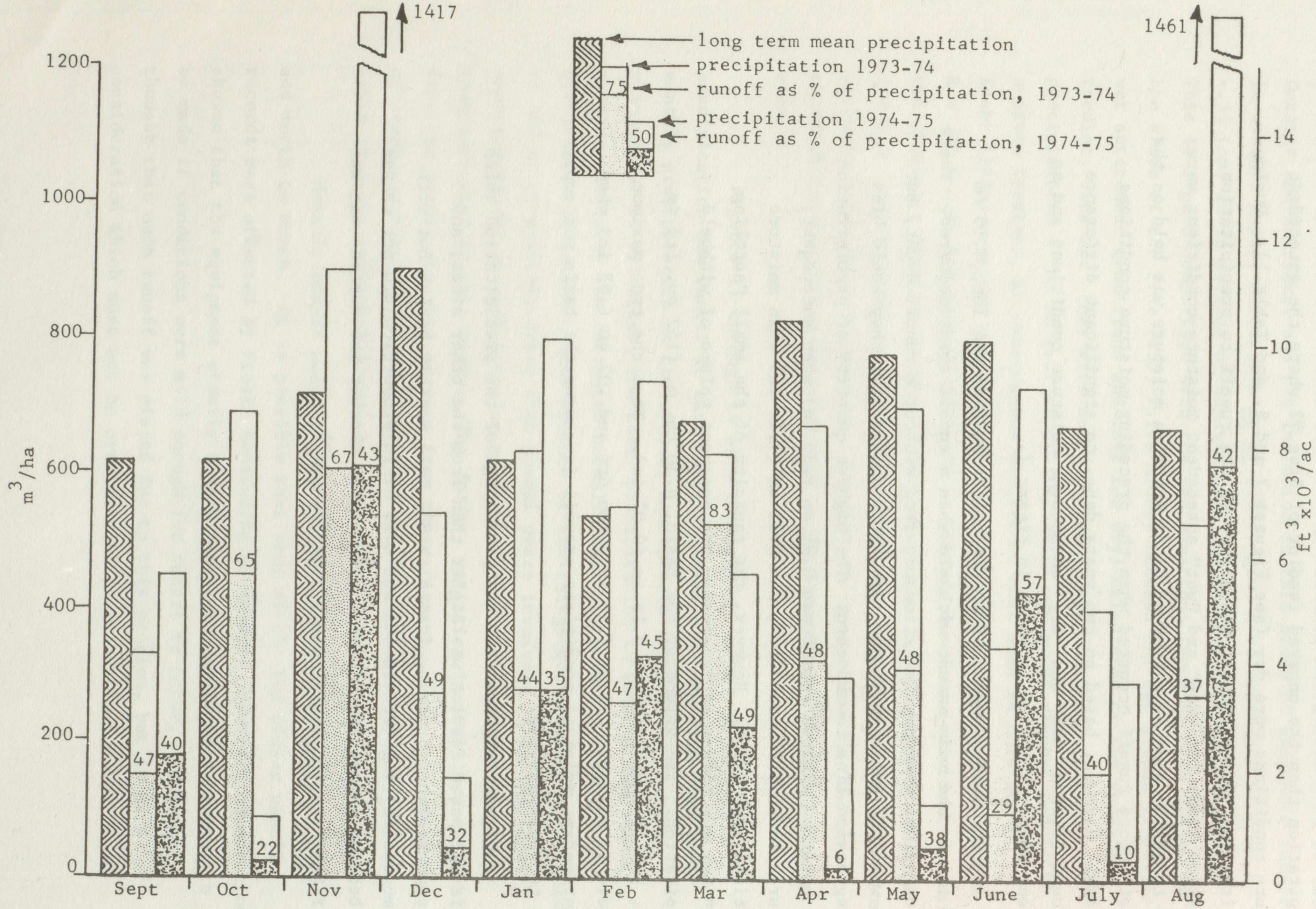

Figure 11: Monthly precipitation (actual and long term mean) and runoff (including some estimates), Site #1 (paved feedlot), 1973-75.

Site #2: Under dry antecedent conditions, runoff from the unpaved feedlot is likely to occur at about 75% of the rate that it would occur following a wet period (.49 compared to .66 times the rainfall, see Table 1 and Figure 8). It has been suggested that the surface of an unpaved feedlot, once runoff has started, will behave like a paved surface, with very little infiltration (Loehr, 1970).

Although the mean moisture withheld by the unpaved surface before runoff occurred was not much greater than that withheld by the paved surface for all events from which runoff was recorded, it is of interest to note that there were occasions when quite large precipitation events were absorbed by the unpaved surface without runoff occurring. The largest amount was 1.60 cm (0.63 ins) from "dry" conditions, and 1.50 cm (0.59 ins) from "wet" antecedent moisture conditions.

Figure 12 shows that the runoff from the unpaved feedlot was lower than that from the paved feedlot (Fig. 11) throughout the year. The range was from zero to 45% of precipitation on a monthly basis, with most months falling between 15 and 30% -- about half that for the paved feedlot. This difference does not show clearly on the rainfall-runoff scatter diagrams and regression lines (Figures 7 and 8) as the large numbers of events from which no runoff occurred at the unpaved feedlot do not appear on these graphs. It is probably that the deeper manure/ soil pack on the unpaved feedlot holds back more water before runoff occurs, but that once runoff starts, the depressions and hoof marks which held the water begin to collapse and fill with sediment, allowing the water to rill towards the outlet. This results in an overall loss, once runoff has started, which is not greatly different from that seen at the paved feedlot. However, if the rainfall is insufficient to cause the initial flow to commence, then the water remains on the feedlot in the depressions and hoof marks to a far greater extent than is seen on the paved surface.

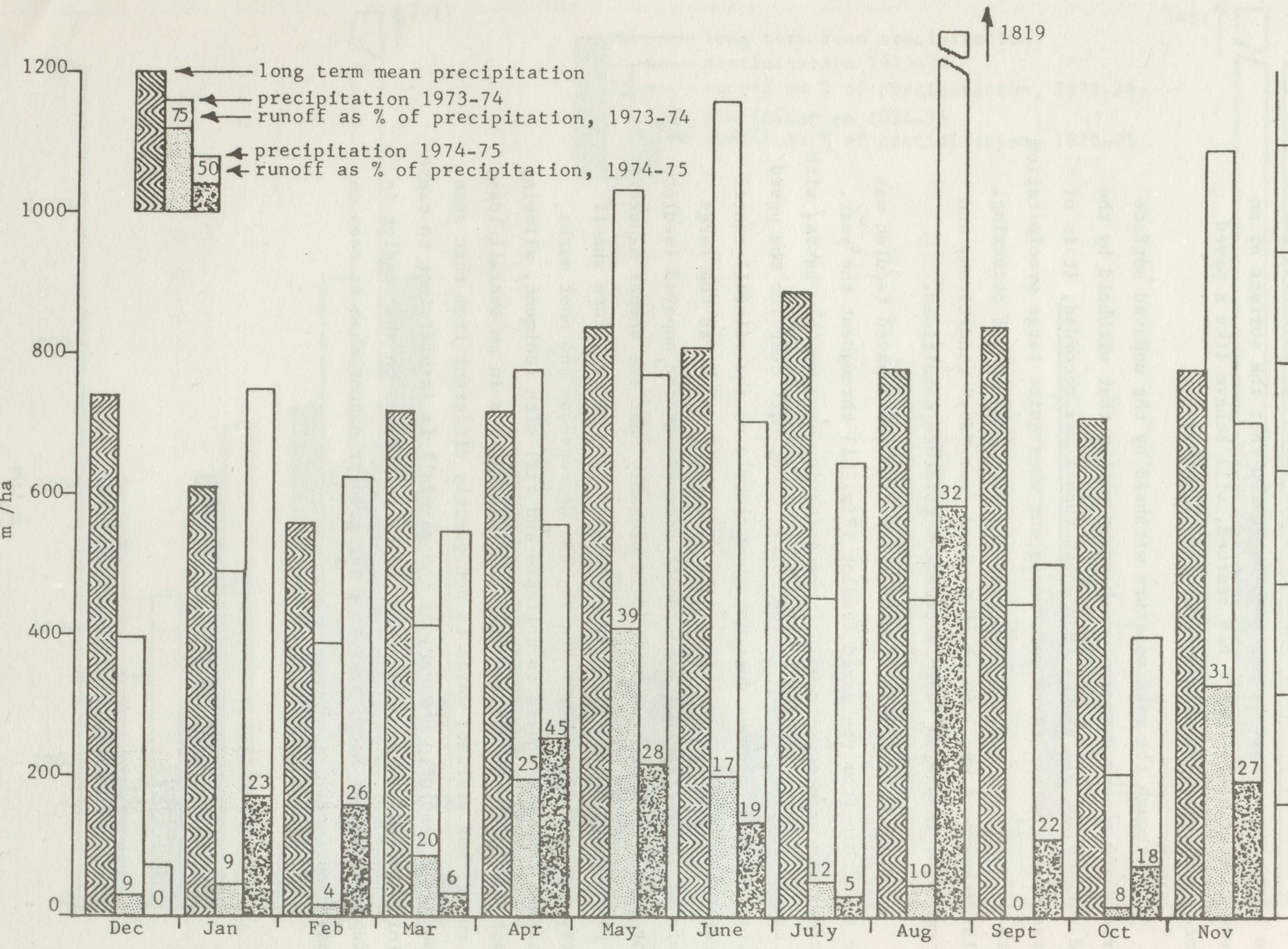

Figure 12: Monthly precipitation (actual and long term mean) and runoff (including some estimates), Site #2 (unpaved feedlot), 1973-75.

Site #3: The paved solid manure storage area withheld about the same amount of precipitation before runoff occurred as did the unpaved feedlot. The rate of runoff compared to rainfall once runoff had commenced was, however, greater than either of the feedlots (see Table 1 and Figures 7, 8 and 9). This indicates that the absorbence capacity of the stored manure (with bedding) was about as high as that of the material on an unpaved feedlot surface, but that once this capacity was exceeded and runoff occurred, then there was little other loss such as infiltration and a high proportion of the precipitation left the paved area as runoff.

Site 3, the paved solid manure storage area showed the greatest variability in the proportion of precipitation which ran off on a monthly basis - see Figure 13. It ranged from zero to 67% and was well distributed within this range. The effect of the manure pile is clearly shown in this Figure by the dramatic increase in the amount of runoff which occurred in April and corresponds to the removal of manure from the storage area at this time. During the months of December through March, the accumulating manure and the freezing conditions reduced the runoff to zero to 38%.

Site #4: Very few runoff events were recorded during 1974 and 1975. This is primarily due to good management at the manure storage area which the farm operator dammed up with a wall of well-rotted, high-bedding (straw) content manure from the calf barn. With improved record keeping at this site during the second year*, it was evident that measurable runoff occurred only about 18 times. Figures 10 and 14 indicate that the precipitation quantities which are withheld were similar to the other manure storage area. However, runoff was only observed after the manure had been partially cleared out of the storage area in April (see Figure 14). At other times, a slow seepage around and under the retaining wall (see Figure 5) was

*Peter Perk of the School of Engineering, University of Guelph, provided invaluable assistance with chart changing during the second year, for which the authors wish to record their appreciation.

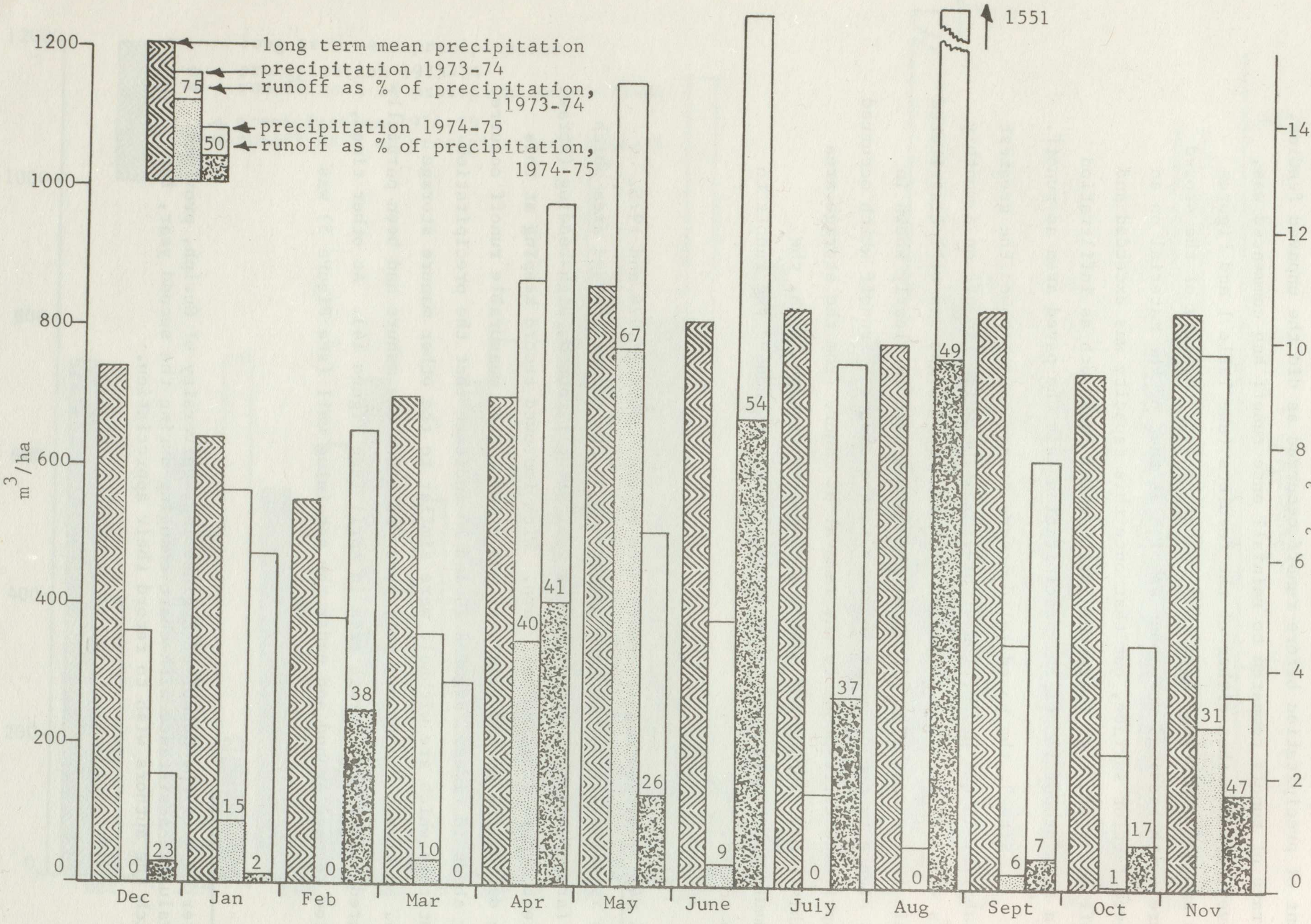

Figure 13: Monthly precipitation (actual and long term mean) and runoff (including some estimates), Site #3 (solid manure storage), 1973-75.

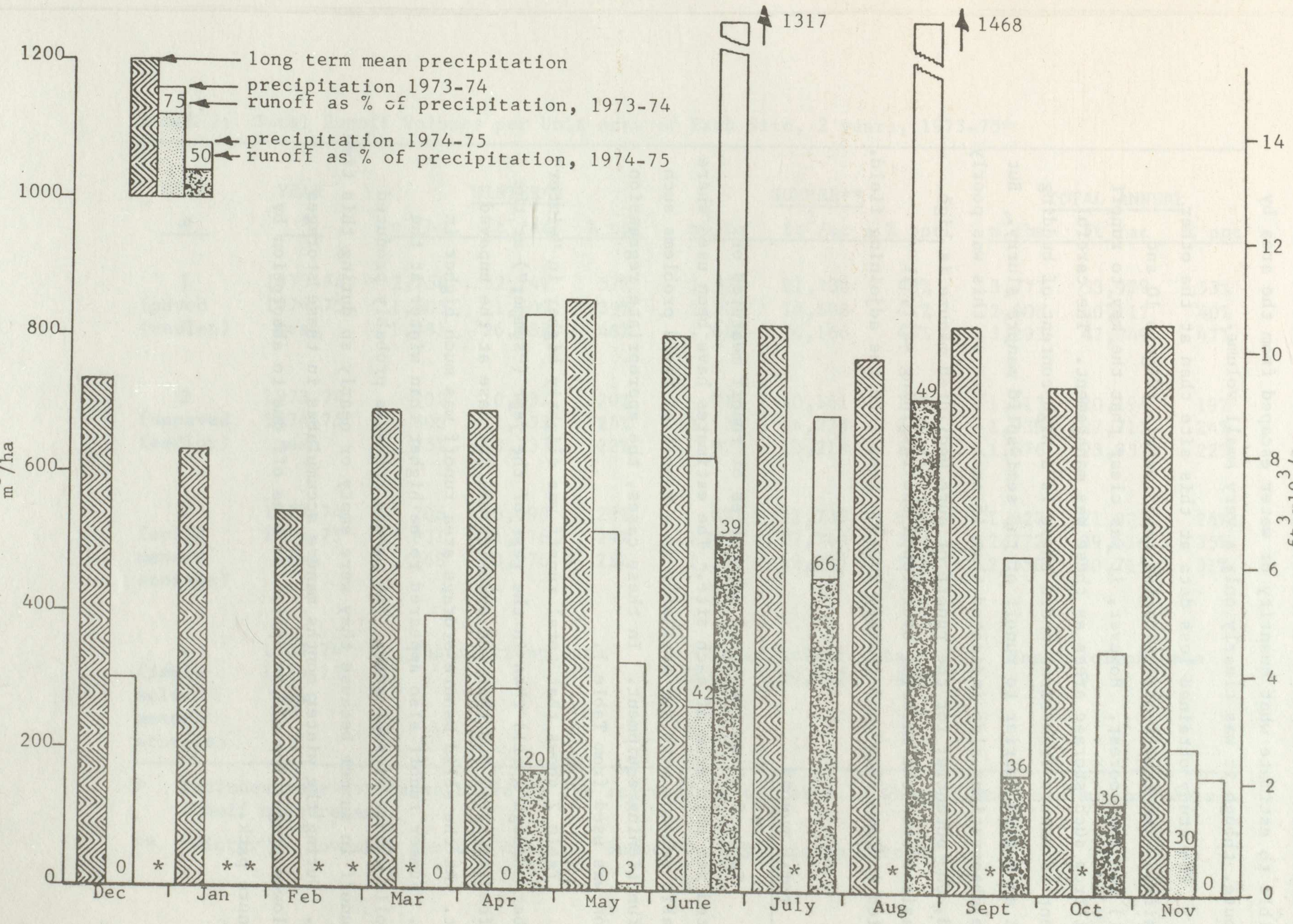

Figure 14: Monthly precipitation (actual and long term mean) and runoff (including some estimates), Site #4 (semi-solid manure storage), 1973-75.

*Missing Data

evident which was not measured on the stage height recorder. It is impossible to estimate what quantity of water escaped from the area by this route, though it was clearly only a very small volume.

The study obtained less data at this site than at the other three sites. The runoff-precipitation relationship (Figure 10 and Table 1) was the poorest. However, it was clear that the key to runoff control from such storage areas as these was management. The careful placement of manure from barns where there is a high content of bedding can act as a good barrier to runoff of the semi-solid manure slurry. But on-site observations also indicated that if such a site as this was poorly managed, the potential for the runoff of pure undiluted manure is high. On occasions when the material overflowed the retaining wall, it resembled a "lava flow" and reached 200-300 feet into the adjoining field.

1.5.2. TOTAL RUNOFF

Table 2 shows the total quantities of runoff measured or estimated per unit area of each site. The estimates have been used where dependable records were not available as a result of field problems such as malfunctioning equipment. In these cases, the appropriate regression equation was used from Table 1.

Table 2 shows that total runoff was slightly higher in "winter" (December through April) than in the rest of the year ("summer") at the paved feedlot site, but that the opposite was the case at the unpaved feedlot. At the solid manure storage area runoff was much higher in summer. Summer runoff also appeared to be higher than winter at the semi-solid manure storage area. The manure storages probably produced more runoff in summer because they were empty or nearly so during this time period. During the winter months manure accumulates in these storages and a lower proportion of precipitation runs off due to absorption by the manure pack.

TABLE 2: Total Runoff Volumes per Unit Area of Each Site, 2 years, 1973-75*

SITE #	YEAR	WINTER** m^3/ha	WINTER** ft^3/ac	WINTER** % ppt	SUMMER** m^3/ha	SUMMER** ft^3/ac	SUMMER** % ppt	TOTAL ANNUAL m^3/ha	TOTAL ANNUAL ft^3/ac	TOTAL ANNUAL % ppt
1	1973-74	2,256	32,241	57%	1,521	21,738	48%	3,777	53,979	53%
(paved	1974-75	1,505	21,509	39%	1,302	18,608	41%	2,808	40,117	40%
feedlot)	mean	1,881	26,883	48%	1,411	20,166	44%	3,293	47,049	47%
2	1973-74	702	10,033	20%	711	10,161	19%	1,413	20,194	19%
(unpaved	1974-75	800	11,433	25%	1,139	16,278	24%	1,939	27,711	24%
feedlot)	mean	751	10,733	22%	925	13,219	22%	1,676	23,952	22%
3	1973-74	706	10,090	20%	821	11,733	36%	1,527	21,823	26%
(solid	1974-75	831	11,876	29%	1,941	27,740	39%	2,772	39,616	35%
manure	mean	768	10,976	25%	1,381	19,737	38%	2,150	30,713	31%
storage)										
4	1973-74		insufficient data			insufficient data			insufficient data	
(semi-	1974-75		"	"	2,072	29,612	45%		"	"
solid	mean									
manure										
storage)										

* Includes some estimates based on the regressions of Table 1, where flume problems prevented runoff measurement.

** "Winter" - November through April; "Summer" - May through October.

At the paved feedlot, although a greater volume ran off in winter, the proportion (as indicated by the "% of precipitation" column in Table 2) was about the same through both seasons when averaged over the two years. The nature of the feedlot surface suggests that this would be the case. This consistency in runoff is also seen in Figure 7 where differences between wet and dry antecedent moisture conditions were not apparent.

The unpaved feedlot yielded about the same proportion of runoff to precipitation in both seasons, with a slightly higher total runoff in summer due to the nature of the annual distribution of precipitation. However, the percentage of precipitation which ran off was about half that at the paved site, due to infiltration and greater moisture retention.

The solid manure storage yields more runoff in summer than in winter. This is undoubtedly because of the rainfall retaining and absorbing effect of the stored manure which accumulates during winter. The total annual runoff fell between the paved and the unpaved feedlots in terms of percentage of precipitation.

The volumes shown in Table 2 indicate the likely quantities of runoff which would need to be stored if total runoff control was required. It should be noted that the precipitation measured at all sites during the two years of this study was lower than the long term mean for the area as indicated by Atmospheric Environment Service (AES) records. This shortfall ranged from 5% to 29% at all sites over the two years of this study. However, available AES records indicate that at their monitoring stations, precipitation in these two years was similar to the long-term mean. It is not known if the shortfall recorded in this study was due to differences in raingauge type (Belfort vs standard Canadian), differences in site and exposure, or simply to aerial variability within the region.

1.5.3. RUNOFF WATER QUALITY

Table 3 presents a summary of the water quality data at the four sites in terms of concentration means, standard deviations, coefficients of variation and numbers of samples. All water quality data are presented in Appendix B.

Table 3 indicates that there was a large degree of variation in the data. Coefficients of variability range from 2% to 172%. Considering all sites, Table 3 shows that, in terms of coefficients of variability, there is least variability in concentrations of Soluble PO_4-P, while suspended solids is probably the most variable. This result is not unexpected, as the factors controlling the former are primarily chemical, while those controlling the latter are primarily physical. The parameters which are strongly influenced by microbiological activity, such as nitrogen and bio-chemical oxygen demand (B.O.D.), fall intermediate in their degree of variability.

Many of the water quality parameters are known to be related to each other, and thus a comparison and discussion of all possible relationships among the parameters would not be useful, except as a check on the data. In practical terms, the "pollutant" most readily susceptible to control is undoubtedly suspended solids. Indeed, construction of a settling basin of adequate capacity has been suggested as a primary treatment for feedlot runoff (Canada Animal Waste Management Guide, 1974; Gilbertson et al, 1972; Madden and Dornbush, 1971).

The following discussion will present water quality parameters primarily in terms of their relationship to suspended solids. Thus, if there is a cause-effect relationship, as appears likely, an indication can be obtained as to the effect that removal or reduction of suspended solids may have on the overall quality of runoff from the sites studied. Suspended solids themselves were very high at all sites, but were approximately twice as high at the two feedlot sites compared to the two manure storage areas. (mean of feedlots -- 6756 mg/l, mean of manure storage -- 2810 mg/l, suspended solids).

TABLE: 3 RUNOFF WATER QUALITY DATA SUMMARY (mg/L) *

B.O.D.	SITE 1				SITE 2				SITE 3				SITE 4			
	mean	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]
Site	4971	1707	38	34	1366	1357	53	99	3243	3958	25	122	2285	1878	12	82
Winter	5223	1466	22	28	1999	1589	26	79	5390	5351	10	99	1965	1701	8	87
Summer	4625	1987	16	43	757	686	27	91	1812	1723	15	95	2925	2314	4	79
Level[4] 1	4000	1317	13	33	1427	912	27	61	4135	4517	17	109	2022	1952	10	97
" 2	5453	1903	13	35	1119	834	15	58	1446	1057	7	73	3600	566	2	16
" 3	5454	1569	11	29	1281	1907	7	170	650	--	1	--	--	--	--	--
" 4	6000	--	1	--	2280	3494	4	153	--	--	--	--	--	--	--	--
TOTAL SOLIDS																
Site	14491	5047	23	35	10791	8798	53	82	9604	8723	25	91	6790	5268	10	76
Winter	13469	4816	16	36	14580	10900	24	75	14440	12033	10	83	5070	4414	6	87
Summer	16829	5124	7	30	7655	4861	29	64	6380	3087	15	48	9370	6003	4	64
Level 1	11075	3705	8	33	10181	7140	27	70	11147	10193	17	91	6351	5872	8	92
" 2	14950	3961	8	27	10491	9684	15	92	6527	3376	7	52	8545	837	2	10
" 3	16866	5685	6	34	12543	11576	7	92	4900	--	1	--	--	--	--	--
" 4	23900	--	1	--	12963	13295	4	103	--	--	--	--	--	--	--	--
SUSP. SOLIDS																
Site	6846	5006	35	73	6699	8748	55	130	2998	2114	25	71	2419	3442	12	142
Winter	6630	5303	22	80	9296	11697	26	126	3255	2685	10	82	1224	1303	8	106
Summer	7212	4644	13	64	4371	3681	29	84	1827	1468	15	80	4807	5298	4	110
Level 1	3721	2481	12	67	5598	7212	28	129	2220	2116	17	95	2755	3705	10	134
" 2	7892	3669	12	46	6269	9248	16	148	2803	2377	7	85	737	17	2	2
" 3	9620	6841	10	71	9778	12013	7	123	2600	--	1	--	--	--	--	--
" 4	4050	--	1	--	10825	11656	4	108	--	--	--	--	--	--	--	--

* Analyses conducted by the Ontario Ministry of the Environment Laboratories, London, Ontario

1. Standard deviation based on N-1 degrees of freedom.
2. Number of samples.
3. Coefficient of variability (%).
4. Increasing flow depth at point of sampling (see page 21) - levels 1,2,3 and 4 at 0,1",2",3" depths respectively.

TABLE: 3 (cont'd) RUNOFF WATER QUALITY DATA SUMMARY (mg/L)*

	SITE 1				SITE 2				SITE 3				SITE 4			
FREE NH_3-N	mean	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]
Site	264	163	30	62	86	75	55	87	411	696	24	169	240	174	12	73
Winter	335	178	17	53	136	76	26	56	761	992	10	130	238	193	8	81
Summer	172	77	13	45	41	34	29	83	160	122	14	76	244	157	4	64
Level[4] 1	223	132	11	59	100	76	28	76	530	802	17	151	199	160	10	80
" 2	307	186	10	61	72	59	16	82	125	59	6	47	445	64	2	14
" 3	266	189	8	71	63	70	7	111	87	--	1	--	--	--	--	--
" 4	270	--	1	--	91	121	4	133	--	--	--	--	--	--	--	--
KJELDAHL N																
Site	772	318	37	41	355	311	55	88	572	710	23	134	425	257	12	60
Winter	805	315	21	39	517	367	26	71	904	1047	9	116	408	289	8	71
Summer	730	328	16	45	209	146	29	67	359	225	14	63	607	239	4	39
Level 1	600	153	13	26	357	253	28	71	700	823	16	117	423	279	10	66
" 2	857	324	12	38	323	323	16	100	290	105	6	36	730	28	2	4
" 3	873	402	11	46	372	423	7	113	220	--	1	--	--	--	--	--
" 4	900	--	1	--	422	529	4	124	--	--	--	--	--	--	--	--
NO_2^--N																
Site	1.04	.36	30	35	.39	.25	55	64	.70	.70	24	100	.69	.84	10	122
Winter	1.06	.42	17	40	.51	.25	26	49	1.06	.95	10	90	.71	1.13	6	159
Summer	1.00	.27	13	27	.28	.20	29	71	.44	.30	14	68	.68	.13	4	19
Level 1	.87	.28	11	32	.44	.23	28	52	.83	.78	17	94	.72	.90	9	125
" 2	1.12	.34	10	31	.34	.21	16	62	.24	.14	7	58	.50	--	1	--
" 3	1.10	.42	8	38	.38	.32	7	84	1.10	--	1	--	--	--	--	--
" 4	1.60	--	1	--	.31	.43	4	138	--	--	--	--	--	--	--	--

* Analyses conducted by the Ontario Ministry of the Environment Laboratories, London, Ontario.

1. Standard deviation based on N-1 degrees of freedom
2. Number of samples
3. Coefficient of variability (%)
4. Increasing flow depth at point of sampling (see page 21) - levels 1, 2, 3 and 4 at 0, 1", 2", 3" depths respectively.

TABLE: 3 (cont'd) RUNOFF WATER QUALITY DATA SUMMARY (mg/L) *

	SITE 1				SITE 2				SITE 3				SITE 4			
	mean	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]	$\bar{x}$	s.d.[1]	N[2]	cv[3]
NO_3^--N																
Site	.97	.70	30	72	.53	.44	55	83	.81	1.09	25	134	.67	.62	10	93
Winter	1.17	.63	17	54	.63	.40	27	63	.99	.94	10	95	.64	.82	6	128
Summer	.70	.44	13	63	.44	.46	28	105	.70	1.20	15	171	.70	.22	4	31
Level[4] 1	.75	.64	11	85	.56	.45	28	80	.68	.82	17	120	.68	.67	9	99
" 2	1.11	.71	10	64	.58	.41	16	71	.92	1.59	7	172	.50	--	1	--
" 3	1.16	.79	8	68	.40	.39	7	97	2.30	--	1	--	--	--	--	--
" 4	.40	--	1	--	.85	.61	4	72	--	--	--	--	--	--	--	--
TOTAL P																
Site	133	57	39	43	102	89	55	87	83	65	25	77	87	63	12	72
Winter	123	36	23	29	135	113	26	84	102	96	10	94	49	21	8	44
Summer	150	77	16	52	72	42	29	58	70	32	15	46	162	46	4	29
Level 1	102	28	14	27	126	172	28	136	97	75	17	78	92	68	10	74
" 2	146	55	13	38	95	85	16	89	52	17	7	33	43	35	2	82
" 3	155	73	11	47	121	122	7	101	70	--	1	--	--	--	--	--
" 4	170	--	1	--	135	148	4	109	--	--	--	--	--	--	--	--
SOLUBLE PO_4-P																
Site	53	25	30	48	47	37	55	79	39	23	25	60	42	31	12	75
Winter	58	25	17	43	57	50	26	86	41	32	10	77	26	10	8	37
Summer	47	25	13	53	38	21	29	56	38	17	15	43	76	33	4	44
Level 1	45	23	11	51	42	32	28	75	43	27	17	62	46	33	10	71
" 2	57	25	10	44	45	31	16	69	29	9	7	28	26	7	2	27
" 3	57	22	8	39	65	50	7	76	43	--	1	--	--	--	--	--
" 4	81	--	1	--	76	72	4	96	--	--	--	--	--	--	--	--

* Analyses conducted by the Ontario Ministry of the Environment Laboratories, London, Ontario

1. Standard deviation based on N-1 degrees of freedom
2. Number of samples
3. Coefficient of variability (%)
4. Increasing flow depth at point of sampling (see page 21) - levels 1, 2, 3 and 4 at 0, 1", 2", 3" depths respectively.

From a water qulity standpoint, phosphorus - both soluble reactive PO_4-P and Total P - is the pollutant most detrimental to Great Lakes water quality. Nitrogen is a more ubiquitous nutrient, over which it is more difficult to exercise control due to the ease with which water systems can augment their supply by biological nitrogen fixation (Porter, 1975). Less important to Great Lakes water quality, but more significant to local stream water quality is probably B.O.D., which lowers dissolved oxygen levels and causes fish kills.

The discussion which follows will look first at an analysis of variance of all of the data, from which some significant predictive responses can be identified; and then at some correlations between the water quality parameters.

Analysis of Variance

Investigation of the relationships between mean and variance within each site, season and flow depth (in the flume) combination suggested that a logarithmic transformation would substantially reduce the dependence of the variance on the mean (Snedecor and Cochran, 1976, Sect. 11.14). All further analyses and tests of significance on water quality data were based on logarithms ($\log_e$ (value + 1)). Any event for which any one of the parameters was not recorded was excluded from these analyses.

Initial results showed that the suspended solids parameter was significantly related ($P < 0.05$) to all other parameters (B.O.D., total solids, etc.). Since it is feasible to control the amount of suspended solids before runoff reaches a stream, it was decided to include the value of suspended solids in the modelling for the other parameters.

The data were analyzed as a two-level nested design for differences between and within runoff events (Ibid., Sect. 12-12). The combined analysis of variance is exemplified in Table 4 for the transformed B.O.D. values. Interactions involving site and season were found to be non-significant ($P > 0.05$) for all parameters. Thus, if the error terms are assumed to be normally distributed with zero means and constant variances, and within each flow depth they are uncorrelated one with another, and if the interaction is ignored, then the models reduce to the following forms:

between events: $\bar{Y}_{ijk} = m + g_1\bar{X}_{ijk} + a_i + b_j$ (1)

within events: $Y_{ijkh} = \bar{Y}_{ijk} + g_2(X_{ijkh} - \bar{X}_{ijk}) + c_h$ (2)

where Y_{ijkh} = transformed water quality parameter (except suspended solids) value for event k at site i, season j and at flow depth h

$\bar{Y}_{ijk}$ = average of Y_{ijkh} over flow depths

X_{ijkh}, $\bar{X}_{ijk}$ = corresponding values for suspended solids

m = overall constant (mean)

g_1 = coefficient for $\bar{X}_{ijk}$ (between events)

a_i = constant for (effect due to) site i (i = 1,2,3,4)

b_j = constant for (effect due to) season j (summer, winter)

g_2 = coefficient for X_{ijkh} (within events)

c_h = constant for (effect due to) flow depth h (h = 1,2,3,4).

The constants and coefficients for use with each parameter are summarized in Table 5.

It is noteworthy that the sums of squares between events were generally much larger than within events, the ratios ranging from 17.1 for B.O.D. to 2.5 for NO_3-N. Because of this, "percentages explained" are shown for the between events analysis only. Furthermore, in every analysis, the between event error (a) was significantly ($P < 0.05$) larger than the within event error (b) (Table 4).

Table 4. Hierarchical Analysis of variance for log (BOD+1) values.

Source of Variation[1]	df	Mean Square	F[2]
Between Events			
Suspended Solids (SS)	1	31.218	35.1**
Sites|SS	3	14.123	15.9**
Season|Sites, SS	1	11.004	12.4**
Interaction Season X Site| Season, Sites, SS	3	0.978	1.1
Error (a)	45	0.890	1.0
Within Events			
Suspended Solids (SS)	1	1.012	6.9*
Levels|SS	3	0.129	0.9
Error (b)	41	0.147	1.0

1/ The vertical lines in the "source of variation" column describe the hierarchy - e.g. the effect of season is calculated after allowing for the effects of site and suspended solids.

2/ Error (a) is used for comparisons between events and error (b) is used for comparisons within events.

Table 5. Summary of the results from fitting the models to the transformed data, without interaction between season and site.

	BETWEEN EVENTS												WITHIN EVENTS					
	Constant	Susp. Solids	Site					Season			Variation Explained		Level				
Parameter	m	g_1	a_1	a_2	a_3	a_4	Sig	S	W	Sig	(%)	g_2	c_1	c_2	c_3	c_4	Sig
Suspended solids	7782	-	666	553	-277	-942	*	-143	143		22	-	-336	153	167	16	**
BOD	3205	0.548**	435	-920	323	162	**	-346	346	**	66	0.290*	3	32	-152	117	
Total solids	4948	0.517**	146	-197	45	6		-49	49		71	0.578**	16	3	-38	20	
NH_3-N	87	0.051**	14	-116	46	56	**	-41	41	**	60	0.056**	14	-5	-16	8	
Kjeld-N	229	0.048**	27	-65	12	26	**	-25	25	**	62	0.052**	6	-5	-5	4	
NO_2-N	-0.29	0.00010**	0.16	-0.22	-0.04	0.10	**	-0.05	0.05		57	0.00003	-0.01	-0.01	0.01	0.01	
NO_3-N	-0.28	0.00010**	0.03	-0.14	0.01	0.10		-0.07	0.07		27	-0.00007	-0.14	0.04	0.00	0.11	
Total P	8.36	0.0047**	0.43	-2.77	-0.47	2.81	*	-0.45	0.45		60	0.0041**	0.25	-0.80	0.13	0.42	
Sol. Ortho-PO_4 P	5.11	0.0041**	0.25	-2.55	-0.29	2.59	*	0.29	-0.29		59	0.0024**	-0.06	-0.18	-0.87	1.12	

*, ** Significant at 5% and 1% respectively in the context of the hierarchical analysis of variance as illustrated in Table 4 (without interaction).

The most variable parameter was suspended solids, and this variability was only partly explained by differences in flow depths at sampling, differences between sites and seasons, and the two-way interaction between sites and seasons (total reduction in "between events" sum of squares was 33.5%). These explanatory variables including the site by season interaction, together with covariance on suspended solids, accounted for a reduction in the "between events" residual sum of squares of 69% for B.O.D., 74% for total solids, 63% for ammonia-N, 66% for total Kjeldahl-N, 58% for nitrite-N, 33% for nitrate-N, 66% for total P and 63% for soluble ortho-PO_4 phosphorus.

Suspended Solids:

Suspended solids are seen in Table 5 to be affected most significantly by the level of sample - this being an indication of the effect of runoff flow rate as deeper flows fill higher level sample bottles. This is a reasonable observation, as at higher flow rates the tractive forces are such that more solid material will be transported in the runoff. Since other parameters showed what is probably a cause-effect relationship to suspended solids concentration, it will be seen in Table 5 that none of them are significantly related to level directly, the level effect being accounted for in the regression with suspended solids. The two feedlots had higher concentrations than the manure storage sites. The manure in the storages is likely to have greater resistance to being moved by runoff than the thin layer of manure on the feedlot surface.

B.O.D.:

B.O.D. was strongly affected by site differences, the paved feedlot showing the highest values and the unpaved feedlot showing the lowest. It was also significantly affected by the season and by the suspended solids level (see Table 5 and Figure 15). B.O.D. concentrations were high in winter at the paved feedlot. This suggests that biological activity is low under these conditions. The unpaved feedlot, in summer, on the other hand, would be expected to supply good conditions for bio-chemical oxygen demand reduction, which is evident from the data.

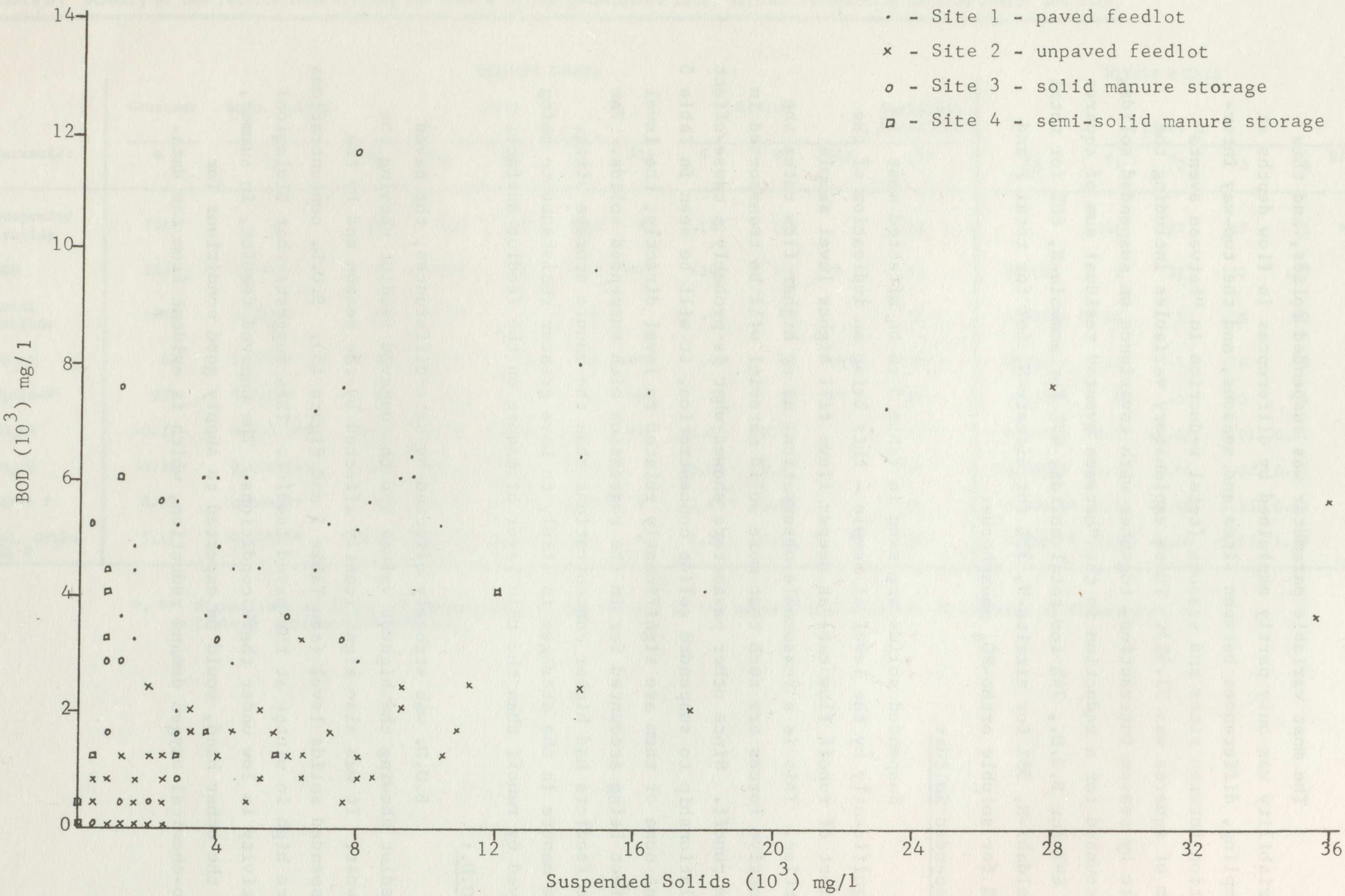

Figure 15: BOD versus Suspended Solids, all sites, 1973-75 (from computer printouts)

Values for B.O.D. found in this study were similar to those reported by Loehr (1974) from the literature, but were far higher than Ogilvie and Savoie (1974) reported in feedlot runoff in the Montreal area. Somewhat surprisingly, the literature contains few reported data on B.O.D. values in runoff from feedlots and manure storages. However, it appears that some degree of comparability exists with other areas. If discharged to a water course, the values found in this study could be a serious local pollution problem and might result in fish kills due to lowering of dissolved oxygen levels. As a comparison, the British "Royal Commission" standards permit the discharge of water with a B.O.D. not exceeding 20 mg/l (Jones and Riley, 1970) - or 144 times lower than the mean value found in these studies.

Total solids:

This parameter appears to be significantly related only to suspended solids (see Table 5 and Figure 16), - season, site and level having no additional effect.

Nitrogen:

Nitrate was the most constant of all the parameters, being influenced slightly by suspended solids between events, but not significantly by any of the other possible effects. Nitrite was significantly higher at the paved feedlot. Kjeldahl and ammonia nitrogen were influenced by season as well as by suspended solids, being higher in winter, when nitrification is low. They followed the same pattern as B.O.D.

The soluble nitrate (NO_3^-) form of nitrogen is readily available to aquatic vegetation (Porter, 1975). It was found to be consistently low - even compared to natural stream water. It was also far lower than values reported by Miner et al (1966) at Kansas feedlots especially during the summer months when he reported values as high as 11 mg/l compared to a maximum of 2.6 mg/l at the paved feedlot; and lower than those reported by Gilbertson et al (1971) for Nebraska which were reported to have reached 80 mg/l at unpaved feedlots. Kjeldahl nitrogen on the other hand, was consistently rather high, but did not display the tendency seen by

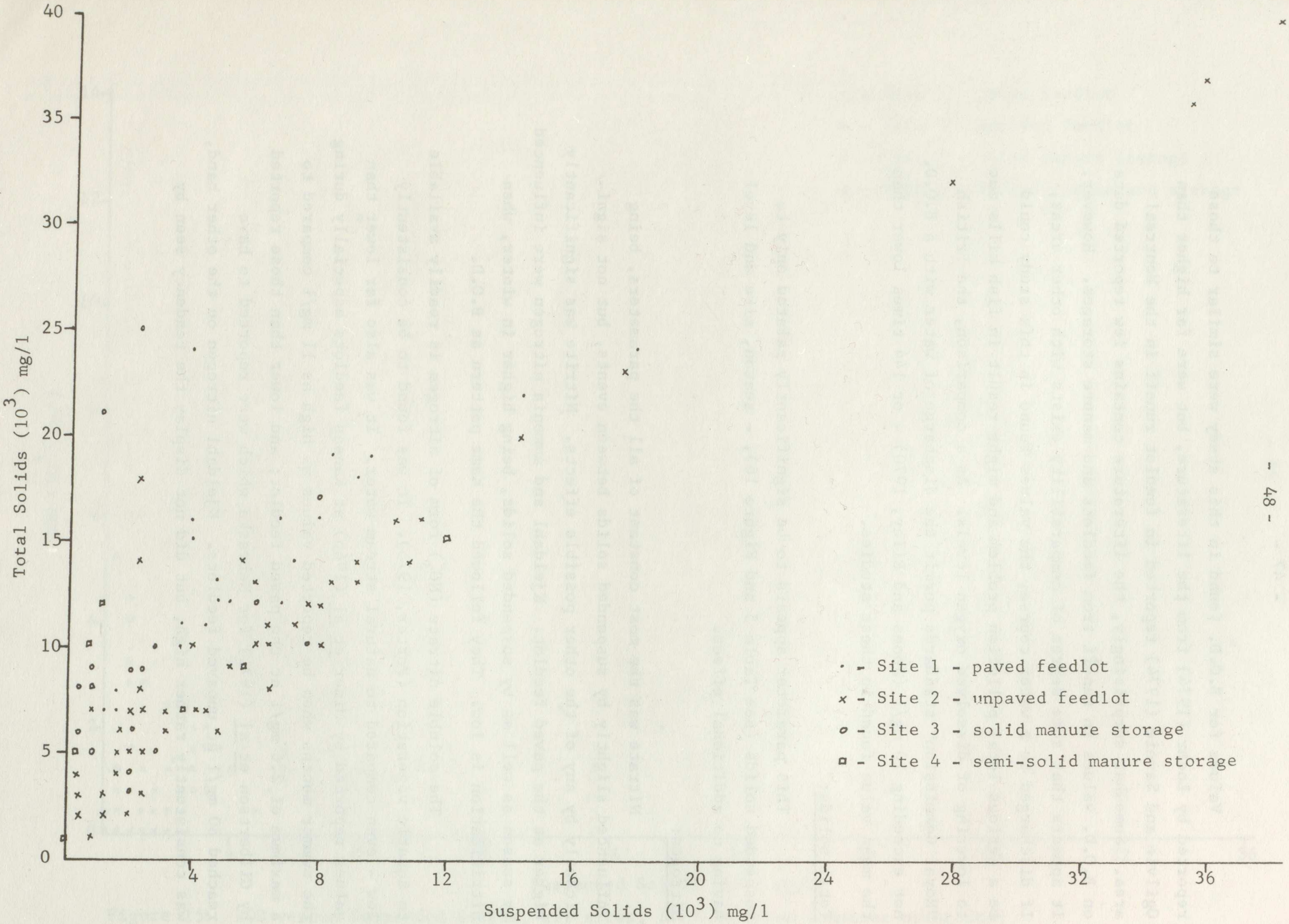

Figure 16: Total Solids versus Suspended Solids, all sites, 1973-75 (from computer printouts)

Edwards et al (1972) to be higher in the summer months, and was found to be far lower than the values reported in Loehr's (1974) literature review. Ammonia nitrogen was also found to be high in this study. Since nitrogen is relatively unstable in water and may be oxidized, nitrified and denitrified - often simultaneously, during stream transport, it is difficult to estimate the ultimate significance of the high ammonia and Kjeldahl nitrogen concentrations found in the runoff water from these sites. However, high ammonia values have been implicated as contributing to the causes of fish kills in receiving water (McQuitty et al, 1971).

Phosphorus:

Total phosphorus was significantly affected by suspended solids concentration and by site differences, being highest at the paved feedlot (Site #1). Season and flow level effects were not significant. These effects were, however, showing similar trends to Kjeldahl nitrogen. Figure 17 shows the close relationship of total P with Kjeldahl N, suggesting that much of the total P is tied up in biologically unstable organic material.

Soluble P was related most closely to suspended solids, all other effects, except site, being non-significant. Both total and soluble phosphorus show the least overall variability as measured by the coefficients of variability of Table 3.

Figures 18 and 19 show the relationship between suspended solids and soluble and total phosphorus respectively by scatter diagrams. It can be seen that there was a very poor correlation between soluble P and suspended matter looking at all sites together. However, the trend was clear at Site No.1 (the paved feedlot) and No.2 (the unpaved feedlot) for an increase with increasing suspended solids. Total phosphorus, however, showed a better relationship to suspended solids at all of the sites taken together and at the individual feedlot sites. There was little correlation at the manure storage sites. This suggests that solids removal would be quite effective in reduction of total and soluble phosphorus from the feedlots but would have little effect on either at the manure storages. Average soluble phosphorus values were lower at the unpaved feedlot, so that the benefit from solids reduction would be smaller than at Site No.1 (paved feedlot).

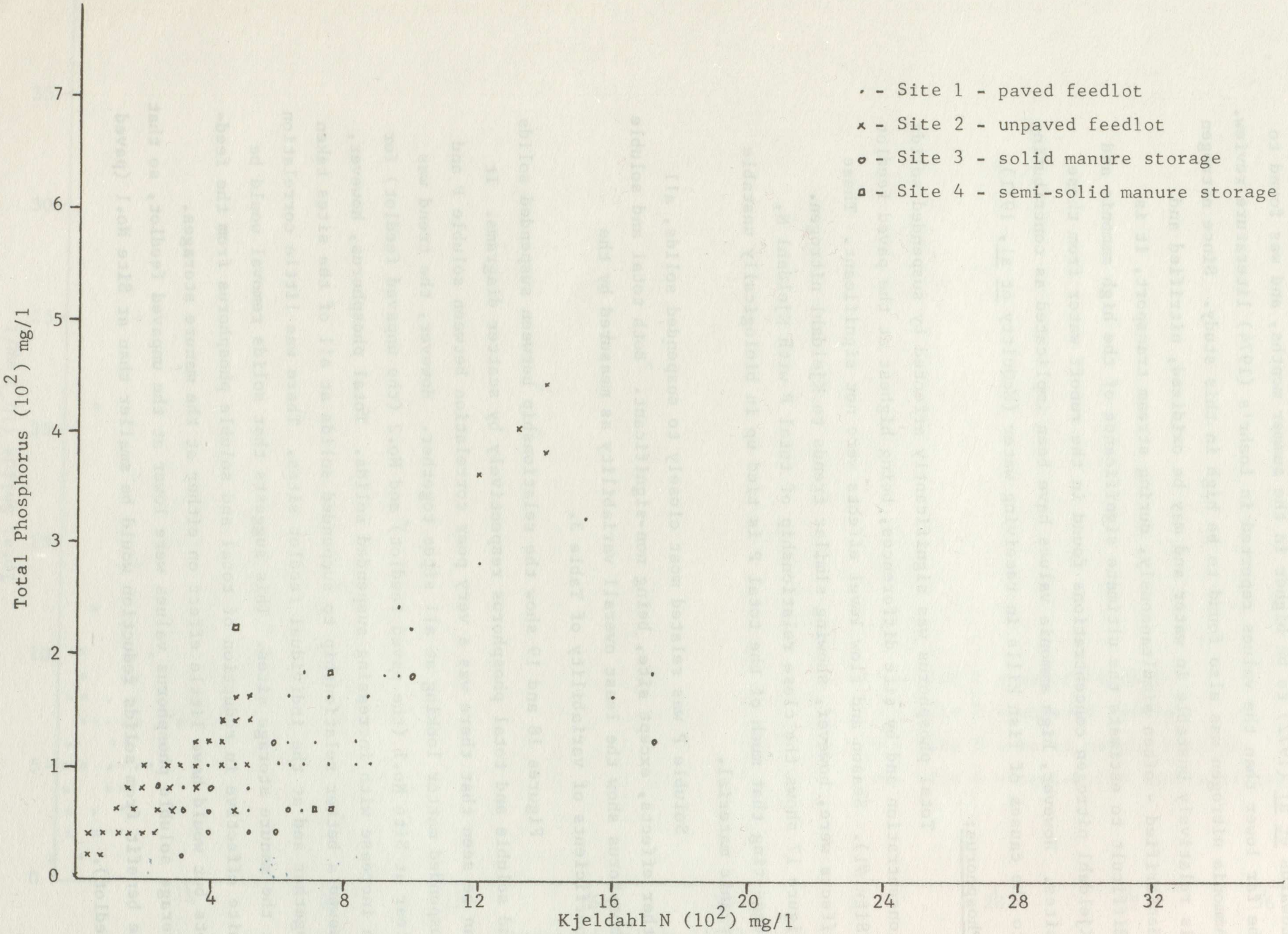

Figure 17: Total Phosphorus versus Kjeldahl N, all sites, 1973-75 (from computer printouts)

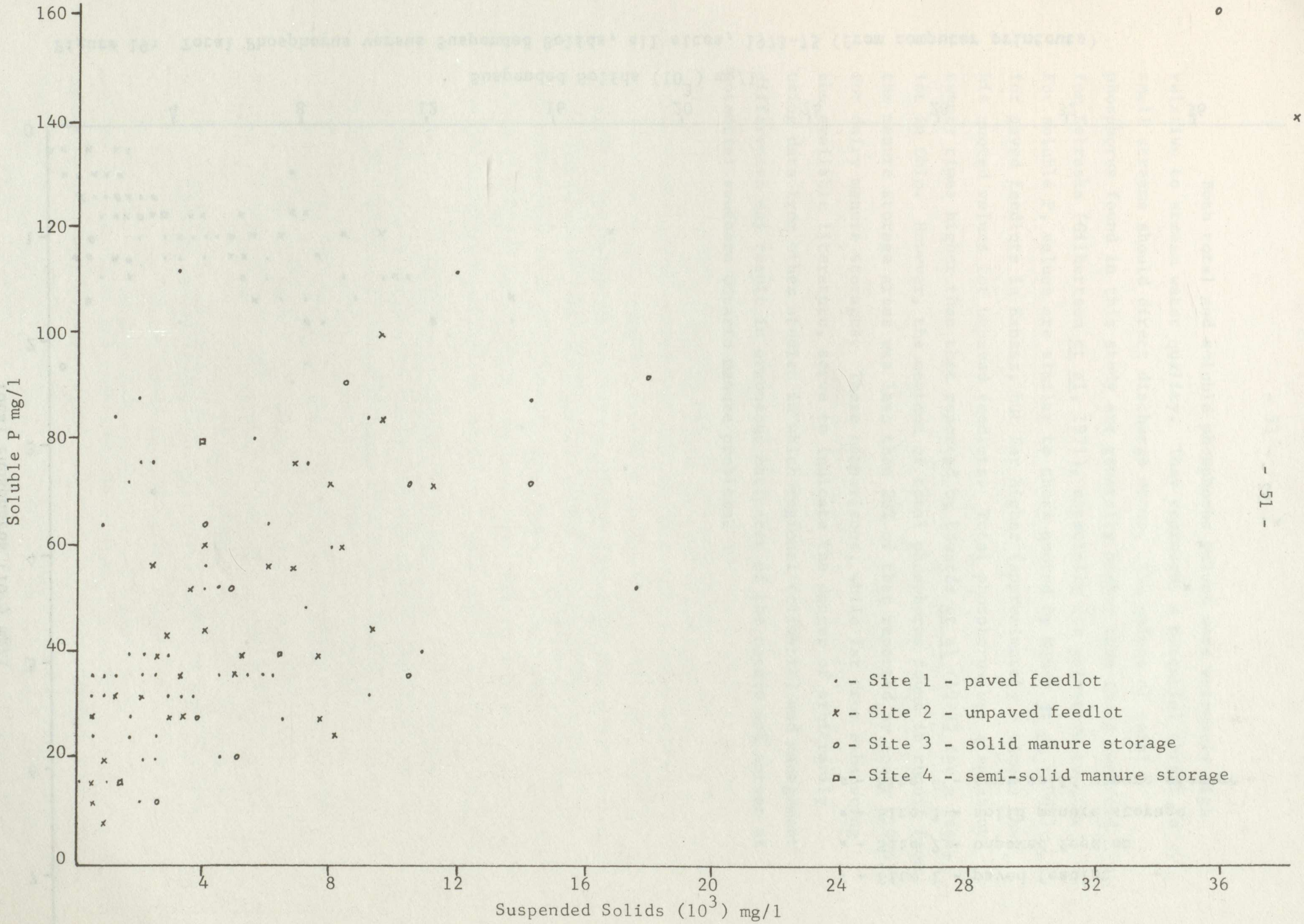

Figure 18: Soluble P versus Suspended Solids, all sites, 1973-75 (from computer printouts)

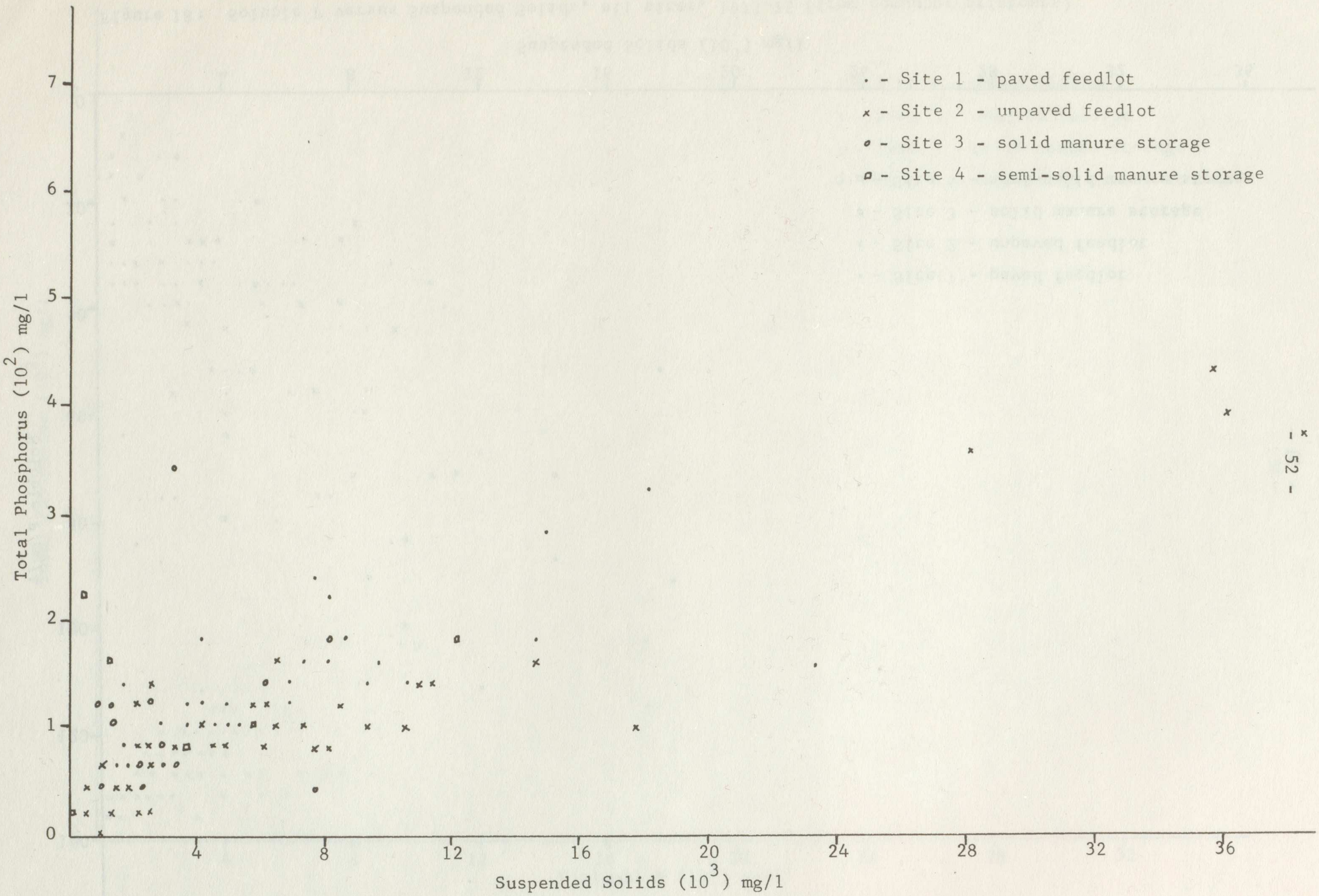

Figure 19: Total Phosphorus versus Suspended Solids, all sites, 1973-75 (from computer printouts)

Both total and soluble phosphorus values were extremely high relative to stream water quality. They represent a potential threat to small streams should direct discharge occur. The values of total phosphorus found in this study are generally higher than those reported for Nebraska (Gilbertson et al, 1971), especially for rainstorm runoff. For soluble P, values are similar to those quoted by Miner et al (1966) for paved feedlots in Kansas, but far higher (approximately 5 times) than his quoted values for unpaved feedlots. Total phosphorus was also about twenty times higher than that reported by Edwards et al (1972) for a feedlot in Ohio. However, the content of total phosphorus found in runoff from the manure storage areas was less than 20% of that reported by Loehr (1974) for dairy manure storages. These comparisons, while far from exhausting the available literature, serve to indicate the danger of arbitrarily using data from other studies in which regional (climatic) and management differences may result in erroneous estimates of the nature and extent of potential southern Ontario manure problems.

1.5.4. MICROBIOLOGY

During this study very little was done with regard to the bacterial content of the runoff waters from the four sites. One reason for this was the difficulty of collecting and transporting to the laboratory a sample before deterioration occurs. Generally speaking this can only be done if a sample is iced on collection and transported directly to the laboratory. This was done on one occasion only, in November 1974, and samples were collected only at Sites Nos. 2, 3 and 4*. Table 6 summarizes the data collected at that time. Mr. Eric Leggatt* has made the following comments regarding the data:

"In general, the bacterial levels are exceptionally high in spite of the fact that this was the residual flow after the major runoff from the previous heavy rains. It is interesting to note that Sample #2 (downstream of Sample #1) had higher levels of total coliforms and background colonies but slightly lower levels of fecal coliforms and fecal streptococcus. This suggests the possibility of TC regrowth while FC and FS have died off slightly. The low temperatures at the time of sampling should have sustained the numbers of organisms by a) slowing down any reproduction, and b) slowing metabolism which limits die-off.

The numbers of Pseudomonas aeruginosa are surprisingly high. These bacteria are actual pathogens and hence their presence should be viewed with some concern."

TABLE 6 : Results of single sample bacterial determinations, November 1974.

Sample**	Colonies (in thousands) per 100 ml.				
	Total Coliform	Backgrnd. Colonies	Fecal Coliform	Fecal Strep	Pseudomonas Aeruginosa
1	2,900	2,000	1,200	2,500	1.6
2	3,500	5,000	930	1,550	12
3	11,500	18,000	4,900	1,880	10
4	6,000	14,000	1,770	1,320	300

**Sample #1 - flume - feedlot Site #2

" #2 - 200 ft. downstream of flume - feedlot Site #2

" #3 - flume - manure storage area Site #3

" #4 - flume - manure storage area Site #4

---

* Mr. Eric Leggatt, Ontario Ministry of the Environment, Microbiology Section, assisted with sample collection and transportation, and performed the determinations given in Table 6.

It had been hoped that it would be possible to incorporate a detailed bacterial investigation into the second year of this study. Discussions were held with personnel from the Microbiology Section of Ontario Ministry of the Environment and it was concluded that it was not practical at this time for a number of reasons including -- the need for their mobile laboratory which was fully employed elsewhere; shortage of available staff; unpredictability of runoff events; and the unsuitability of any of the existing four sites for such a detailed investigation. With these restrictions presenting somewhat insurmountable difficulties, and in view of the bacterial examinations being conducted by BEAK Consultants Ltd. elsewhere in the I.J.C. PLUARG Agricultural Watershed Study Programme, this aspect of the study was not pursued.

Subsequently, discussions were held with Dr. B. Derbyshire of the Department of Veterinary Microbiology of the Ontario Veterinary College at Guelph University, to see if some of the questions related to the potential of livestock entero-viruses to be carried in feedlot and manure storage runoff could be answered through this study. Dr. Derbyshire is an authority on this subject, and with his guidance, a random sampling procedure was initiated with examinations being conducted by his laboratory. These examinations (described briefly in the section on Methods and Materials, page 7 of this report) are time-consuming and costly, and the number of samples was therefore limited. Six samples were analysed with the following results:

Table: 7 Virus Isolation - Feedlot and Manure Storage Runoff

Site	Type	Date	Result
1	paved feedlot	21/11/75	positive - enterovirus
2	unpaved feedlot	6/ 6/75	negative
3	solid manure storage	6/ 6/75	negative
3	" " "	21/11/75	negative
4	semi-solid manure storage	6/ 6/75	positive - enterovirus
4	" " " "	21/11/75	negative

The results shown indicate that a virus of livestock origin is capable of surviving in manure and leaving the area of defecation in runoff water. They also show that it is possible for these organisms to survive in manure during storage and leave the storage area in seepage and runoff water.

It is important to point out that the types of virus found in the positive samples are harmless enteric organisms, often found in fresh bovine manure, and that they are among the more resistant strains of virus in terms of survival. Thus the results give no indication of any health hazard from viruses in manure-contaminated runoff water. They do, however, indicate that a potential does exist for viruses to be transmitted via this route; and that if a virus, capable of infecting other livestock or humans, should be shed by an infected animal housed in the feedlot or contributing manure to the storage area, then the potential for infection from contaminated runoff water also exists.

1.5.5. TOTAL LOADINGS

Tables 8 through 11 present the total loadings of each parameter in the runoff leaving the four monitored areas.

Although large differences existed in these loadings between sites when expressed on a per unit area basis, the differences are far less when expressed per animal unit (1000 lb liveweight). On this latter basis, the two feedlots yielded very similar loadings when calculated as the mean of two years. Most of the loadings were also similar from the manure storage area when experessed per animal unit, the main exceptions being that suspended solids were much lower and ammonia was higher than either of the feedlots.

These tables give an indication of the total polluting potential of these sites, if the runoff was to enter a water course. They also indicate the magnitude of the content of the various parameters in the runoff material if this was to be stored and returned to the field by tank spreader or irrigation system. It is interesting to note that, of the approximately 64 kg of nitrogen produced per year by a dairy cow, less than 2% of this was lost in runoff from the manure storage area, while about 6% of the approximately 26 kg of N produced by a beef steer was lost in the runoff from the feedlot areas. The loss of phosphorus from the manure storage area and feedlots was approximately 0.4% and 1.5% of that produced by the cattle respectively.

Table 8 : Pollutant loads in runoff, by seasons*, 1973-75, Site #1 (paved feedlot)**

Parameter	Year	Kg/ha***			Kg/animal unit****		
		Winter	Summer	Total	Winter	Summer	Total
B.O.D.	1973-74	11,709	6,905	18,614	5.21	3.07	8.28
	1974-75	7,874	5,098	12,972	3.85	2.50	6.35
	mean	9,792	6,002	15,793	4.53	2.79	7.32
Total Solids	1973-74	32,016	25,720	57,736	14.24	11.44	25.68
	1974-75	20,303	18,549	38,852	9.93	9.08	19.01
	mean	26,160	22,135	48,294	12.09	10.26	22.35
Suspended Solids	1973-74	13,058	11,235	24,293	5.81	5.00	10.81
	1974-75	9,996	7,948	17,944	4.90	3.88	8.78
	mean	11,527	9,592	21,119	5.36	4.44	9.80
Kjeldahl Nitrogen	1973-74	1,802	1,187	2,989	.80	.53	1.33
	1974-75	1,213	805	2,018	.59	.40	0.99
	mean	1,508	996	2,504	.70	.46	1.16
NH_3-N	1973-74	763	265	1,028	.34	.12	0.46
	1974-75	505	190	695	.24	.09	0.33
	mean	634	228	862	.29	.10	0.39
NO_2-N	1973-74	2.052	1.517	3.569	.00091	.00067	.00158
	1974-75	1.599	1.104	2.703	.00078	.00054	.00132
	mean	1.826	1.311	3.137	.00084	.00061	.00145
NO_3-N	1973-74	2.617	1.108	3.725	.00116	.00049	.00165
	1974-75	1.762	.773	2.535	.00086	.00037	.00123
	mean	2.190	0.941	3.131	.00101	.00043	.00144
Total P	1973-74	264	235	499	.12	.10	.22
	1974-75	186	165	351	.09	.08	.17
	mean	225	200	425	.11	.09	.20
Soluble PO_4-P	1973-74	115	71	186	.05	.03	.08
	1974-75	87	52	139	.04	.02	.07
	mean	101	62	163	.05	.03	.08

* "Winter" - November through April
"Summer" - May through October

** Includes some calculations based on mean concentrations and/or estimated runoff values.

*** lbs/ac = Kg/ha x 0.89

**** assumes average of 550 animal units (1000 lbs) 1973-74
assumes average of 500 head @ 1000 lbs/head 1974-75

Table 9 : Pollutant loads in runoff, by seasons*, 1973-75, Site #2 (unpaved feedlot)**

Parameter	Year	Kg/ha*** Winter	Kg/ha*** Summer	Kg/ha*** Total	Kg/animal unit**** Winter	Kg/animal unit**** Summer	Kg/animal unit**** Total
B.O.D.	1973-74	1,324	905	2,229	3.00	2.06	5.06
	1974-75	2,612	881	3,493	5.92	2.00	7.92
	mean	1,968	893	2,861	4.46	2.03	6.49
Total Solids	1973-74	9,368	4,951	14,319	21.26	11.24	32.50
	1974-75	8,621	8,912	17,533	19.58	20.24	39.82
	mean	8,995	6,932	15,926	20.42	15.74	36.16
Suspended Solids	1973-74	4,289	2,783	7,072	9.74	6.32	16.06
	1974-75	5,207	5,158	10,365	11.82	11.72	23.54
	mean	4,748	3,971	8,719	10.78	9.02	19.80
Kjeldahl Nitrogen	1973-74	338	130	468	.76	.30	1.06
	1974-75	360	254	614	.82	.58	1.40
	mean	349	192	541	.79	.44	1.23
NH_3-N	1973-74	94	25	119	.22	.06	.28
	1974-75	106	50	156	.24	.12	.36
	mean	100	38	138	.23	.09	.32
NO_2-N	1973-74	.377	.176	.553	.00086	.00040	.00126
	1974-75	.358	.352	.710	.00082	.00080	.00162
	mean	.368	.264	.632	.00084	.00060	.00144
NO_3-N	1973-74	.419	.316	.735	.00096	.00072	.00168
	1974-75	.559	.474	1.033	.00126	.00108	.00234
	mean	.489	.395	.884	.00111	.00090	.00201
Total P	1973-74	91	46	137	.20	.10	.30
	1974-75	117	86	203	.26	.20	.46
	mean	104	66	170	.23	.15	.38
Soluble PO_4-P	1973-74	41	25	66	.10	.06	.16
	1974-75	35	45	80	.08	.10	.18
	mean	38	35	73	.09	.08	.17

* "Winter" - November through April
"Summer" - May through October

** Includes some calculations based on mean concentrations and/or estimated runoff values.

*** lbs/ac = Kg/ha x 0.89

**** assumes average of 145 animal units (1000 lbs) over the total feedlot area, 50% of which is monitored (net 72.5 animal units assumed)

Table 10 : Pollutant loads in runoff, by seasons*, 1973-75, Site #3 (solid manure storage)

Parameter	Year	Kg/ha*** Winter	Kg/ha*** Summer	Kg/ha*** Total	Kg/animal unit**** Winter	Kg/animal unit**** Summer	Kg/animal unit**** Total
B.O.D.	1973-74	3,466	2,012	5,478	2.18	1.26	3.44
	1974-75	4,482	2,450	6,932	2.81	1.54	4.35
	mean	3,974	2,231	6,205	2.50	1.40	3.90
Total Solids	1973-74	10,120	4,900	15,020	6.35	3.08	9.43
	1974-75	11,192	10,518	21,710	7.53	6.60	14.13
	mean	10,656	7,709	18,365	6.94	4.84	11.78
Suspended Solids	1973-74	2,649	1,514	4,163	1.66	.95	2.61
	1974-75	2,709	3,247	5,956	1.70	2.04	3.74
	mean	2,679	2,381	5,060	1.68	1.50	3.18
Kjeldahl Nitrogen	1973-74	562	355	917	.35	.22	.57
	1974-75	751	556	1,307	.47	.35	.82
	mean	657	456	1,112	.41	.29	.70
NH_3-N	1973-74	504	167	671	.32	.11	.43
	1974-75	631	249	880	.40	.16	.56
	mean	568	208	776	.36	.14	.50
NO_2-N	1973-74	.657	.339	.996	.00041	.00021	.00062
	1974-75	.876	.797	1.673	.00055	.00050	.00105
	mean	.767	.568	1.335	.00048	.00035	.00083
NO_3-N	1973-74	.677	.817	1.494	.00043	.00051	.00094
	1974-75	.817	1.155	1.972	.00051	.00073	.00124
	mean	.747	.986	1.733	.00047	.00062	.00109
Total P	1973-74	70	58	128	.04	.04	.08
	1974-75	86	129	215	.05	.08	.13
	mean	78	94	172	.05	.06	.11
Soluble PO_4-P	1973-74	30	28	58	.02	.02	.04
	1974-75	34	80	114	.02	.05	.07
	mean	32	54	86	.02	.04	.06

* "Winter" - November through April
"Summer" - May through October

** Includes some calculations based on mean concentrations and/or estimated runoff values.

*** lbs/ac = Kg/ha x 0.89

**** assumes average of 80 animal units (1000 lbs) (based on 40 cows @ 1,250 lbs and 60 young stock @ 500 lbs)

Table 11 : Pollutant loads in runoff
Site #4 (semi-solid manure storage) - Summer 1975 only*

Parameter	Kg/ha**	Kg/animal unit***
B.O.D.	5,531	2.89
Total Solids	18,545	9.65
Suspended Solids	9,990	5.22
Kjeldahl Nitrogen	1,158	.61
NH_3-N	471	.25
NO_2-N	.345	.00018
NO_3-N	1.340	.00070
Total P	308	.16
Soluble P	149	.08

* Insufficient data for completion of table during other time periods.

** lbs/ac = Kg/ha x 0.89

*** assumes average of 120 animal units (1000 lbs) (based on 100 cows @ 1,250 lbs)

1.6 ESTIMATING THE EXTENT OF THE POLLUTION POTENTIAL

Tables 8, 9, 10 and 11 have been compiled to indicate the probable loadings, of each of the parameters studied, as they leave the study area. They have been expressed in terms of loading per unit area and per animal unit (nominally 1000 lb liveweight) to allow the greatest amount of flexibility in their use.

One of the primary objectives of the I.J.C. PLUARG Programme is to extend, or extrapolate, the data from its monitoring and detailed studies to the Great Lakes Basin as a whole, in order to improve the state of knowledge of the relative contributions of different land use activities to lake loadings. With this in mind, an attempt has been made to use existing information to estimate the significance of beef and dairy operations in the Canadian Lower Great Lakes Basin in terms of potential loadings of pollutants to the drainage system.

For this purpose it was decided to look at total phosphorus only. This is because most of the other parameters are unstable and subject to considerable modification in stream transport - more so than total phosphorus - and because phosphorus per se is most often implicated as the limiting nutrient controlling lake degeneration by biological processes.

The problems of extrapolating the data obtained in a study such as this are many. Two of the greatest of these are: (i) estimating the distance that a pollutant load may travel, allowing for infiltration, dispersion, transformations, etc.; - and (ii) estimating the magnitude of the sources involved.

To attempt to solve these two major problems, the data collected during an interesting project conducted in 1973-74, have been reviewed (Coote, MacDonald and Rigby, 1974). Briefly, this project made use of airphotos of a large portion of the Canadian Lower Great Lakes Basin, to observe and characterize livestock operations in terms of criteria which might be related to their probable pollution potential. Among these criteria were - probable type of livestock, estimated size of operation (maximum capacity), and distance to nearest stream (perennial) or runoff receiving channel (intermittent). All information was recorded and stored in computer useable form.

The data have been selectively retrieved from computer storage to obtain the following information:

325,691 steers (or other confined fattening cattle) could be held in observed feedlots: Of these, 31,286 (9.6%) could be held in feedlots located less than 25 ft from a stream or runoff receiving channel; 35,287 (10.8%) could be held in feedlots located between 25 ft and 50 ft from a stream or runoff receiving channel; and 39,761 (12.2%) could be held in feedlots located between 50 ft and 100 ft from a stream or runoff receiving channel. These totals do not include all fattening steers. This is because the airphotos used ranged from 1966 to 1972 in date, because the whole area was not studied, and because small operations were not included in the survey. To obtain an estimate of the actual total, the 1974 Agricultural Statistics for Ontario (OMAF, 1975) were used to estimate a total of 634,300 cattle in the steers' category. Thus the airphoto survey covered over 51% of this total. This is a very good sample, and considering that the increase in numbers of steers between 1971 and 1974 is 15% (OMAF, 1975) then it is safe to assume that a good portion of the difference between the survey total and 1974 statistics is due to increasing herd sizes. Although it is certain that not all fattening cattle are housed in feedlots, it is clear from the above discussion that a very large portion of them are. For the purposes of this example, it will be assumed that all are housed this way.

The above procedure has been repeated for other cattle, dairy cattle and heifers, beef cows and bulls, to obtain the following statistics: From the airphoto survey, a total capacity of 121,990 animal units were observed and classified. This is only 10.2% of the 1,196,500 found in the 1974 Ontario statistics. The reason for this smaller sample is that only "large" operations were recorded in the airphoto survey, and the proportion of this type of cattle held in small units is far greater than is the case for steers and other feedlot cattle where most are held in fairly large units. However, of the total categorized, 4.979 (4.1%) were located less than 25 ft from a stream or runoff receiving channel; 12,267 (10.1%) were located between 25 ft and 50 ft from a stream or runoff receiving channel; and 15,890 (13%) were located between 50 ft and 100 ft from a stream or runoff receiving channel.

TABLE 12: Observed and Estimated Numbers of Cattle Housed near Streams and Runoff Receiving Channels, Canadian Lower Great Lakes Basin

Cattle Type	Total	distance from stream or channel <25 ft	25-50 ft	50-100 ft
Beef in feedlot				
observed	325,691	31,286	35,287	39,761
actual (1974)	634,300	-	-	-
estimated (1974)	-	60,931	68,723	77,437
Other cattle				
observed	121,990	4,979	12,263	15,890
actual (1974)	1,196,500	-	-	-
estimated (1974)	-	48,835	120,278	155,852

From the above percentages, it is possible to estimate the proportion of the total known cattle housed in these distance zones from streams or runoff receiving channels. These estimates are presented in Table 12.

Tables 8 and 9 show the estimated runoff load of total phosphorus from two different, but representative Southern Ontario feedlots. There is no way at this time to estimate the portion of the total feedlot cattle housed in paved versus unpaved feedlots. For the purposes of this example the mean load expressed per animal unit, 0.29 kg P/animal unit, was used and the distribution problem thus ignored. Tables 10 and 11 show the estimates of loadings from the two manure storage areas studied. Only the data from Site 3 are useable, but these solid manure storage sites are the most common. Thus an assumption of a total phosphorus load of 0.11 kg/animal unit/ur in runoff from these storages was made, - and is reasonable in the light of existing knowledge, and in the absence of more extensive data. There is no way of knowing at this time how much manure is deposited directly in streams by pasturing cattle, or what the effect of other routes of movement of manure to streams may be.

The next step in this extrapolation model is to estimate the proportion of the runoff load which reaches the stream. Two intuitive, but somewhat arbitrary assumptions will be considered: (i) that all runoff from sites less than 25 ft from a stream or runoff channel enters the Great Lakes drainage system, while 50% of that from sites between 25 ft and 50 ft enters the system; (ii) that all runoff from sites less than 50 ft from a stream or runoff channel enters the system, and 50% of that from sites between 50 ft and 100 ft enters the system.[1/]

With these two assumptions, and with the mean loads of total phosphorus per animal unit discussed above, the following estimates can be made:

Assumption (i) - total of 35,476 kg P/yr

Assumption (ii) - total of 68,678 kg P/yr

1/ Since this work was completed, Robinson and Draper (1978) have made improved estimates of these assumptions.

To put these figures into perspective, it is useful to compare these loadings with the overall yield of phosphorus from agricultural areas to the lakes. Data reported in the C.D.A. Task Force Report (Hore and MacLean, 1973) show that yields from small agricultural watersheds in Ontario ranged from 150 gP/ha/yr to 300 gP/ha/yr. Data collected under the PLUARG programme and presented in the final summary report of the Agricultural Watershed Studies (Coote, MacDonald and Dickinson (Eds), 1978) indicate that 160 - 1,510 gP/ha/yr may be leaving agricultural sub-basins. Armstrong et al (1974) reviewed a number of references and concluded that an average yield of 380 gP/ha/yr (with a range of 30 to 2,300 gP/ha/yr) has been reported in the literature in the U.S. From the foregoing, a range of from 150 to 2,000 gP/ha/yr has been chosen as reasonable. The total area of non-urban land in the part of Ontario south of latitude 45°N which is included in the "Lower Great Lakes Basin" is approximately 35,000 km^2. This means that the contribution of total phosphorus from this land area probably falls between 525,000 KgP/yr and 7,000,000 KgP/yr. Miller and Spires (1978) have estimated this load to be 3,000,000 kg/yr.

From these figures it can be further estimated that the effect of runoff from beef and dairy operations in this area lies between 0.5% and 13% of the total load. This is quite a wide range, but is an estimate based on a certain amount of measured data, and by combining the high end of one range in data with the low end of another range of data, and vice versa, the resulting range can probably be referred to with a fair degree of confidence.[1/]

1/ For a more rigorous examination of this type of extrapolation, the reader is referred to Robinson and Draper (1978). They concluded that approximately 216,000 kg P/yr enters streams in the Canadian Great Lakes Basin from cattle operations, based on a different set of assumptions of P attenuation between facilities and stream. This is approximately 7% of Miller and Spire's (1978) estimated agricultural P load.

Other Livestock Sources

This report has dealt exclusively with cattle manure sources. To put the whole livestock situation into perspective, it is useful to briefly consider other sources. The number of pigs and poultry in the Canadian Lower Great Lakes Basin in 1974 were 1,855,700 and 35,213,000 respectively. This is the equivalent of about 185,570 animal units of pigs (assuming average pig size of 100 lbs) and 140,852 animal units of poultry (assuming average poultry size of 4 lbs) where an animal unit is 1000 lb liveweight. These combined totals are less that the total cattle in this area. The nature and management of most pig and poultry operations is such that manure piles are less common, and outside feed-lots almost non-existent. Much of the pig manure is handled in a liquid form, and this, together with the accumulated manure from poultry operations tends to be spread directly on fields without outside storage. Thus these livestock types may present a manure spreading problem equivalent to that from cattle, but in terms of the runoff of manure from the housing facilities directly to streams, it is likely that they will have far less impact.

2.0 CONTAMINATION OF SHALLOW GROUNDWATER BY AN UNPAVED FEEDLOT

2.1 SUMMARY AND CONCLUSIONS

The results of this groundwater monitoring study around an unpaved feedlot on Guelph loam confirm that a process (probably denitrification) is causing nitrogen levels to decline more rapidly than would be expected from dilution alone as groundwater travels further from the feedlot source. However, detailed groundwater sampling 0-30 m from the source indicated a build-up of nitrate with distance, and a corresponding (but greater) decline in total Kjeldahl nitrogen and its component ammonium in the same distance. This indicated mineralization of organic nitrogen, probably with fixation and adsorption of ammonium in the subsoil, in the zone 0-10 m from the feedlot. Nitrification appeared to be the dominant process between 10 m and 20 m distance, where a peak nitrate nitrogen level in excess of 60 mg/l was observed. The results indicated the sensitivity of nitrate concentrations to processes in the immediate vicinity of the source and the potential of wells, streams or tile drains to be contaminated with nitrate if located in the zone of high nitrification. This zone was found to be at approximately 20 m from the feedlot source. The unpaved feedlot was also found to be a source of shallow groundwater contamination by sodium and chloride, but not of phosphorus.

2.2. INTRODUCTION

The International Joint Commission study of the effects of land use activities on pollution of the Great Lakes recognized the potential of livestock operations to contribute to water pollution. Initially a detailed study was carried out on runoff from feedlots and manure storage areas (Coote and Hore, 1976). Subsequently a study was established to investigate the role of unpaved feedlot areas in contributing to groundwater pollution and to stream pollution via discharge of contaminated groundwater.

Little work has been carried out in the Canadian Great Lakes Basin on the potential problem of feedlots and groundwater pollution. Gillham and Webber (1969) quantified the flux of nitrogen in groundwater away from a barn lot. They showed that the movement of nitrogen closely followed the movement of the groundwater, and that the concentration increased with increasing flow. However, the total flux of nitrogen was extremely small compared to the source. This was attributed, in part, to the fixation of ammonium ions in the soil profile. Studies by Partridge and Racz (1975) showed that nitrogen levels in groundwater near a manure pile declined more rapidly than chloride, suggesting that denitrification was occurring in the groundwater zone. Sowden and Hore (1976) obtained similar results.

2.3 METHODS AND MATERIALS

A suitable site was selected near Rockwood, Ontario. The feedlot, which was approximately 24 m by 34 m on a 5% slope, housed an average of 100 head of beef steers and heifers weighing between 320 kg and 430 kg. It was located on well-drained Guelph loam over a subsoil of sandy, gravelly, calcareous loam till. Figure 20 shows a plan view of the site.

Groundwater sampling piezometers and watertable wells were located as indicated in Figures 20 and 21. Nests 1, 2, 3 and 4 were installed in December 1975 by a hollow-auger drill operated by the Department of Earth Sciences, University of Waterloo. The piezometers were installed with a cement seal above a 60 cm section of perforated pipe wrapped with glass-fibre cloth, and surrounded by sand. The water table wells consisted of perforated and glass-fibre wrapped sections of pipe 150 cm long, at a depth within the likely range of the water table fluctuations. All of these pipes were of 3.65 cm inside diameter PVC. Sampling wells 6 through 14 were installed in September 1976. They consisted of 3.49 cm PVC pipes with filters made of nylon-rayon pelon and glass-fibre cloth stretched and taped across the bottom ends. They were installed using a 5 cm hand-operated auger. In May 1977, the University of Waterloo installed two nests of 3 piezometers each (15A,B,C and 16A,B,C) in the vicinity of shallow wells 10, 11, 13 and 14.

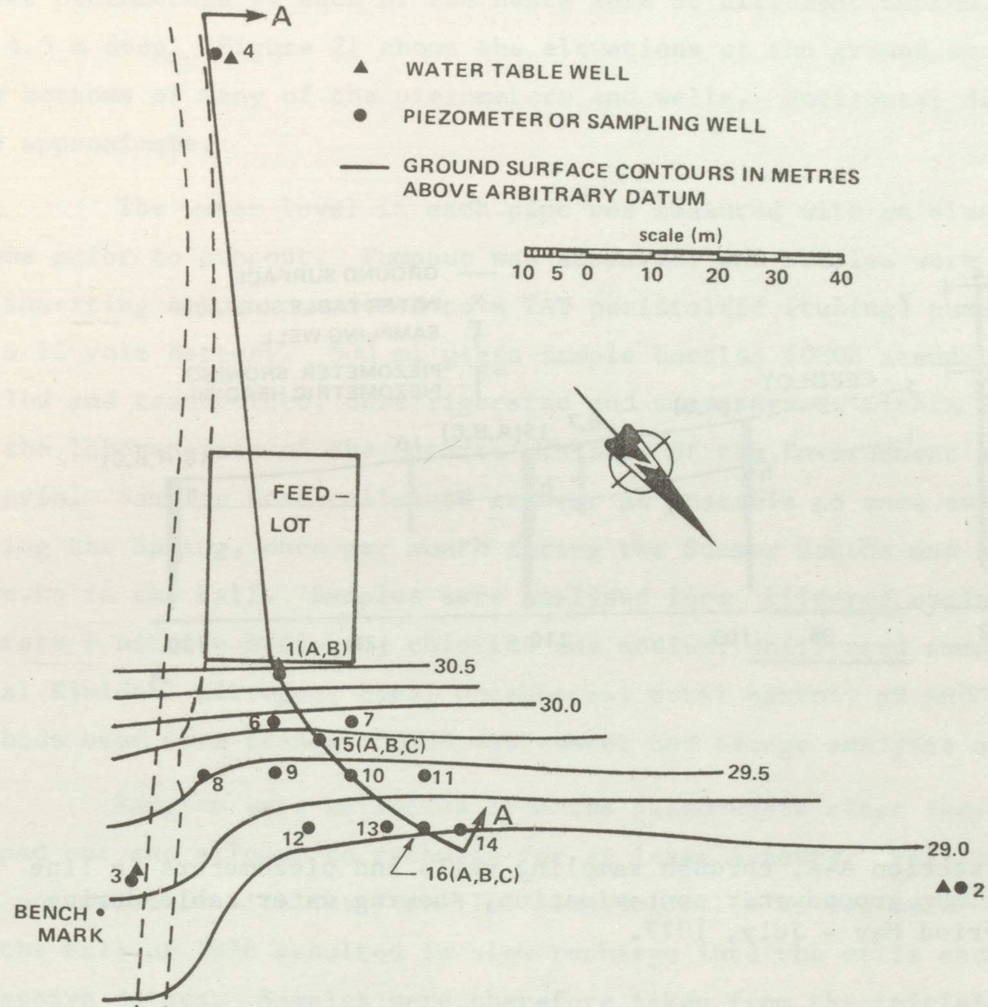

Figure 20: Site plan, ground surface and locations of Piezometers and Water Table Wells.

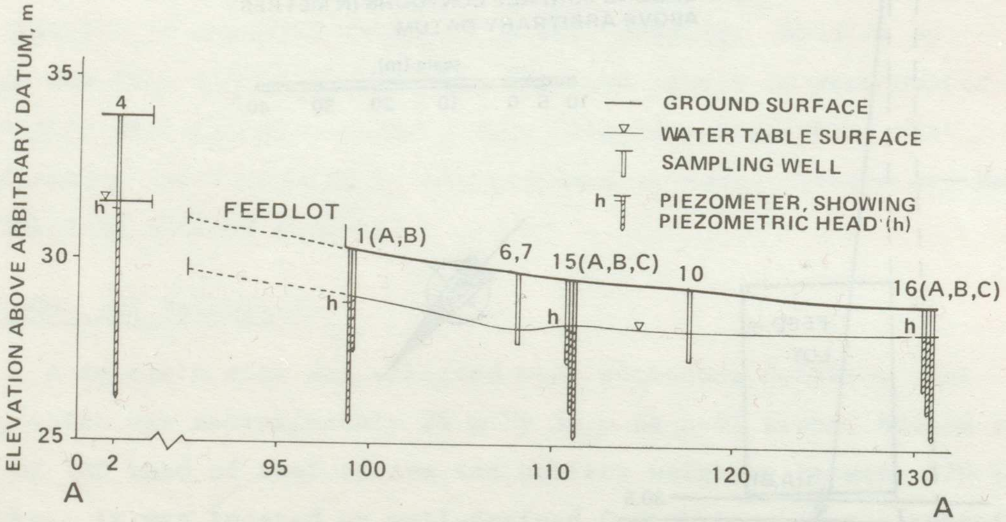

Figure 21: Cross section A'-A, through sampling wells and piezometers in line of maximum groundwater contamination, showing water table during the period May - July, 1977.

These nests consisted of 3.65 cm PVC pipes with 30 cm perforated bottom sections wrapped with glass-fibre and surrounded by sand; they were similar to piezometers 1, 2, 3 and 4, but without the cement seal. The three piezometers in each of the nests were at different depths from 2.3 m to 4.5 m deep. Figure 21 shows the elevations of the ground surface and the bottoms of many of the piezometers and wells. Horizontal distances are approximate.

The water level in each pipe was measured with an electrode probe prior to pumpout. Pumpout was achieved, and samples were collected, by inserting a hose connected to a TAT peristaltic (tubing) pump powered by a 12 volt battery. 500 ml glass sample bottles (OMOE standard) were filled and transported, unrefrigerated and unpreserved, within 2 hours to the laboratories of the Ontario Ministry of the Environment at Rexdale, Ontario. Samples were collected as near as possible to once every 2 weeks during the Spring, once per month during the Summer months and once every 3 weeks in the Fall. Samples were analysed for: filtered organic carbon, nitrate + nitrite nitrogen, chloride and sodium; unfiltered ammonia nitrogen, total Kjeldahl nitrogen, total phosphorus, total carbon, pH and conductivity. Methods used were standard OMOE wastewater and sewage analysis procedures.[1/]

Samples were collected from the piezometers after they were pumped out and allowed to recharge for at least 4 hours. This procedure was not possible with the 9 shallow sampling wells as low water table levels in the Fall of 1976 resulted in slow recharge into the wells and caused excessive delays. Samples were therefore taken from the initial pumpout. To investigate possible problems with this approach, some comparison samples were examined. It was found that differences in water quality before and after pumpout were generally less than the standard deviation of the other samples from each well, and that differences were positive and negative with about equal frequency. It was therefore concluded that little error would result from this procedure, - a conclusion also reached by Sowden and Hore (1976).

1/ These methods are described in Section 1.4 of this report with the following exceptions: Total carbon was determined by injection into a combustion tube at 950° C containing cobalt oxide on asbestos, and CO_2 measured by infrared analysis; dissolved organic carbon was found by difference between filtered total carbon and inorganic carbon measured by I.R. analysis after combustion at 150° C in tube containing H_3PO_4 on quartz chips; chloride was found by colorimetry on an autoanalyser using color development with ferric ammonium sulphate and mercuric thiocyanate; sodium was determined by atomic absorption spectroscopy after spiking with lithium.

Table 13 presents the comparisons between 5 sets of samples taken before and after pumpout at a relatively contaminated piezometer, a moderately contaminated piezometer, an uncontaminated piezometer and at one shallow well. It can be seen that variability is very low between pre and post pumpout samples (generally far lower than variability between sample dates) for all parameters except those of the nitrogen forms. The non-nitrogen parameters also showed no consistency with regard to pre pumpout samples being higher or lower than those collected after pumpout, suggesting that variability is not influenced by the sample being collected before or after pumpout. The nitrogen values, however, show considerable variation at the contaminated sites, especially as $(NO_2 + NO_3)$-N and NH -N when these values were low (less than 0.50 mg/L). On each occasion on which values exceeded 1 mg/L of $(NO_2 + NO_3)$ or NH_4-N, variability from the mean was very low. Since the mean concentrations of nitrate + nitrite at the 9 shallow wells generally exceeded 1 mg/L, it appears that it is unlikely that time of sampling relative to pumpout is critical for this parameter. However, the observed variability in NH_4-N concentrations between pre and post pumpout samples may be of concern. Sowden and Hore (1976) compared groundwater samples collected prior to and after pumpout of sampling wells and concluded that variation in nitrate and ammonium concentrations were equally well reflected by either procedure. In view of Sowden and Hore's statements, the validity of data collected was accepted.

During installation of the 9 additional wells it was apparent that there was a compact layer of subsoil throughout the whole area, with all wells except No.6 extending below this layer. Hydraulic conductivity measurements were made using a modified Hvorslev method (Lambe and Whitman, 1969, and personal communication with R. Gillham, University of Waterloo), assuming an isotropic soil and calculating the Basic Time Lag as follows:

$$T = (t - t_o)/\ln(h_o/h)$$

where T = Basic Time Lag (2)

t_o = initial time when head-raising rod inserted into well;

t = time after head falls through given known distance;

h_o = head above watertable after inserting rod;

$h = h_o$ - fall in head.

Table 13: Comparison of Concentrations of Water Quality Parameters in Samples Collected Before and After Pumpout of Piezometers and Wells (5 independent data sets)*

		TC	TOC	FOC	(NO_2+NO_3)-N	NH_4-N	TKN	Cl	Na	Cond	pH	TP
1A**	i)***	312(-1)	-	64(+7)	0.005(<±67)	10.8 (-13)	19.3 (+ 2)	500 (- 6)	215 (+ 8)	3700(0)	7.61	0.050(-17)
5/5/76	ii)	315(6)	-	60(2)	<.008 >.003 (195)	12.4 (15)	18.9 (25)	530 (10)	200 (16)	3700(6)	7.29	0.060(136)
19/9/76	i)	316(+2)	480(+23)	-	0.095(+850)	13.3 (- 2)	21.3 (+58)	625 (+ 4)	146 (- 9)	3750(+3)	7.53	0.086(+ 5)
	ii)	310(6)	390(39)	-	0.010(195)	13.5 (15)	13.5 (25)	600 (10)	1[illegible]0 (16)	3650(6)	7.62	0.082(136)
1B	i)	820(+12)	-	480(+23)	0.250(+372)	24.0 (- 6)	43.75(- 3)	560 (-17)	195 (- 5)	5000(0)	7.08	3.7 (+ 6)
5/5/76	ii)	730(29)	-	390(79)	0.053(187)	26.5 (45)	45.00(41)	720 (11)	205 (10)	5000(8)	7.04	3.5 (68)
4A	i)	63(-2)	8(-11)	-	0.010(-95)	0.55 (+83)	0.65(+16)	11.5(+10)	8.3(+ 3)	590(0)	8.02	0.045(+ 7)
19/8/76	ii)	64(62)	9(48)	-	0.200(117)	0.30 (29)	0.56(47)	10.5(77)	8.1(102)	590(87)	8.15	0.042(139)
8	i)	-	-	-	18.8 (-16)	0.074(+147)	-	105 (0)	-	1600(-3)	-	-
8/10/76	ii)	-	-	-	22.5 (68)	0.030(54)	-	105 (1)	-	1650(4)	-	-

* Values given in mg/L except for pH and conductivity (umho/cm); TC - total carbon; TOC - total organic carbon; FOC - filtered organic carbon; $(NO_2 + NO_3)$-N - filtered nitrite plus nitrate nitrogen; NH_4-N - filtered ammonium nitrogen; TKN - total Kjeldahl-N; TP - total phosphorus.

** See Figures 1 and 2 for locations and depths of piezometers and wells.

*** i) sampled before pumpout (% difference above or below value after pumpout).

ii) sampled after pumpout (% coefficient of variation among all samples at the site).

The hydraulic conductivity, k, was found from the following equation:

$$k = \frac{d^2 \ln \left(\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D}\right)^2} \right)}{8\, L\, T} \qquad (3)$$

where the dimensions of the well (d,L,D) are as follows:

d = diameter of piezometer (inside)

D = diameter of cavity

L = height of cavity

and m = 1, when the material is assumed to be isotropic.

The hydraulic conductivity was measured as follows: the well casing was drawn upwards a distance of 15.24 cm to leave a cavity at the base. It was assumed the walls of this cavity remained stable during the course of the permeability test. The filter on the bottom of the pipe was destroyed by piercing with a 1.2 cm rod. The water table was measured, then an aluminum rod 1.2 cm diameter was rapidly inserted into the well until the water level reached 914 cm above the watertable level (h_o). The fall in the head (h_o-h) was then timed at intervals to give a series of time:head points until the head had fallen at least 70% of the distance to the original water table level. The time lag:head data were plotted and the best fit line estimated; the Basic Time Lag was determined from this line by selecting the time at which $^{h_o}/_{h} = 0.37$ (from expansion of equation (1)).

2.4 RESULTS AND DISCUSSION

Table 14 summarizes the water quality results during the period of study.[1] Data from 1976 and 1977 have been averaged since analyses revealed very few significant differences during the 2 years and no significant seasonal differences in concentrations of materials at given sampling sites. However, it was readily apparent that differences existed between sampling wells. Among the original 4 sampling piezometer nests (Sites 1, 2, 3 and 4, Table 13), only the site adjacent to the feedlots was significantly contaminated compared to Site 4, which is upslope of the feedlot, and assumed to be unaffected by it. Data from the additional sites show a distinct zone of influence downslope of the feedlot.

1. All water quality data can be found in appendix C

Table 14: Mean concentrations of nitrogen, chloride, sodium, total phosphorus, total carbon, and electrical conductivity, in ground water samples, 1976-77 (mg/L)*

Site	Depth (...)	NO_2+NO_3-N			NH_4-N			TKN			CL			Na			TP			Cond.			TC		
		$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples	$\bar{X}$	CV	no. of samples
1A	2.9	0.22	192	23	35.0	72	21	68.9	60	21	664	14	23	192	10	23	7.585	96	22	4745	9	23	716	35	15
1B	4.9	0.03	188	23	14.70	23	21	21.47	21	23	555	11	23	199	14	23	0.137	115	23	3689	6	23	325	10	13
2	3.0	0.05	170	22	0.11	71	18	0.59	53	19	80	16	22	23	15	21	0.077	160	22	915	8	22	85	19	14
3	4.6	0.59	218	23	0.06	126	21	0.51	118	22	18	47	22	9	65	23	0.043	110	22	417	58	23	32	52	14
4	6.8	0.82	149	19	0.48	54	18	1.20	62	19	31	88	19	66	121	19	0.086	146	19	1398	89	19	46	54	13
6	2.1	0.45	115	8	5.43	69	8	10.67	55	8	380	7	7	118	9	7	0.386	105	8	2794	4	9	241	83	5
7	2.1	46.70	49	7	0.82	102	7	3.01	34	8	311	2	6	109	6	5	0.269	71	8	3056	4	9	206	10	2
8	2.0	16.71	43	10	0.10	73	11	0.72	63	10	63	58	11	50	14	10	0.093	119	10	1313	18	11	140	18	7
9	2.0	26.60	23	10	0.23	135	9	0.23	49	9	329	13	10	111	10	9	0.374	186	9	2428	3	10	159	14	7
10	2.0	63.17	13	9	0.24	94	9	1.69	32	8	296	8	9	88	9	7	0.501	95	7	2942	4	9	179	2	3
11	2.0	34.29	45	6	0.37	82	7	1.26	28	6	96	19	7	31	10	6	0.474	100	5	1614	3	7	127	18	4
12	1.9	38.25	25	8	0.20	205	8	1.16	62	9	246	9	9	88	4	8	0.199	102	9	2139	5	9	140	5	5
13	1.9	35.11	11	9	0.30	138	8	1.49	60	8	279	9	9	93	7	8	0.267	89	8	2422	5	9	151	3	6
14	1.9	29.82	6	10	0.36	168	10	2.58	77	10	234	5	10	69	6	10	0.265	131	10	2150	2	10	150	20	7
15A	2.4	35.73	7	3	0.02	118	3	2.45	23	3	331	2	3	116	11	3	0.041	38	3	3133	2	3	232	10	3
15B	3.7	16.95	15	5	0.02	85	5	1.18	22	5	312	4	5	91	8	5	0.052	87	5	2650	4	5	185	4	5
15C	4.5	21.60	1	3	0.05	112	3	1.11	30	3	322	2	3	94	3	3	0.036	82	3	2717	1	3	184	1	3
16A	2.3	25.40	10	3	0.01	90	3	0.51	30	3	263	2	3	82	1	3	0.034	33	3	2317	1	3	151	1	3
16B	2.9	17.80	6	3	0.05	106	3	0.81	37	3	275	6	3	83	2	3	0.030	112	3	2200	2	3	141	3	3
16C	3.6	8.25	19	4	0.01	71	4	0.33	34	4	79	3	4	23	3	3	0.013	77	4	1032	2	4	79	2	4

* Analyses performed by the Laboratories Branch, Ontario Ministry of the Environment, Toronto.

$\bar{x}$ = mean

C.V. = percent coefficient of variability (100 s/$\bar{x}$), where S is the standard deviation.

Figures 22 through 26 show the distribution of the mean value of chloride, nitrate + nitrite nitrogen, ammonium nitrogen, total nitrogen and total carbon respectively, downslope of the feedlot for the study period. The distinct pattern of a plume of contaminated groundwater is shown moving in the general direction of groundwater flow as indicated by examination of the water table levels in the piezometers and wells. Site 8, to the northeast of the feedlot, was at the edge of the apparent plume of contamination from the feedlot (see Figure 20). This site had nitrate and ammonium nitrogen and sodium concentrations within the range of those found in shallow groundwater under similar soils and cropping (corn) conditions elsewhere in the area (Gillham, Blackport and Cherry, 1978).

Figures 23 and 25 show that in the same distance in which the mean nitrate + nitrite nitrogen concentration increased from 0.2 mg/L to 63 mg/L (Table 14), the mean concentration of unnitrified forms (TKN) decreased from 68.9 mg/L to 1.7 mg/L (Table 14). The total nitrogen (sum of nitrate + nitrite and total Kjeldahl nitrogen) varied over the same distance from an average of 69.1 mg/L to approximately 75 mg/L (Figure 25 and Table 14). The close agreement in the mean values for total N suggest that total N was fairly well conserved in the 20 meter distance zone. It can be assumed that organic N was mineralizing to NH_4 within this distance and that the major movement of nitrogen in the highly contaminated zone in the immediate vicinity of the feedlot was in the ammonium ion and soluble organic forms. As the water moved further from the highly contaminated zone around Site 1, in which nitrification is clearly very low (Figure 23), nitrification is apparently taking place so that a peak nitrate + nitrite concentration is seen at about 20 m from the center of the downslope boundary of the feedlot.

Figure 25 shows that the distribution of total nitrogen does not fit the pattern of chloride concentration very well in the vicinity of the sample site immediately downslope of the feedlot (Site 6). At this site total nitrogen is lower than expected. Although both ammonium and total Kjeldahl nitrogen are high, they do not compensate for the low nitrate + nitrite concentrations observed at this site. The low values of nitrate + nitrite found in well No.6 are believed to be the result of low hydraulic conductivity at this site as discussed below.

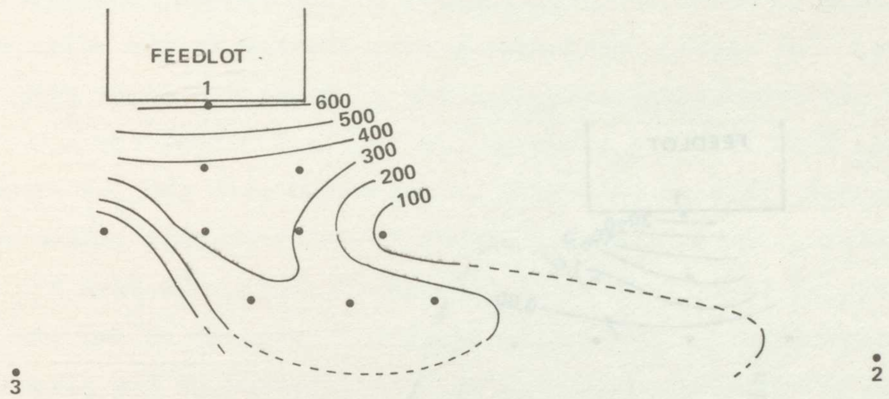

Figure 22: Distribution of mean chloride concentrations, mg/L, in shallow groundwater downslope of feedlot, 1976-77.

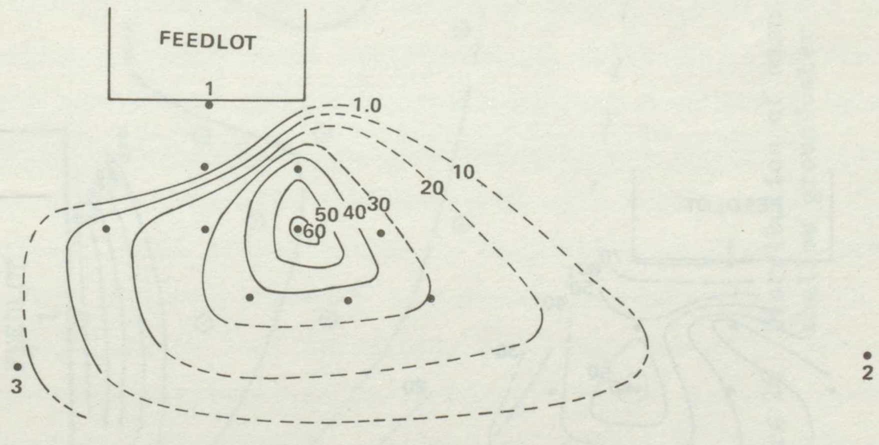

Figure 23: Distribution of mean nitrate plus nitrite nitrogen concentrations, mg/L, in shallow groundwater downslope of feedlot, 1976-77.

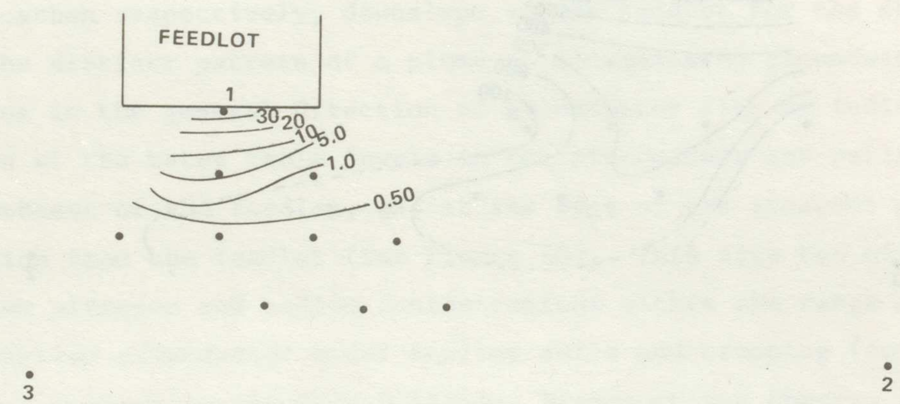

Figure 24: Distribution of mean ammonium nitrogen concentrations, mg/L, in shallow groundwater downslope of feedlot, 1976-77.

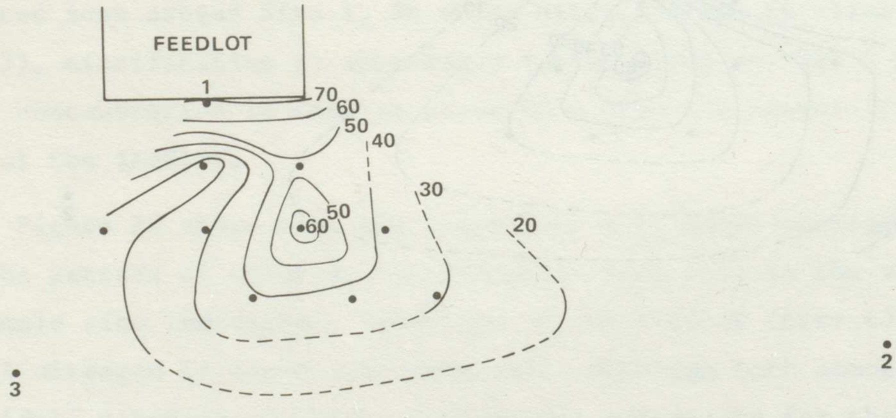

Figure 25: Distribution of mean total nitrogen concentrations, mg/L, in shallow groundwater downslope of feedlot, 1976-77.

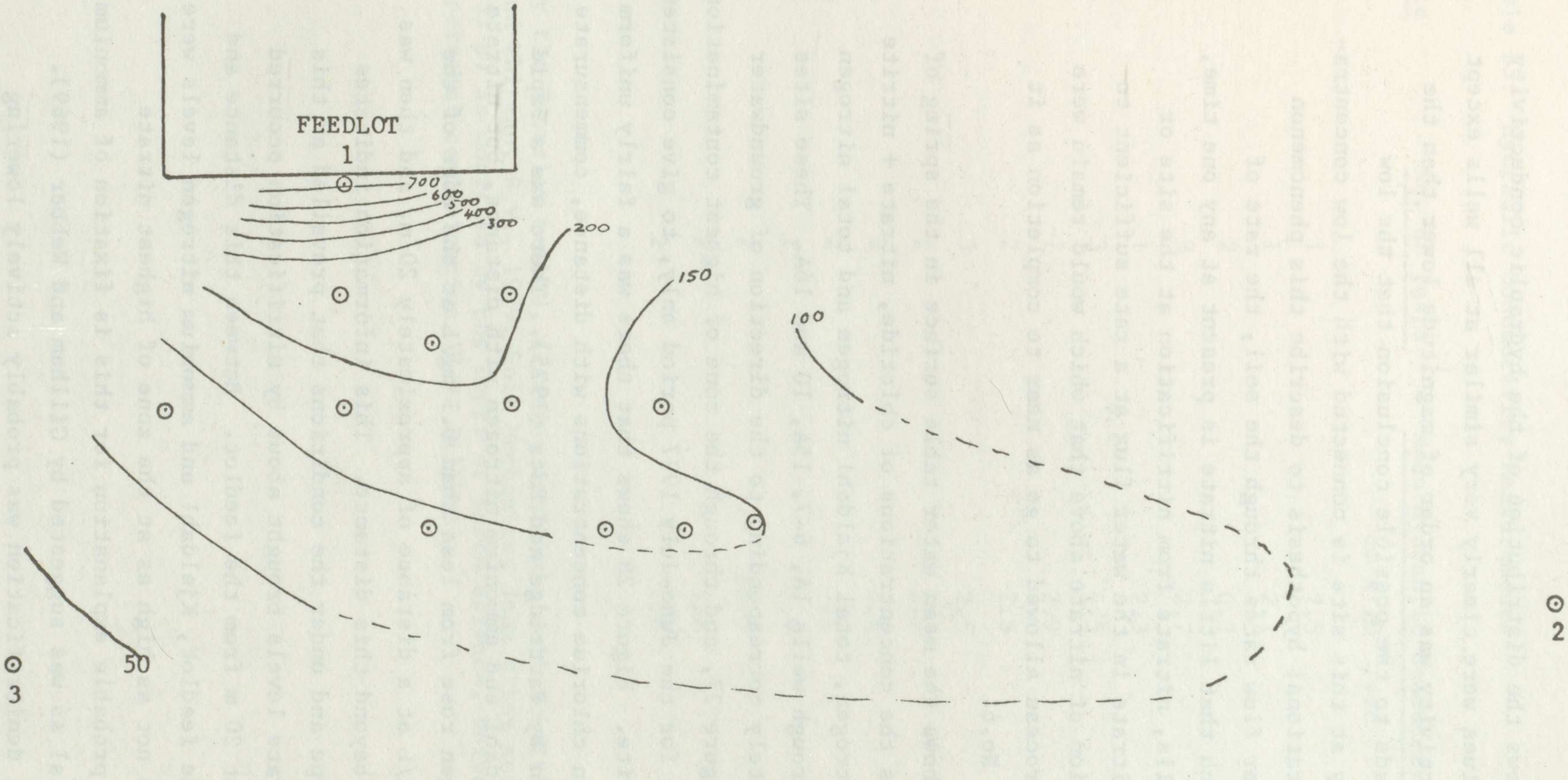

Figure 26 Distribution of mean total carbon concentrations, mg/L, in shallow groundwater downslope of feedlot, 1976-77

Table 15 shows the distribution of the hydraulic conductivity measurements. The values were clearly very similar at all wells except No.6. Here the conductivity was an order of magnitude lower than the other wells. This leads to the possible conclusion that the low hydraulic conductivity at this site is connected with the low concentrations of nitrate. A rational hypothesis to describe this phenomenon would be that, at lower flow rates through the soil, the rate of denitrification is such that little nitrate is present at any one time, while at the other wells, nitrate from nitrification at the site or upslope is supplying nitrate in the water flux at a rate sufficient to maintain a concentration of nitrate above that which would remain were the denitrification process allowed to go as near to completion as it appears to go at well No.6.

Figure 27 shows the mean water table surface in the spring of 1977.[1] Figure 28 shows the concentrations of chloride, nitrate + nitrite nitrogen, ammonium nitrogen, total Kjeldahl nitrogen and total nitrogen in a cross section through wells 1A, 6-7, 15A, 10 and 16A. These sites form a line approximately corresponding to the direction of groundwater flow, indicated by Figure 27, and through the zone of highest contamination. The results are those for the June-July 1977 period only, to give consistency of sampling at each site. Figure 28 shows that there was a fairly uniform logarithmic decline in chloride concentrations with distance, commensurate with dilution as shown by Partridge and Racz (1975). There was a rapid decline in total Kjeldahl and ammonium nitrogen with distance, but nitrate (plus nitrite) nitrogen rose from less than 0.1 mg/L at the edge of the feedlot to over 60 mg/L at a distance of approximately 20 m, and then was seen to fall rapidly beyond this distance. This information indicates that, in this soil type and under the conditions that prevailed at this feedlot, maximum nitrate levels brought about by nitrification occurred at a distance of about 20 m from the feedlot. Between this distance and the source area of the feedlot, Kjeldahl and ammonium nitrogen levels were high, but total N was not as high as at the zone of highest nitrate concentrations. The probable explanation for this is fixation of ammonium in the subsoil material as was suggested by Gillham and Webber (1969). Beyond the 20 m zone, denitrification was probably actively lowering nitrate (and total N) levels since the decline in these parameters was at a rate far exceeding that for chloride - the latter being presumed to be due entirely to dilution.

1. All water table elevations can be found in appendix D

Table 15: Hydraulic Conductivity Measurements

Site	No. of Tests	Mean Hydraulic Conductivity* cm x 10^{-4}/sec	Range (cm x 10^{-4}/sec)
1A	1	7.5	-----
1B	1	2.1	-----
6	2	0.3	0.2 - 0.4
7	3	2.7	2.4 - 2.9
9	1	2.3	-----
10	3	4.5	2.2 - 5.6
11	1	2.9	-----
12	2	2.6	same value
13	3	2.5	2.2 - 2.6
14	2	2.9	same value
15a	2	5.4	5.3 - 5.5
15b	2	3.1	2.5 - 3.6
15c	1	1.9	
16a	2	14.5	14.0 - 15.0
16b	2	3.7	3.6 - 3.8
16c	2	1.9	1.6 - 2.2

* By the Hvorslev method, assuming isotropic soil conditions (Lambe, T.W. and Whitman, R.V., 1969, Soil Mechanics, John Wiley and Sons Inc., New York, 553 p) as modified by the Dept. of Earth Science, University of Waterloo, (personal communication, R.W. Gillham).

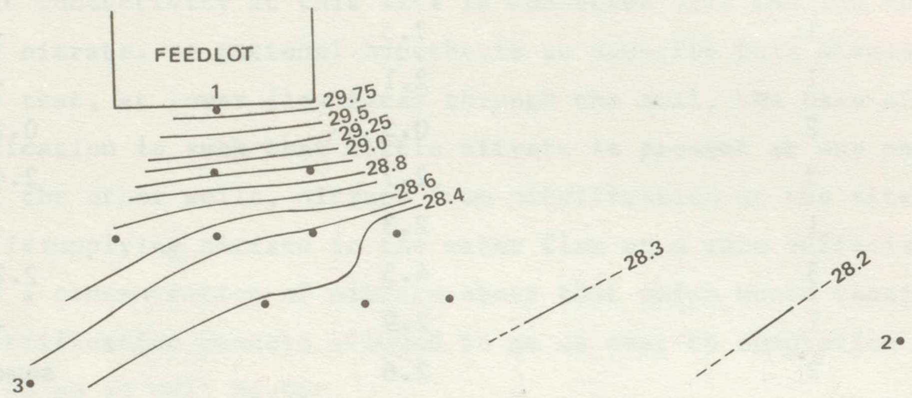

Figure 27: Average water table position in spring, 1977; mean of three dates, March - May.

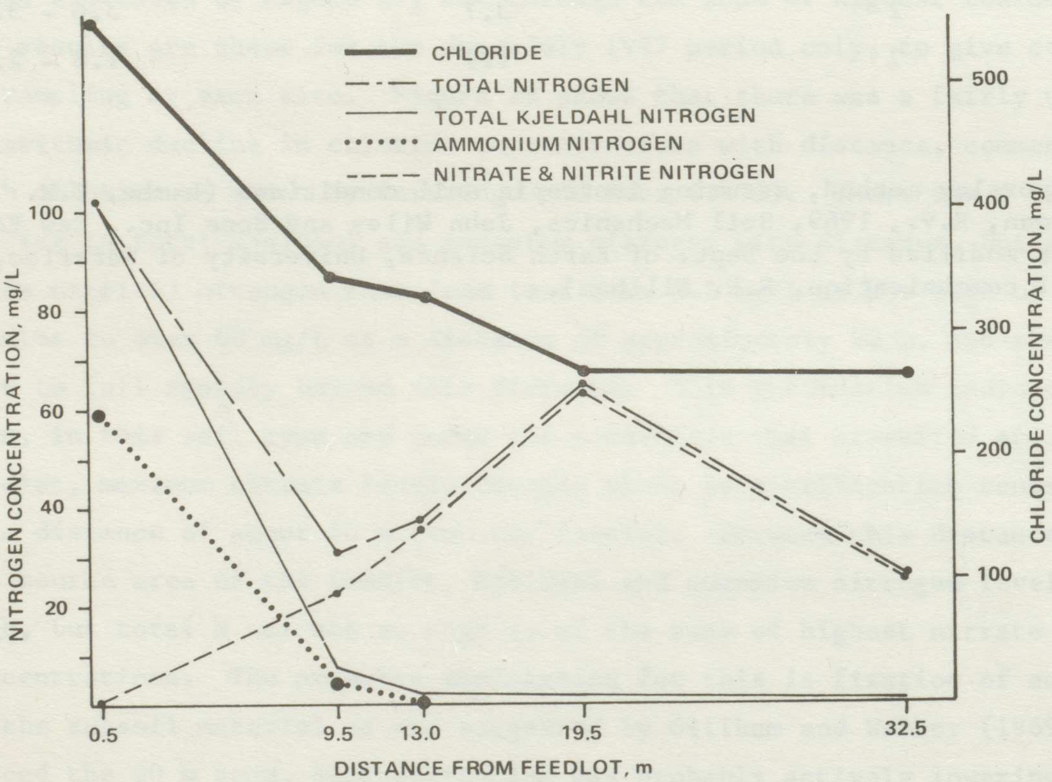

Figure 28: Nitrogen and chloride concentrations in shallow groundwater with distance from feedlot along part of cross section A-A in Figure 20; mean of three sample dates, June - July 1977.

Compared with the studies of Sowden and Hore (1976) and Partridge and Racz (1975), the sample wells used in this study were more densely spaced and closer to the source. Both studies showed higher levels of nitrate at the wells adjacent to the feedlot than were observed in this study. However, the Site 1 wells in this study were less than 1 m from the edge of the feedlot while in the Sowden and Hore, and Partridge and Racz studies, they were 3-6 m away. In this study, nitrate levels at the 3-6 m distance would have been expected to be about 10-15 mg/L (see Figure 28). This is the same order of magnitude as was observed in both these other studies at this distance from the source, but somewhat lower than the means observed by Partridge and Racz. Sowden and Hore had ammonium data, which were very comparable (1-10 mg/L) to those expected in the 3-6 m distance zone in this study. They also noted high ammonium nitrogen contents of soil samples in the vicinity of the manure pile (up to 78 ppm at 61-91 cm depth). This supports the assumption used in this study that soil absorption and fixation of ammonium nitrogen was the prime cause of differences in total N (NO_3 + NO_2 + TKN) in the 0-20 m distance zone.

Sodium was also plotted against distance from the feedlot (Figure 29). Its decline was similar to chloride, suggesting a low rate of sorption activity with respect to sodium within the 30 m zone. Total phosphorus concentrations were highly variable but mean values showed no apparent influence of the feedlot beyond the sample well at the edge of the feedlot. Some of the variability in total phosphorus is probably due to variability in fine sediment contents of samples from wells with different filters, some of which were functioning more efficiently than others. For this reason, Figure 29 shows total phosphorus concentrations at wells 1A, 15A and 16A only, which were all fitted with similar filters.

There was evidence of movement of contaminated water to the 4.5 m depth adjacent to the feedlot, as indicated by chloride concentrations at Site 1B (Table 14). This depth was also seen to be contaminated at the 15 m distance zone from the feedlot (Site 15C, Table 14), but at the 30 m distance zone the deeper samples were consistently lower in concentrations of all parameters compared with the shallower sampling depths at this site (Site 16). The elevations of the water table surface and piezometric head data indicated that the lower edge of the feedlot was in a recharge zone, while there was no apparent net vertical movement of water at the

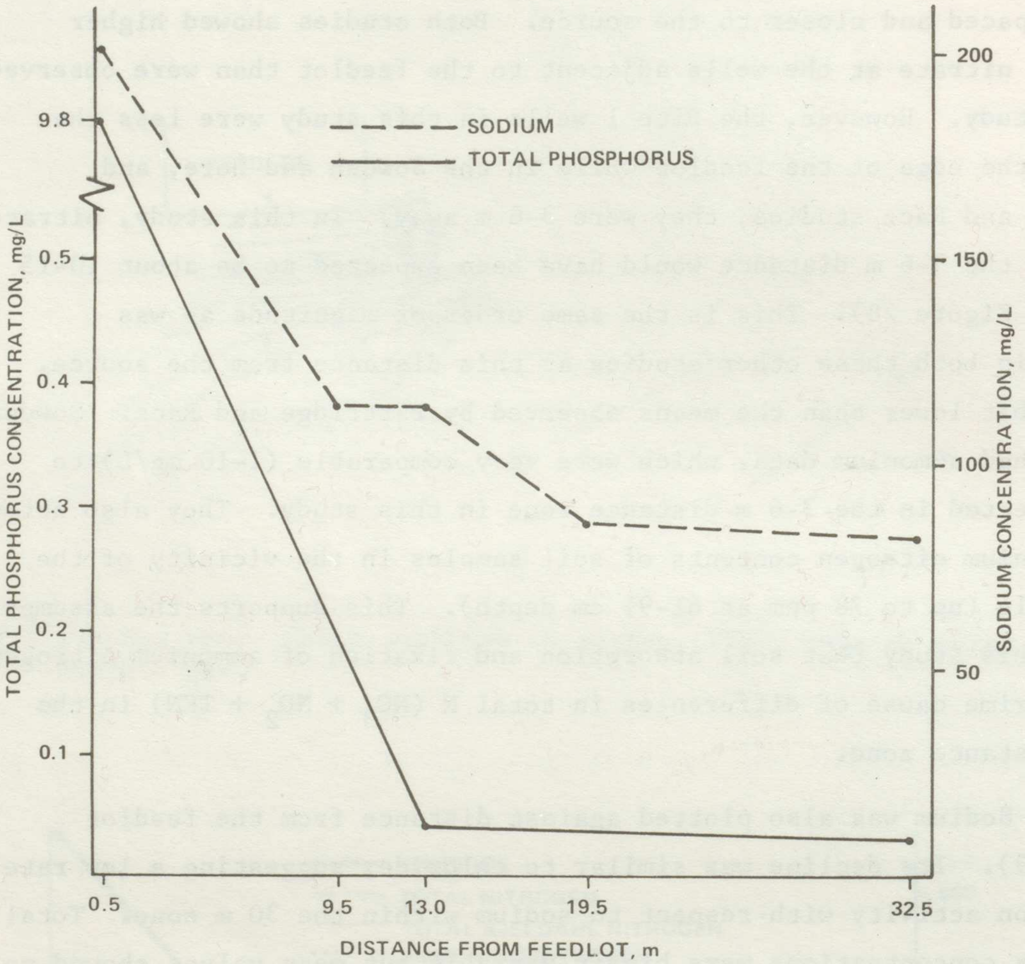

Figure 29: Sodium and total phosphorus concentrations in shallow groundwater with distance from feedlot along part of cross section A-A in Figure 20; mean of three sample dates, June - July 1977.

downslope sites for which piezometric head data were available (Sites 15 and 16, Figure 21). These results suggest that the groundwater was not seriously influenced by the feedlot to depths much greater than approximately 4.5 m.

There was evidence of movement of contaminated water to the 4.5 m depth adjacent to the feedlot, as indicated by chloride concentrations at Site 1B (Table 14). This depth was also seen to be contaminated at the 15 m distance zone from the feedlot (Site 15C, Table 14), but at the 30 m distance zone the deeper samples were consistently lower in concentrations of all parameters compared with the shallower sampling depths at this site (Site 16). The elevations of the water table surface and piezometric head data indicated that the lower edge of the feedlot was in a recharge zone, while there was no apparent net vertical movement of water at the downslope sites for which piezometric head data were available (Sites 15 and 16, Figure 21). These results suggest that the groundwater was not seriously influenced by the feedlot to depths much greater than approximately 4.5 m.

3.0 REMEDIAL MEASURES RECOMMENDATIONS

The studies described in this report, as with most PLUARG Task C studies, were not originally formulated to compare alternative remedial measures. Few quantitative evaluations are therefore possible regarding possible remedial measures.

By observation, it is possible to recommend that the most advantageous measure which can be taken to control stream contamination by runoff and seepage from livestock feedlots and manure storage areas is the maintenance of adequate separation distances between these facilities and streams. This permits attenuation of phosphorus (and probably also bacteria and viruses) in runoff, and de-nitrification of nitrogen in groundwater. The result should be protection of streams, provided that the separation distance allows for attenuation and/or de-nitrification during the periods of greatest nutrient mobility - namely, the period of snow-melt and early spring rains. Robinson and Draper (1978) found that a model which assumed complete attenuation of phosphorus within a distance of 400 ft (122 m) was verified fairly well by monitoring data. This suggests that 400 ft (122 m) may represent a good approximation of the average attenuation distance.

While not strictly a legitimate extrapolation of the data contained in Section 2 of this report, it is possible to estimate by linear extension of these data that most nitrogen was lost, probably by de-nitrification, from the groundwater below the unpaved feedlot within a distance of 50 m from the feedlot. Certainly, nitrogen enrichment was not evident in groundwater at a distance of about 110 m downslope from the feedlot. The 400 ft (122 m) distance may therefore be satisfactory for both surface and groundwater nutrient removal - recognizing, of course, that certain conditions may well exist in which these generalizations, which are based on very limited data, will not apply. Such conditions as steep slopes, excessively permeable or excessively impermeable soils may lead to more direct movement to surface and/or groundwater, with insufficient opportunity for nutrient attenuation by soil colloids and microbiological activity. Under these conditions, separation distances may need to be increased above the suggested "average" of 122 m (400 ft). Furthermore, the presence of sub-surface drains in the vicinity of feedlots or manure storages may "short circuit" the attenuation process by reducing the period of contact of contaminated water with the soil. Such drainage systems are not recommended if water quality is to be preserved.

If runoff holding facilities are constructed in lieu of the recommended separation distance, then it is suggested that feedlot and manure storage area surfaces should be paved to prevent infiltration to the groundwater. Holding capacities must be sufficient to contain runoff for the maximum anticipated length of time between opportunities for emptying the storage and utilizing the manure. Runoff values presented in this report can be used as a guide to the design of runoff storages.

If manure is given full recognition as a source of crop nutrients and soil building organic matter, the problem of water contamination from this source would probably not arise. This is because any measures taken to conserve the nutrient value of manure will, simultaneously, reduce the incidence of stream and groundwater pollution.

Those concerned with control of pollution from livestock feedlots and manure storages should consult the Canada Animal Manure Management Guide, and corresponding Provincial guides such as the Ontario Agricultural Code of Practice, in which will be found to be a source of considerable information on this subject.

4.0 LIST OF REFERENCES

Armstrong, D.E., K.W. Lee, P.D. Uttormark, D.R. Keeny and R.F. Harris, 1974; Pollution of the Great Lakes by Nutrients from Agricultural Land; (In) I.J.C. PLUARG Task A Report (U.S.) Volume 1, Section A6., November 1974.

Canada Animal Waste Management Guide, 1974; Agr. Can. Pub. 1534, Ottawa.

Coote, D.R., 1975; Data Discussion, Water Quality Monitoring; (In) Agricultural Watershed Studies, Annual Report 1974-75, I.J.C. PLUARG Task C, Canada, April 1975, Section IV.

Coote, D.R., E.M. MacDonald and M. Dwyer Rigby, 1974; A Selective Inventory of Large Livestock Operations, Southern Ontario; (In) Agricultural Land Uses, Livestock and Soils of the Canadian Great Lakes Basin, Report for Task C PLUARG, Section IV, June.

Coote, D.R., and F.R. Hore, 1976. Runoff Characteristics and Pollution Potential from Cattle Feedlots and Manure Storages in the Canadian Lower Great Lakes Basin, Report to Task C, PLUARG, March 1976.

Coote, D.R., E.M. MacDonald and T.W. Dickinson (Editors), 1978; Agricultural Watershed Studies in the Canadian Great Lakes Drainage Basin, Final Summary Report to Pollution From Land Use Activities Reference Group, Task C - Canada, I.J.C., Windsor, Ont., May 1978.

Edwards, W.M., E.C. Simpson and M.H. Frere, 1972; Nutrient Content of Barnlot Runoff Water; Journal of Environmental Quality; 1(4):401-405.

Gilbertson, C.B., T.M. McCalla, J.R. Ellis, O.E. Cross and W.R. Woods, 1971; Runoff, Solid Wastes and Nitrate Movement on Beef Feedlots; Jour. Water Poll. Cont. Fed., 43(3):483-493.

Gilbertson, C.B., J.A. Nienaber, T.M. McCalla, J.R. Ellis and W.R. Woods, 1972; Beef Cattle Feedlot Runoff, Solids Transport and Settling Characteristics; Trans. ASAE, pp. 1132-1134, 1972.

Gillham, R.W., and L.R. Webber, 1969. Nitrogen Contamination of Groundwater by Barnyard Leachates, Jour. Water Poll. Control Fed., 41 (10):1752-1762.

Gillham, R.W., R.J. Blackport and J.A. Cherry, 1978. Studies of the Agricultural Contribution to Nitrate Enrichment of Groundwater and the Subsequent Nitrate Loading to Surface Waters, Pt. II, Reconnaissance Survey of Nitrate Concentrations in Shallow Groundwater, Project report to Task C, PLUARG, Jan. 1978, University of Waterloo Research Institute.

Hore, F.R. and A J. MacLean, 1973; Task Force Report on Fertilizer Nutrients and Animal Husbandry Operations; (In) CDA Task Force for Implementation of Great Lakes Water Quality Agreement, Report Section II, 1973.

International Joint Commission, PLUARG, Task C, Agricultural Watershed Studies, Canada, Detailed Study Plan, October 1975.

Irwin, R.W. and J.B. Robinson, 1975; Runoff Volumes and Groundwater Quality from a Beef Feedlot; Canadian Agricultural Engineering; 17(2):103-105.

Jensen, N.E., 1972; Feedlot Runoff Study, Unpublished Report, Ontario Ministry of Agriculture and Food.

Jones, K.B.C. and C.T. Riley, 1970; Origins and Nature of Farm Wastes; Proc. Sym. of Inst. Water Poll. Cont., Univ. Newcastle.

Lambe, T.W., and R.V. Whitman, 1969; Soil Mechanics. John Wiley and Sons, Inc., N.Y. 553 p.

Loehr, R.C., 1970; Characteristics and Comparative Magnitude of Non-Point Sources; Jour. Water Poll. Cont. Fed; 46(8):1849-1871.

Loehr, R.C., 1974; Water Pollution Problems Associated with Animal Wastes and Intensive Animal Feedlots in the United States Portion of the Great Lakes Basin; (In) I.J.C. - PLUARG, Task A Report (U.S.), Volume 1, Section A8-A9.

MacDonald, L.G., 1973; An Assessment of the Effects of Runoff from Cattle Feedlots on the Water Quality of Receiving Streams; Report prepared for Social Science Research Section, Canada Centre for Inland Waters, Burlington, Ontario.

Madden, J.M. and J.N. Dornbush, 1971; Pollution Potential of Runoff from Livestock Feeding Operations; ASAE Paper No. 71-212, 1971 ASAE Annual Meetings, Pullman, Washington.

McQuitty, J.B., J.A. Robertson and E.M. Barber, 1971; Feedlot Pollution - A Literature Review; Univ. Alberta, Dept. Agr. Engr. Res. Bull. 71-2.

Miller, M.H., and A.C. Spires, 1978; Contribution of Phosphorus to the Great Lakes from Agricultural Land and Associated Activities in Ontario; Report to Pollution From Land Use Activities Reference Group, Task C, Agricultural Watershed Studies, I.J.C., Windsor, Ontario (in press).

Miner, J.R., R.I. Lipper, L.R. Fina and J.W. Funk, 1966; Cattle Feedlot Runoff - Its Nature and Variation; Jour. Water Poll. Cont. Fed., 38:1582-91.

Ogilvie, J.R. and P. Savoie, 1974; Runoff from Cattle Feedlots in the Montreal Region; CSAE Paper 74-412. 1974 Annual Meeting, Laval Univ., St.Foy, Quebec.

Partridge, J.D.R., and G.J. Racz, 1975. Studies of Nitrate-Nitrogen in Soil and Groundwater, Paper pres. at 19th An. Manitoba Soil Science Meeting, U. of Man., Dec. 10, 11, 1975.

Porter, K.S., 1975; Nitrogen and Phosphorus, Food Production, Waste and the Environment; Ann Arbor Science, 372 pp.

Presant, E.W. and R.E. Wicklund, 1971; The Soils of Waterloo County; Report No. 44, Ont. Soil Survey.

Robinson, J.B. and D.W. Draper, 1978; A Model for Estimating Inputs to the Great Lakes from Livestock Enterprises in the Great Lakes Basin; Report to Pollution From Land Use Activities Reference Group, Task C, Agricultural Watershed Studies, I.J.C., Windsor, Ontario (in press).

Snedecor, G.W. and W.G. Cochran, 1976; Statistical Methods; 6th ed., Iowa State Univ. Press, Ames, Iowa.

Sowden, F.J., and F.R. Hore, 1976. Nitrogen Movement near Surface Manure Storages, Can. J. of Soil Sci., 56:223-231.

Standard Methods; 12th ed., 1965; Am. Public Health Assoc.

Townshend, A.R., J.F. Janse and S.A. Black, 1969; Beef Feedlot Operations in Ontario; Paper presented to 42nd Ann. Conf. Water Poll. Cont. Fed., Dallas, Texas, Oct. 1969.

Townshend, A.R., K.A. Reichert and J.H. Nodwell, 1969; Status Report on Water Pollution Control Facilities for Farm Animal Wastes in the Province of Ontario; Proc. Cornell U. Conf. Animal Waste Management, Syracuse, N.Y., 1969 pp. 131-148.

APPENDIX A

RUNOFF AND PRECIPITATION

1973 - 75

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU,FT	FLOW CU,M	ACCUMULATED FLOW CU,FT	ACCUMULATED FLOW CU,M	PRECIPITATION CU,FT	PRECIPITATION CU,M	INS	CM	RUNOFF AS % PRECIP,	COMMENTS	
1	20/ 8/73	8,40	186,	53,08	1,50	53,08	1,50	988,12	27,98	,45	1,14	5,4	DRY + SB	CLEAN 1 DAY
2	20/ 8/73	13,30	342,	38,75	1,10	91,82	2,60	329,37	9,33	,15	,38	11,8	WET 3HRS/R=O	CLEAN 1 DAY
3	17/ 9/73	20,14	62,	269,63	7,64	361,45	10,24	1207,71	34,20	,55	1,40	22,3	WET + SB	CLEAN 1 DAY
4	30/ 9/73	12,48	340,	637,87	18,06	999,32	28,30	1097,92	31,09	,50	1,27	58,1	DRY + SB	2 DAY MANURE
5	30/ 9/73	18,28	500,	129,47	3,67	1128,79	31,97	548,96	15,55	,25	,63	23,6	WET <1HR/R=O	RAIN FLUSHED
6	4/10/73	19,42	908,	318,42	9,02	1447,21	40,99	1097,92	31,09	,50	1,27	29,0	DRY + SB	8 DAY MANURE
7	13/10/73	14,52	305,	1139,81	32,28	2587,02	73,26	1646,87	46,64	,75	1,90	69,2	DRY + SB	CLEAN 1 DAY
8	28/10/73	13,00	670,	951,57	26,95	3538,59	100,21	1537,08	43,53	,70	1,78	61,9	DRY + SB	CLEAN 1 DAY
9	29/10/73	6,24	856,	319,14	9,04	3857,73	109,25	658,75	18,66	,30	,76	48,4	WET 6HR/R=O	RAIN FLUSHED
10	29/10/73	20,40	720,	241,49	6,84	4099,22	116,09	329,37	9,33	,15	,38	73,3	WET CONT,R=O	RAIN FLUSHED
11	31/10/73	20,00	444,	258,34	7,32	4357,56	123,41	658,75	18,66	,30	,76	39,2	DAMP + SB	5 DAY MANURE
12	2/11/73	8,00	1056,	17,24	,49	4374,80	123,89	219,58	6,22	,10	,25	7,9	WET 1DAY/R=O	+ SB
13	15/11/73	11,00	966,	351,12	9,94	4725,92	133,84	988,12	27,98	,45	1,14	35,5	DRY +SB	
14	21/11/73	8,00	316,	717,73	20,33	5443,65	154,16	1317,50	37,31	,60	1,52	54,5	DRY +	2 DAY MANURE
15	21/11/73	13,28	78,	2,79	,08	5446,44	154,24	21,96	,62	,01	,03	12,7	WET	RAIN FLUSHED
16	21/11/73	14,48	50,	1,86	,05	5448,30	154,30	21,96	,62	,01	,03	8,5	WET	RAIN FLUSHED
17	21/11/73	17,08	84,	12,42	,35	5460,72	154,65	65,87	1,87	,03	,08	18,9	WET	RAIN FLUSHED
18	24/11/73	8,04	17,	6,88	,19	5467,59	154,84	263,50	7,46	,12	,30	2,6	DAMP + SB	FLUSH 2 DAYS
19	24/11/73	8,28	684,	249,71	7,07	5717,31	161,91	944,21	26,74	,43	1,09	26,4	WET	FLUSH 2 DAYS
20	25/11/73	8,00	0,	,00	,00	5717,31	161,91	329,37	9,33	,15	,38	,0	DAMP 1DAY/RO	+ SB
21	26/11/73	8,00	0,	,00	,00	5717,31	161,91	153,71	4,35	,07	,18	,0	DAMP 1DAY/PP	FLUSH 2 DAY
22	27/11/73	,30	0,	,00	,00	5717,31	161,91	263,50	7,46	,12	,30	,0	DAMP 1DAY/PP	+ SB
23	28/11/73	3,00	1104,	2758,63	78,12	8475,93	240,04	3183,96	90,17	1,45	3,68	86,6	DAMP + SB	CLEAN 2 DAYS
24	13/12/73	12,20	1047,	677,09	19,18	9153,02	259,21	1207,71	34,20	,55	1,40	56,1	DRY + SB	
25	16/12/73	21,30	0,	,00	,00	9153,02	259,21	1317,50	37,31	,60	1,52	,0	FROZEN=SNOW	FROZEN

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL CU.FT	FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS
26	25/12/73	12.20	488.	234.55	6.64	9387.57	265.86	768.54	21.77	.35	.89	30.5	SNOW-FROZEN + SB
27	26/12/73	18.10	653.	1136.56	32.19	10524.12	298.04	1097.92	31.09	.50	1.27	103.5	WET 1DAY/R=0 CLEAN 1 DAY
28	27/12/73	6.50	160.	.53	.01	10524.65	298.06	109.79	3.11	.05	.13	.5	WET-CONT.R=0
29	31/12/73	1.30	0.	.00	.00	10524.65	298.06	219.58	6.22	.10	.25	.0	SNOW
30	31/12/74	23.30	0.	.00	.00	10524.65	298.06	109.79	3.11	.05	.13	.0	SNOW
31	8/ 1/74	10.00	0.	.00	.00	10524.65	298.06	439.17	12.44	.20	.51	.0	SNOW
32	10/ 1/74	4.30	0.	.00	.00	10524.65	298.06	109.79	3.11	.05	.13	.0	SNOW
33	20/ 1/74	1.30	1391.	551.68	15.62	11076.33	313.68	1097.92	31.09	.50	1.27	50.2	DRY + SB CLEAN 2 DAYS
34	20/ 1/74	8.30	143.	406.78	11.52	11483.11	325.20	1537.08	43.53	.70	1.78	26.5	WET=3HR/R=0 FLUSH TODAY
35	21/ 1/74	5.00	940.	331.99	9.40	11815.10	334.60	658.75	18.66	.30	.76	50.4	WET 10HR=RO + SB
36	26/ 1/74	19.50	807.	665.13	18.84	12480.23	353.44	988.12	27.98	.45	1.14	67.3	DRY + SB 5 DAY MANUR?
37	28/ 1/74	13.30	0.	.00	.00	12480.23	353.44	658.75	18.66	.30	.76	.0	SNOW
38	6/ 2/74	1.15	0.	.00	.00	12480.23	353.44	878.33	24.87	.40	1.02	.0	SNOW
39	9/ 2/74	10.30	0.	.00	.00	12480.23	353.44	439.17	12.44	.20	.51	.0	SNOW
40	18/ 2/74	16.00	823.	368.86	10.45	12849.09	363.89	1097.92	31.09	.50	1.27	33.6	DRY + SB CLEAN 1 DAY
41	21/ 2/74	22.45	603.	1352.22	38.29	14201.31	402.18	2086.04	59.08	.95	2.41	64.8	DRY + SB CLEAN 1 DAY
42	28/ 2/74	18.30	756.	49.92	1.41	14251.23	403.59	263.50	7.46	.12	.30	18.9	DRY +SB
43	2/ 3/74	2.35	812.	296.53	8.40	14547.76	411.99	483.08	13.68	.22	.56	61.4	DAMP 3DAY/RO + SB
44	4/ 3/74	13.12	225.	198.69	5.63	14746.44	417.62	329.37	9.33	.15	.38	60.3	DAMP 2DAY/RO + SB
45	4/ 3/74	21.10	376.	1596.39	45.21	16342.84	462.83	1537.08	43.53	.70	1.78	103.9	WET 4HR/R=0 FLUME PROBS
46	4/ 3/74	21.10	-381.	-352.17	-9.97	15990.66	452.86	.00	.00	.00	.00	*****	FLUME PROBS SUBTRACT FLO
47	7/ 3/74	4.20	422.	205.43	5.82	16196.09	458.67	439.17	12.44	.20	.51	46.8	DRY FULL S-BASIN
48	8/ 3/74	5.42	264.	541.99	15.35	16738.08	474.02	988.12	27.98	.45	1.14	54.9	WET 1DAY/RO + SB
49	8/ 3/74	13.15	194.	188.11	5.33	16926.19	479.35	219.58	6.22	.10	.25	85.7	WET 5HR/R=0 FLUSHED 5HRS
50	9/ 3/74	3.00	332.	263.25	7.46	17189.43	486.80	219.58	6.22	.10	.25	119.9	WET 13HR/R=0 FLUSH 13HRS
51	9/ 3/74	12.40	350.	589.90	16.71	17779.33	503.51	592.87	16.79	.27	.69	99.5	WET 9HRS/R=0 FLUSHED 9HRS

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
52	18/ 3/74	6.00	578.	47.87	1.36	17827.19	504.87	197.62	5.60	.09	.23	24.2	WET ? PRECIP	+ SB
53	31/ 3/74	5.30	240.	174.59	4.94	18001.78	509.81	461.12	13.06	.21	.53	37.9	WET 1DAY/R=O	+ SB
54	3/ 4/74	10.00	448.	1048.10	29.68	19049.87	539.49	1581.00	44.77	.72	1.83	66.3	DRY +SB	CLEAN TODAY
55	7/ 4/74	12.06	690.	426.48	12.08	19476.35	551.57	988.12	27.98	.45	1.14	43.2	WET SNOW +SB	2 DAY MANURE
56	12/ 4/74	10.00	0.	.00	.00	19476.35	551.57	483.08	13.68	.22	.56	.0	DRY	
57	13/ 4/74	9.00	0.	.00	.00	19476.35	551.57	329.37	9.33	.15	.38	.0	DAMP + SB	
58	13/ 4/74	12.30	0.	.00	.00	19476.35	551.57	153.71	4.35	.07	.18	.0	DAMP	
59	18/ 4/74	21.06	370.	551.48	15.62	20027.83	567.19	1141.83	32.34	.52	1.32	48.3	DRY +SB	
60	21/ 4/74	3.00	0.	.00	.00	20027.83	567.19	329.37	9.33	.15	.38	.0	DRY	
61	22/ 4/74	14.00	86.	19.24	.54	20047.07	567.73	505.04	14.30	.23	.58	3.8	DRY +SB	
62	22/ 4/74	22.30	0.	.00	.00	20047.07	567.73	329.37	9.33	.15	.38	.0	WET	
63	9/ 5/74	12.06	1287.	1072.03	30.36	21119.09	598.09	1800.58	50.99	.82	2.08	59.5	DRY + SB	
64	11/ 5/74	18.12	717.	920.97	26.08	22040.05	624.17	1383.37	39.18	.63	1.60	66.6	DAMP 2DAY/RO	+SB
65	12/ 5/74	6.28	84.	1.55	.04	22041.60	624.22	263.50	7.46	.12	.30	.6	WET	FLUSHED
66	12/ 5/74	4.10	0.	.00	.00	22041.60	624.22	153.71	4.35	.07	.18	.0	DAMP	FLUSHED 1DAY
67	15/ 5/74	3.32	358.	502.33	14.23	22543.93	638.44	878.33	24.87	.40	1.02	57.2	DAMP +SB	FLUSHED 1DAY
68	24/ 5/74	17.36	124.	87.76	2.49	22631.69	640.93	658.75	18.66	.30	.76	13.3	DRY +SB	
69	25/ 5/74	4.46	188.	167.12	4.73	22798.81	645.66	483.08	13.68	.22	.56	34.6	DAMP	
70	14/ 6/74	13.30	154.	67.43	1.91	22866.24	647.57	548.96	15.55	.25	.63	12.3	DRY + SB	
71	17/ 6/74	13.30	0.	.00	.00	22866.24	647.57	439.17	12.44	.20	.51	.0	DRY + SB	JUST RAN OFF
72	18/ 6/74	9.15	0.	.00	.00	22866.24	647.57	219.58	6.22	.10	.25	.0	DRY	
73	25/ 6/74	17.00	0.	.00	.00	22866.24	647.57	548.96	15.55	.25	.63	.0	DRY + SB	
74	26/ 6/74	14.55	0.	.00	.00	22866.24	647.57	548.96	15.55	.25	.63	.0	DAMP +SB	
75	30/ 6/74	7.45	253.	104.14	2.95	22970.38	650.52	702.67	19.90	.32	.81	14.8	DRY + SB	R/O
76	2/ 7/74	1.45	161.	154.91	4.39	23125.29	654.91	1141.83	32.34	.52	1.32	13.6	DRY + SB	R/O
77	4/ 7/74	16.40	0.	.00	.00	23125.29	654.91	153.71	4.35	.07	.18	.0	DRY	TRICKLE

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
78	14/ 7/74	14.00	683.	927.67	26.27	24052.95	681.18	2151.92	60.94	.98	2.49	43.1	DRY + SB	R/O
79	8/ 8/74	8.05	0.	.00	.00	24052.95	681.18	3601.17	101.99	1.64	4.17	.0	DRY	R/O-TAP OPEN
80	16/ 8/74	20.36	99.	92.03	2.61	24144.99	683.79	1844.50	52.24	.84	2.13	5.0	DRY + SB	R/O
81	3/ 9/74	9.50	0.	.00	.00	24144.99	683.79	131.75	3.73	.06	.15	.0	DRY	NO R/O
82	11/ 9/74	1.40	0.	.00	.00	24144.99	683.79	878.33	24.87	.40	1.02	.0	DRY E 12.91	R/O-NO REC'D
83	12/ 9/74	14.50	0.	.00	.00	24144.99	683.79	439.17	12.44	.20	.51	.0	DAMP E 3.95	R/O-NO REC'D
84	27/ 9/74	20.10	0.	.00	.00	24144.99	683.79	944.21	26.74	.43	1.09	.0	DRY E 13.95	R/O-NO REC'D
85	28/ 9/74	17.30	0.	.00	.00	24144.99	683.79	746.58	21.14	.34	.86	.0	DAMP E10.54	R/O-NO REC'D
86	29/ 9/74	4.49	145.	59.99	1.70	24204.98	685.48	768.54	21.77	.35	.89	7.8	WET	R/O
87	28/10/74	4.55	122.	16.03	.45	24221.01	685.94	768.54	21.77	.35	.89	2.1	DRY + SB	R/O
88	2/11/74	15.25	1150.	375.12	10.62	24596.12	696.56	1317.50	37.31	.60	1.52	28.5	DRY + SB	R/O
89	3/11/74	18.00	69.	32.66	.92	24628.78	697.49	702.67	19.90	.32	.81	4.6	DAMP + SB	R/O
90	4/11/74	7.30	359.	118.42	3.35	24747.19	700.84	878.33	24.87	.40	1.02	13.5	WET	R/O
91	11/11/74	17.45	600.	11.68	.33	24758.87	701.17	768.54	21.77	.35	.89	1.5	DRY + SB	R/O
92	12/11/74	9.20	46.	.48	.01	24759.35	701.18	65.87	1.87	.03	.08	.7	DAMP	R/O
93	13/11/74	13.20	777.	45.99	1.30	24805.34	702.49	1075.96	30.47	.49	1.24	4.3	DAMP + SB	R/O
94	18/11/74	22.45	0.	.00	.00	24805.34	702.49	1646.87	46.64	.75	1.90	.0	DRY E 25.96	NO RECORD
95	21/11/74	17.35	0.	.00	.00	24805.34	702.49	131.75	3.73	.06	.15	.0	DAMPE 0.01	NO RECORD
96	22/11/74	9.25	0.	.00	.00	24805.34	702.49	65.87	1.87	.03	.08	.0	DAMP	NO RECORD
97	22/11/74	19.00	0.	.00	.00	24805.34	702.49	351.33	9.95	.16	.41	.0	DAMP E 3.87	NO RECORD
98	23/11/74	9.40	0.	.00	.00	24805.34	702.49	87.83	2.49	.04	.10	.0	DAMP	NO RECORD
99	29/11/74	7.30	0.	.00	.00	24805.34	702.49	5160.21	146.14	2.35	5.97	.0	DRY E 86.29	NO RECORD
100	13/12/74	16.00	0.	.00	.00	24805.34	702.49	548.96	15.55	.25	.63	.0	DRY ES 7.13	NO RECORD
101	18/12/74	21.10	0.	.00	.00	24805.34	702.49	43.92	1.24	.02	.05	.0	DRY	NO R/O
102	19/12/74	12.35	0.	.00	.00	24805.34	702.49	307.42	8.71	.14	.36	.0	DAMP	NO R/O
103	21/12/74	5.40	0.	.00	.00	24805.34	702.49	373.29	10.57	.17	.43	.0	DAMP + SB	R/O -TRICKLE

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
104	1/ 1/75	14.20	0.	.00	.00	24805.34	702.49	241.54	6.84	.11	.28	.0	DRY	NO R/O REC'D
105	4/ 1/75	1.55	0.	.00	.00	24805.34	702.49	351.33	9.95	.16	.41	.0	DRY	NO R/O REC'D
106	6/ 1/75	13.30	0.	.00	.00	24805.34	702.49	219.58	6.22	.10	.25	.0	DRY ES 1.5	NO RECORD
107	8/ 1/75	2.25	0.	.00	.00	24805.34	702.49	329.37	9.33	.15	.38	.0	DAMP E 3.42	NO RECORD
108	8/ 1/75	12.00	0.	.00	.00	24805.34	702.49	1976.25	55.97	.90	2.29	.0	DAMP E 31.74	NO RECORD
109	10/ 1/75	10.35	0.	.00	.00	24805.34	702.49	1251.62	35.45	.57	1.45	.0	FLUME BLKD	
110	20/ 1/75	10.10	137.	5.34	.15	24810.68	702.64	570.92	16.17	.26	.66	.9	DRY + SB	R/O
111	25/ 1/75	13.00	379.	121.26	3.43	24931.94	706.07	658.75	18.66	.30	.76	18.4	DRY + SB	R/O
112	26/ 1/75	13.10	208.	17.43	.49	24949.37	706.57	131.75	3.73	.06	.15	13.2	WET	R/O
113	29/ 1/75	5.22	186.	555.33	15.73	25504.70	722.29	1185.75	33.58	.54	1.37	46.8	DRY + SB	R/O
114	4/ 2/75	11.45	0.	.00	.00	25504.70	722.29	790.50	22.39	.36	.91	.0	DRY	NO R/O
115	9/ 2/75	13.20	0.	.00	.00	25504.70	722.29	219.58	6.22	.10	.25	.0	DRY EST 1.5	R/O PEN DRY
116	14/ 2/75	19.00	0.	.00	.00	25504.70	722.29	439.17	12.44	.20	.51	.0	DRY EST 5.35	R/O PEN DRY
117	15/ 2/75	9.55	0.	.00	.00	25504.70	722.29	351.33	9.95	.16	.41	.0	WET EST 3.87	R/O PEN DRY
118	16/ 2/75	10.35	0.	.00	.00	25504.70	722.29	505.04	14.30	.23	.58	.0	WET EST 6.39	R/O PEN DRY
119	17/ 2/75	18.15	0.	.00	.00	25504.70	722.29	241.54	6.84	.11	.28	.0	WET EST 1.94	R/O PEN DRY
120	22/ 2/75	16.55	0.	.00	.00	25504.70	722.29	1581.00	44.77	.72	1.83	.0	DRY E 24.92	R/O PEN DRY
121	23/ 2/75	17.15	0.	.00	.00	25504.70	722.29	2217.79	62.81	1.01	2.57	.0	WET E 35.89	R/O PEN DRY
122	11/ 3/75	9.05	938.	104.32	2.95	25609.01	725.25	1493.17	42.29	.68	1.73	7.0	DRY + SB	R/O
123	18/ 3/75	9.25	204.	4.14	.12	25613.15	725.36	505.04	14.30	.23	.58	.8	DRY + SB	R/O
124	20/ 3/75	9.05	232.	41.81	1.18	25654.97	726.55	197.62	5.60	.09	.23	21.2	DRY + SB	R/O
125	21/ 3/75	5.45	287.	503.25	14.25	26158.21	740.80	395.25	11.19	.18	.46	127.3	WET	R/O
126	22/ 3/75	23.10	656.	780.55	22.11	26938.76	762.91	1317.50	37.31	.60	1.52	59.2	DAMP	R/O
127	2/ 4/75	12.50	0.	.00	.00	26938.76	762.91	1163.79	32.96	.53	1.35	.0	DRY FLUME	ICED UP
128	18/ 4/75	15.00	119.	12.00	.34	26950.76	763.25	878.33	24.87	.40	1.02	1.4	DRY + SB	
129	24/ 4/75	15.05	0.	.00	.00	26950.76	763.25	197.62	5.60	.09	.23	.0	DRY	NO RUNOFF

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
130	30/ 4/75	20.30	0.	.00	.00	26950.76	763.25	329.37	9.33	.15	.38	.0	DRY	NO RUNOFF
131	30/ 5/75	.34	198.	171.00	4.84	27121.76	768.09	746.58	21.14	.34	.86	22.9	DRY + SB	
132	30/ 5/75	22.50	160.	61.15	1.73	27182.92	769.82	263.50	7.46	.12	.30	23.2	WET	
133	11/ 6/75	17.50	269.	743.86	21.07	27926.78	790.89	1251.62	35.45	.57	1.45	59.4	DRY + SB	
134	15/ 6/75	22.00	739.	947.98	26.85	28874.76	817.73	1537.08	43.53	.70	1.78	61.7	DRY =R/O	+ SB
135	17/ 6/75	22.05	163.	49.75	1.41	28924.51	819.14	1010.08	28.61	.46	1.17	4.9	DAMP + SB	
136	18/ 6/75	8.15	108.	12.01	.34	28936.51	819.48	285.46	8.08	.13	.33	4.2	WET =R/O	
137	19/ 6/75	8.20	0.	.00	.00	28936.51	819.48	329.37	9.33	.15	.38	.0	WET + SB	TRICKLE
138	23/ 6/75	17.10	0.	.00	.00	28936.51	819.48	417.21	11.82	.19	.48	.0	DRY +SB	TRICKLE
139	24/ 6/75	11.28	665.	900.08	25.49	29836.59	844.97	1449.25	41.04	.66	1.68	62.1	WET =R/O	+ SB
140	11/ 7/75	14.10	0.	.00	.00	29836.59	844.97	131.75	3.73	.06	.15	.0	DRY	
141	13/ 7/75	.30	0.	.00	.00	29836.59	844.97	724.62	20.52	.33	.84	.0	DAMP	PLUG OUT?
142	14/ 7/75	4.48	104.	126.13	3.57	29962.72	848.54	746.58	21.14	.34	.86	16.9	DAMP + SB	
143	14/ 7/75	16.30	0.	.00	.00	29962.72	848.54	1097.92	31.09	.50	1.27	.0	WET =R/O	PLUG OUT?
144	2/ 8/75	22.30	0.	.00	.00	29962.72	848.54	109.79	3.11	.05	.13	.0	DRY	
145	3/ 8/75	3.55	0.	.00	.00	29962.72	848.54	263.50	7.46	.12	.30	.0	WET	
146	3/ 8/75	7.26	190.	422.31	11.96	30385.03	860.50	1515.12	42.91	.69	1.75	27.9	WET =R/O	
147	3/ 8/75	11.14	704.	1393.08	39.45	31778.11	899.96	373.29	10.57	.17	.43	373.2	WET =R/O	
148	4/ 8/75	12.45	0.	.00	.00	31778.11	899.96	592.87	16.79	.27	.69	.0	DRY + SB	TRICKLE
149	21/ 8/75	4.40	0.	.00	.00	31778.11	899.96	548.96	15.55	.25	.63	.0	DRY	
150	21/ 8/75	15.30	304.	1299.94	36.81	33078.04	936.77	3579.21	101.36	1.63	4.14	36.3	WET =R/O	
151	22/ 8/75	12.52	217.	55.76	1.58	33133.80	938.35	153.71	4.35	.07	.18	36.3	WET =R/O	
152	23/ 8/75	5.10	0.	.00	.00	33133.80	938.35	219.58	6.22	.10	.25	.0	WET	
153	23/ 8/75	19.40	0.	.00	.00	33133.80	938.35	131.75	3.73	.06	.15	.0	WET	
154	24/ 8/75	7.44	221.	38.36	1.09	33172.16	939.44	263.50	7.46	.12	.30	14.6	WET =R/O	
155	24/ 8/75	11.25	152.	62.34	1.77	33234.50	941.20	658.75	18.66	.30	.76	9.5	WET =R/O	

SITE NUMBER: 1

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS
156	25/ 8/75	19.56	49.	2.82	.08	33237.31	941.28	769.54	21.77	.35	.89	.4	WET *R/O
157	29/ 8/75	8.10	0.	.00	.00	33237.31	941.28	1185.75	33.58	.54	1.37	.0	DRY E 18.1 FLUME BLKD
158	29/ 8/75	20.00	0.	.00	.00	33237.31	941.28	1581.00	44.77	.72	1.83	.0	WET E 24.92 FLUME BLKD
159	31/ 8/75	13.05	0.	.00	.00	33237.31	941.28	702.67	19.90	.32	.81	.0	DAMP E 9.8 FLUME BLKD

*FIN

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	PRECIPITATION INS	PRECIPITATION CM	RUNOFF AS % PRECIP.	COMMENTS	
1	5/12/73	.00	0.	.00	.00	.00	.00	.00	.00	.00	.00	.0	NO RECORD .	SAMPLED
2	19/12/73	16.00	0.	.00	.00	.00	.00	886.75	25.11	.60	1.52	.0	SNOW?	NO SAMPLE
3	25/12/73	10.00	0.	.00	.00	.00	.00	517.27	14.65	.35	.89	.0	SNOW?	NO SAMPLE
4	26/12/73	18.00	0.	.00	.00	.00	.00	443.37	12.56	.30	.76	.0	SNOW? E 5.55	SAMPLED WET
5	27/12/73	18.00	0.	.00	.00	.00	.00	221.69	6.28	.15	.38	.0	WET	NO SAMPLE
6	29/12/73	15.30	0.	.00	.00	.00	.00	221.69	6.28	.15	.38	.0	DRY	NO SAMPLE
7	9/ 1/74	.30	0.	.00	.00	.00	.00	221.69	6.28	.15	.38	.0	DRY	NO SAMPLE
8	20/ 1/74	22.30	0.	.00	.00	.00	.00	916.31	25.95	.62	1.57	.0	EST 6.94 DRY	SAMPLED
9	22/ 1/74	17.00	0.	.00	.00	.00	.00	812.85	23.02	.55	1.40	.0	DRY	NO SAMPLE
10	26/ 1/74	20.15	0.	.00	.00	.00	.00	886.75	25.11	.60	1.52	.0	DRY	NO SAMPLE
11	21/ 2/74	17.30	0.	.00	.00	.00	.00	206.91	5.86	.14	.36	.0	DRY	NO SAMPLE
12	22/ 2/74	5.15	0.	.00	.00	.00	.00	280.80	7.95	.19	.48	.0	WET EST 2.47	SAMPLED
13	25/ 2/74	1.35	0.	.00	.00	.00	.00	1374.46	38.92	.93	2.36	.0	DRY	NO SAMPLE
14	28/ 2/74	11.30	0.	.00	.00	.00	.00	206.91	5.86	.14	.36	.0	DRY	NO SAMPLE
15	28/ 2/74	22.14	0.	.00	.00	.00	.00	162.57	4.60	.11	.28	.0	WET	NO SAMPLE
16	4/ 3/74	10.45	0.	.00	.00	.00	.00	1418.80	40.18	.96	2.44	.0	DRY E 13.97	SAMPLED
17	9/ 3/74	6.00	0.	.00	.00	.00	.00	266.02	7.53	.18	.46	.0	DIY	NO SAMPLE
18	9/ 3/74	11.40	0.	.00	.00	.00	.00	133.01	3.77	.09	.23	.0	WET	NO SAMPLE
19	18/ 3/74	21.00	0.	.00	.00	.00	.00	251.25	7.12	.17	.43	.0	DRY	NO SAMPLE
20	23/ 3/74	9.45	0.	.00	.00	.00	.00	118.23	3.35	.08	.20	.0	DRY	NO SAMPLE
21	29/ 3/74	10.00	0.	.00	.00	.00	.00	147.79	4.19	.10	.25	.0	DRY	NO SAMPLE
22	30/ 3/74	.30	0.	.00	.00	.00	.00	88.67	2.51	.06	.15	.0	DRY	NO SAMPLE
23	1/ 4/74	3.52	0.	.00	.00	.00	.00	206.91	5.86	.14	.36	.0	DRY	NO SAMPLE
24	1/ 4/74	22.25	0.	.00	.00	.00	.00	871.97	24.69	.59	1.50	.0	WET	NO SAMPLE
25	3/ 4/74	21.00	622.	708.48	20.06	708.48	20.06	1330.12	37.67	.90	2.29	53.3	DAMP	

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL CU.FT	FLOW CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
26	7/ 4/74	8.00	568.	109.06	3.09	817.54	23.15	280.80	7.95	.19	.48	38.8	DRY	
27	12/ 4/74	14.00	306.	42.95	1.22	860.49	24.37	354.70	10.05	.24	.61	12.1	DRY	NO SAMPLE
28	14/ 4/74	14.00	272.	166.70	4.72	1027.19	29.09	369.48	10.46	.25	.63	45.1	DAMP	SAMPLED
29	22/ 4/74	14.00	268.	87.89	2.49	1115.08	31.58	591.17	16.74	.40	1.02	14.9	DRY	NO SAMPLE
30	22/ 4/74	20.00	240.	12.33	.35	1127.41	31.93	103.45	2.93	.07	.18	11.9	WET	NO SAMPLE
31	29/ 4/74	7.54	0.	.00	.00	1127.41	31.93	103.45	2.93	.07	.18	.0	DRY	NO SAMPLE
32	30/ 4/74	21.00	7.	11.21	.32	1138.62	32.25	295.58	8.37	.20	.51	3.8	DAMP	NO SAMPLE
33	5/ 5/74	18.10	0.	.00	.00	1138.62	32.25	369.48	10.46	.25	.63	.0		NO SAMPLE
34	7/ 5/74	17.15	193.	19.84	.56	1158.46	32.81	960.65	27.21	.65	1.65	2.1	DRY	NO SAMPLE
35	11/ 5/74	2.30	683.	410.27	11.62	1568.74	44.43	1078.88	30.55	.73	1.85	38.0	DRY	NO SAMPLE
36	12/ 5/74	9.00	0.	.00	.00	1568.74	44.43	147.79	4.19	.10	.25	.0	DRY	NO SAMPLE
37	12/ 5/74	18.05	508.	73.03	2.07	1641.77	46.49	147.79	4.19	.10	.25	49.4	WET	NO SAMPLE
38	15/ 5/74	8.10	348.	184.92	5.24	1826.68	51.73	605.95	17.16	.41	1.04	30.5	DRY	SAMPLED
39	16/ 5/74	16.20	220.	546.55	15.48	2373.24	67.21	990.20	28.04	.67	1.70	55.2	WET	SAMPLED
40	16/ 5/74	20.08	307.	334.30	9.47	2707.54	76.68	443.37	12.56	.30	.76	75.4	WET	SAMPLED
41	17/ 5/74	1.45	449.	792.65	22.45	3500.18	99.13	945.87	26.79	.64	1.63	83.8	WET	SAMPLED
42	28/ 5/74	19.00	0.	.00	.00	3500.18	99.13	236.47	6.70	.16	.41	.0	DRY	NO SAMPLE
43	30/ 5/74	18.30	0.	.00	.00	3500.18	99.13	103.45	2.93	.07	.18	.0	DRY	NO SAMPLE
44	11/ 6/74	1.40	0.	.00	.00	3500.18	99.13	236.47	6.70	.16	.41	.0	DRY	NO SAMPLE
45	12/ 6/74	2.15	0.	.00	.00	3500.18	99.13	29.56	.84	.02	.05	.0	DRY	NO SAMPLE
46	12/ 6/74	18.45	0.	.00	.00	3500.18	99.13	206.91	5.86	.14	.36	.0	DRY	NO SAMPLE
47	13/ 6/74	15.20	0.	.00	.00	3500.18	99.13	192.13	5.44	.13	.33	.0	DRY	NO SAMPLE
48	15/ 6/74	6.00	0.	.00	.00	3500.18	99.13	724.18	20.51	.49	1.24	.0	DRY EST 4.27	SAMPLED
49	15/ 6/74	16.15	0.	.00	.00	3500.18	99.13	443.37	12.56	.30	.76	.0	DRY EST 0.39	SAMPLED
50	17/ 6/74	20.10	0.	.00	.00	3500.18	99.13	88.67	2.51	.06	.15	.0	DRY	NO SAMPLE
51	18/ 6/74	3.00	0.	.00	.00	3500.18	99.13	399.04	11.30	.27	.69	.0	DRY	NO SAMPLE

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.		COMMENTS
52	18/ 6/74	17.45	0.	.00	.00	3500.18	99.13	147.79	4.19	.10	.25	.0	DRY	NO SAMPLE
53	19/ 6/74	7.00	108.	77.77	2.20	3577.96	101.33	399.04	11.30	.27	.69	19.5	DAMP	SAMPLED
54	19/ 6/74	8.48	226.	163.29	4.62	3741.25	105.95	443.37	12.56	.30	.76	36.8	WET	SAMPLED
55	19/ 6/74	15.06	150.	23.68	.67	3764.93	106.62	251.25	7.12	.17	.43	9.4	WET	SAMPLED
56	21/ 6/74	6.48	234.	238.00	6.74	4002.93	113.36	1182.33	33.48	.80	2.03	20.1	DAMP	NO SAMPLE
57	25/ 6/74	15.32	176.	383.87	10.87	4386.80	124.23	1108.44	31.39	.75	1.90	34.6	DRY	SAMPLED
58	29/ 6/74	2.45	0.	.00	.00	4386.80	124.23	487.71	13.81	.33	.84	.0	DRY	NO SAMPLE
59	30/ 6/74	8.06	142.	97.87	2.77	4484.67	127.01	413.82	11.72	.28	.71	23.7	DAMP	NO SAMPLE
60	4/ 7/74	18.40	160.	302.70	8.57	4787.37	135.58	960.65	27.21	.65	1.65	31.5	DRY	NO SAMPLE
61	14/ 7/74	17.45	0.	.00	.00	4787.37	135.58	325.14	9.21	.22	.56	.0	DRY	NO SAMPLE
62	17/ 7/74	16.30	0.	.00	.00	4787.37	135.58	266.02	7.53	.18	.46	.0	DRY	NO SAMPLE
63	26/ 7/74	7.00	0.	.00	.00	4787.37	135.58	177.35	5.02	.12	.30	.0	DRY	NO SAMPLE
64	27/ 7/74	14.45	0.	.00	.00	4787.37	135.58	620.72	17.58	.42	1.07	.0	DRY	NO SAMPLE
65	29/ 7/74	8.23	0.	.00	.00	4787.37	135.58	295.58	8.37	.20	.51	.0	DRY	NO SAMPLE
66	4/ 8/74	.15	0.	.00	.00	4787.37	135.58	517.27	14.65	.35	.89	.0	DRY	NO SAMPLE
67	4/ 8/74	3.45	209.	57.05	1.62	4844.42	137.19	650.28	18.42	.44	1.12	8.8	WET	NO SAMPLE
68	23/ 8/74	15.30	127.	35.01	.99	4879.42	138.19	1123.22	31.81	.76	1.93	3.1	DRY	SAMPLED
69	23/ 8/74	18.30	179.	161.77	4.58	5041.20	142.77	339.92	9.63	.23	.58	47.6	WET	NO SAMPLE
70	2/ 9/74	20.33	0.	.00	.00	5041.20	142.77	561.61	15.90	.38	.97	.0	DRY	NO SAMPLE
71	14/ 9/74	9.05	0.	.00	.00	5041.20	142.77	591.17	16.74	.40	1.02	.0	DRY	NO SAMPLE
72	14/ 9/74	15.30	0.	.00	.00	5041.20	142.77	221.69	6.28	.15	.38	.0	DRY	NO SAMPLE
73	28/ 9/74	.15	0.	.00	.00	5041.20	142.77	266.02	7.53	.18	.46	.0	DRY	NO SAMPLE
74	29/ 9/74	.30	0.	.00	.00	5041.20	142.77	931.09	26.37	.63	1.60	.0	DAMP	NO R-O
75	1/10/74	6.15	0.	.00	.00	5041.20	142.77	369.48	10.46	.25	.63	.0	DRY	NO R-O
76	6/10/74	23.00	0.	.00	.00	5041.20	142.77	177.35	5.02	.12	.30	.0	DRY	NO R-O
77	14/10/74	3.00	0.	.00	.00	5041.20	142.77	354.70	10.05	.24	.61	.0	DRY SAMPLED	NO R-O

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	PRECIPITATION INS	PRECIPITATION CM	RUNOFF AS % PRECIP.	COMMENTS	
78	14/10/74	12.45	0.	.00	.00	5041.20	142.77	295.58	8.37	.20	.51	.0	WET EST 2.82	NO RECORD
79	2/11/74	1.30	0.	.00	.00	5041.20	142.77	295.58	8.37	.20	.51	.0		NO R-O
80	3/11/74	16.30	0.	.00	.00	5041.20	142.77	591.17	16.74	.40	1.02	.0	WET EST 8.38	SAMPLED
81	4/11/74	16.30	0.	.00	.00	5041.20	142.77	295.58	8.37	.20	.51	.0		NO R-O
82	5/11/74	7.15	0.	.00	.00	5041.20	142.77	295.58	8.37	.20	.51	.0	WET EST 2.82	SAMPLED
83	12/11/74	5.00	440.	63.42	1.80	5104.62	144.56	812.85	23.02	.55	1.40	7.8	DRY	
84	14/11/74	5.00	572.	181.18	5.13	5285.80	149.69	472.93	13.39	.32	.81	38.3	DRY	
85	17/11/74	1.00	0.	.00	.00	5285.80	149.69	147.79	4.19	.10	.25	.0		NO R-O
86	20/11/74	4.15	1294.	1309.08	37.07	6594.88	186.77	3103.62	87.89	2.10	5.33	42.2	DRY	
87	23/11/74	20.00	0.	.00	.00	6594.88	186.77	325.14	9.21	.22	.56	.0	DAMP	NO CHART
88	24/12/74	6.15	0.	.00	.00	6594.88	186.77	73.90	2.09	.05	.13	.0	SNOW?	NO R/O
89	25/12/74	.30	0.	.00	.00	6594.88	186.77	147.79	4.19	.10	.25	.0	SNOW?	NO R/O
90	31/12/74	18.00	0.	.00	.00	6594.88	186.77	221.69	6.28	.15	.38	.0	SNOW?	NO R/O
91	3/ 1/75	6.00	0.	.00	.00	6594.88	186.77	295.58	8.37	.20	.51	.0	SNOW?	NO R/O
92	6/ 1/75	18.00	0.	.00	.00	6594.88	186.77	147.79	4.19	.10	.25	.0	SNOW?	NO R/O
93	8/ 1/75	15.00	682.	140.58	3.98	6735.45	190.75	443.37	12.56	.30	.76	31.7	MELT-RAIN	R/O SAMPLED
94	10/ 1/75	17.08	1456.	23.21	.66	6758.66	191.41	221.69	6.28	.15	.38	10.5	WET -RAIN	R/O-NO SMPL
95	18/ 1/75	8.00	0.	.00	.00	6758.66	191.41	295.58	8.37	.20	.51	.0	FROZEN	NO R/O,70 HD
96	25/ 1/75	12.30	0.	.00	.00	6758.66	191.41	886.75	25.11	.60	1.52	.0	RAIN/FREEZE	NO R/O
97	29/ 1/75	.00	0.	.00	.00	6758.66	191.41	2069.08	58.60	1.40	3.56	.0	DRY RAIN-FRZ	EST 23.03
98	6/ 2/75	12.00	0.	.00	.00	6758.66	191.41	295.58	8.37	.20	.51	.0	SNOW?	NO R/O
99	15/ 2/75	21.00	0.	.00	.00	6758.66	191.41	369.48	10.46	.25	.63	.0	SNOW	NO R/O
100	17/ 2/75	12.45	0.	.00	.00	6758.66	191.41	295.58	8.37	.20	.51	.0	SNOW	NO R/O
101	18/ 2/75	19.00	0.	.00	.00	6758.66	191.41	369.48	10.46	.25	.63	.0	SNOW	NO R/O
102	22/ 2/75	19.00	0.	.00	.00	6758.66	191.41	369.48	10.46	.25	.63	.0	WET EST 4.09	SMPL-NO MEAS
103	24/ 2/75	1.40	0.	.00	.00	6758.66	191.41	1330.12	37.67	.90	2.29	.0	WET EST22.02	SMPL-NO MEAS

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
104	25/ 2/75	13.00	0.	.00	.00	6758.66	191.41	443.37	12.56	.30	.76	.0	SNOW?	NO MEASURE
105	28/ 2/75	13.30	0.	.00	.00	6758.66	191.41	147.79	4.19	.10	.25	.0	SNOW?	NO MEASURE
106	6/ 3/75	22.30	0.	.00	.00	6758.66	191.41	221.69	6.28	.15	.38	.0	SNOW?	NO MEASURE
107	8/ 3/75	7.30	0.	.00	.00	6758.66	191.41	665.06	18.83	.45	1.14	.0	SNOW?	NO MEAS-60HD
108	14/ 3/75	12.30	0.	.00	.00	6758.66	191.41	369.48	10.46	.25	.63	.0	SNOW?	NO MEASURE
109	19/ 3/75	4.30	0.	.00	.00	6758.66	191.41	812.85	23.02	.55	1.40	.0	DRY EST 5.56	SMPL-NO MEAS
110	21/ 3/75	8.00	0.	.00	.00	6758.66	191.41	812.85	23.02	.55	1.40	.0	FROZEN?	NO MEASURE
111	24/ 3/75	3.00	0.	.00	.00	6758.66	191.41	295.58	8.37	.20	.51	.0	DRY EST 0	SAMPL-NO MEA
112	4/ 4/75	5.30	0.	.00	.00	6758.66	191.41	1404.02	39.76	.95	2.41	.0	DRY ES 13.73	NO ACC.MEAS
113	18/ 4/75	20.15	1207.	982.21	27.82	7740.87	219.22	1847.40	52.32	1.25	3.17	53.2	RAIN	SAMPLED
114	4/ 5/75	.00	0.	.00	.00	7740.87	219.22	886.75	25.11	.60	1.52	.0	DRY EST 6.54	NO RECORD
115	6/ 5/75	7.36	161.	65.81	1.86	7806.68	221.09	665.06	18.83	.45	1.14	9.9	DAMP-RAIN	SAMPLED
116	6/ 5/75	10.35	450.	253.98	7.19	8060.66	228.28	517.27	14.65	.35	.89	49.1	WET -RAIN	SAMPLED
117	25/ 5/75	23.35	0.	.00	.00	8060.66	228.28	665.06	18.83	.45	1.14	.0	DRY EST3.47	SAMP BROKEN
118	26/ 5/75	14.30	0.	.00	.00	8060.66	228.28	1034.54	29.30	.70	1.78	.0	WET ES 16.51	NO RECORD
119	31/ 5/75	.15	0.	.00	.00	8060.66	228.28	369.48	10.46	.25	.63	.0	DRY	NO R/O
120	31/ 5/75	20.30	0.	.00	.00	8060.66	228.28	369.48	10.46	.25	.63	.0	DAMP	NO R/O
121	2/ 6/75	17.45	0.	.00	.00	8060.66	228.28	266.02	7.53	.18	.46	.0	DAMP	NO R/O
122	5/ 6/75	5.45	234.	99.61	2.82	8160.27	231.10	783.30	22.18	.53	1.35	12.7	DAMP -R/O	
123	11/ 6/75	22.27	203.	7.63	.22	8167.91	231.32	945.87	26.79	.64	1.63	.8	DRY	R/O
124	15/ 6/75	18.00	0.	.00	.00	8167.91	231.32	399.04	11.30	.27	.69	.0	DRY	NO R/O
125	17/ 6/75	21.35	0.	.00	.00	8167.91	231.32	635.50	18.00	.43	1.09	.0	DAMP	NO R/O REC'D
126	19/ 6/75	2.22	446.	667.27	18.90	8835.18	250.21	1285.79	36.41	.87	2.21	51.9	DAMP	R/O
127	7/ 7/75	17.40	0.	.00	.00	8835.18	250.21	221.69	6.28	.15	.38	.0	DRY	NO R/O
128	10/ 7/75	12.20	0.	.00	.00	8835.18	250.21	768.52	21.76	.52	1.32	.0	DRY	NO R/O REC'D
129	10/ 7/75	17.30	126.	174.01	4.93	9009.19	255.14	354.70	10.05	.24	.61	49.1	WET	R/O

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.		COMMENTS
130	14/ 7/75	.10	139.	17.80	.50	9026.99	255.64	768.52	21.76	.52	1.32	2.3	DRY	R/O
131	19/ 7/75	6.15	0.	.00	.00	9026.99	255.64	517.27	14.65	.35	.89	.0	DRY	NO R/O REC'D
132	20/ 7/75	8.30	0.	.00	.00	9026.99	255.64	295.58	8.37	.20	.51	.0	DAMP	NO R/O REC'D
133	20/ 7/75	17.05	0.	.00	.00	9026.99	255.64	73.90	2.09	.05	.13	.0	DAMP	NO R/O REC'D
134	20/ 7/75	23.20	0.	.00	.00	9026.99	255.64	73.90	2.09	.05	.13	.0	DAMP	NO R/O REC'D
135	24/ 7/75	4.45	0.	.00	.00	9026.99	255.64	59.12	1.67	.04	.10	.0	DRY	NO R/O
136	24/ 7/75	19.45	0.	.00	.00	9026.99	255.64	118.23	3.35	.08	.20	.0	DAMP	NO R/O REC'D
137	27/ 7/75	16.45	0.	.00	.00	9026.99	255.64	502.49	14.23	.34	.86	.0	DRY	NO R/O REC'D
138	3/ 8/75	1.40	0.	.00	.00	9026.99	255.64	2069.08	58.60	1.40	3.56	.0	DRY E 23.03	NO RECORD
139	3/ 8/75	10.25	0.	.00	.00	9026.99	255.64	665.06	18.83	.45	1.14	.0	DAMPE 3.47	NO RECORD
140	3/ 8/75	15.10	0.	.00	.00	9026.99	255.64	147.79	4.19	.10	.25	.0	WET EST 0	NO RECORD
141	4/ 8/75	2.10	0.	.00	.00	9026.99	255.64	310.36	8.79	.21	.53	.0	DAMP	NO RECORD
142	11/ 8/75	2.20	0.	.00	.00	9026.99	255.64	73.90	2.09	.05	.13	.0	DRY	NO RECORD
143	13/ 8/75	9.25	0.	.00	.00	9026.99	255.64	325.14	9.21	.22	.56	.0	DRY	NO RECORD
144	19/ 8/75	11.45	0.	.00	.00	9026.99	255.64	783.30	22.18	.53	1.35	.0	DRY EST 5.16	NO RECORD
145	23/ 8/75	20.00	0.	.00	.00	9026.99	255.64	4611.10	130.59	3.12	7.92	.0	DRY E 58.28	NO RECORD
146	24/ 8/75	20.00	0.	.00	.00	9026.99	255.64	295.58	8.37	.20	.51	.0	DAMP,UNTIMED	NO RECORD
147	25/ 8/75	20.50	0.	.00	.00	9026.99	255.64	73.90	2.09	.05	.13	.0	DAMP	NO RECORD
148	28/ 8/75	13.10	0.	.00	.00	9026.99	255.64	384.26	10.88	.26	.66	.0	DRY	NO RECORD
149	31/ 8/75	18.25	0.	.00	.00	9026.99	255.64	842.41	23.86	.57	1.45	.0	DRY EST 5.97	NO RECORD
150	11/ 9/75	14.30	0.	.00	.00	9026.99	255.64	886.75	25.11	.60	1.52	.0	DRY EST 6.54	BAD RO CHART
151	12/ 9/75	21.00	0.	.00	.00	9026.99	255.64	44.34	1.26	.03	.08	.0	DAMP	BAD RO CHART
152	13/ 9/75	11.30	0.	.00	.00	9026.99	255.64	236.47	6.70	.16	.41	.0	DAMP	BAD RO CHART
153	19/ 9/75	12.50	0.	.00	.00	9026.99	255.64	1256.23	35.58	.85	2.16	.0	DRY E 11.71	BAD RO CHART
154	21/ 9/75	23.40	0.	.00	.00	9026.99	255.64	399.04	11.30	.27	.69	.0	DAMP	BAD RO CHART
155	30/ 9/75	2.40	0.	.00	.00	9026.99	255.64	118.23	3.35	.08	.20	.0	DRY	BAD RO CHART

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
156	1/10/75	9.10	0.	.00	.00	9026.99	255.64	236.47	6.70	.16	.41	.0	DAMP	BAD RO CHART
157	11/10/75	13.20	0.	.00	.00	9026.99	255.64	103.45	2.93	.07	.18	.0	DRY	BAD RO CHART
158	13/10/75	2.00	0.	.00	.00	9026.99	255.64	59.12	1.67	.04	.10	.0	DAMP	BAD RO CHART
159	13/10/75	11.40	0.	.00	.00	9026.99	255.64	561.61	15.90	.38	.97	.0	DAMP E 2.09	SAMPLED
160	15/10/75	18.20	0.	.00	.00	9026.99	255.64	177.35	5.02	.12	.30	.0	DRY	BAD RO CHART
161	17/10/75	19.50	0.	.00	.00	9026.99	255.64	310.36	8.79	.21	.53	.0	DRY	BAD RO CHART
162	19/10/75	21.30	0.	.00	.00	9026.99	255.64	73.90	2.09	.05	.13	.0	DRY	BAD RO CHART
163	20/10/75	.00	0.	.00	.00	9026.99	255.64	679.84	19.25	.46	1.17	.0	WET EST 9.95	BAD RO CHART
164	25/10/75	10.55	0.	.00	.00	9026.99	255.64	118.23	3.35	.08	.20	.0	DRY	BAD RO CHART
165	1/11/75	9.25	0.	.00	.00	9026.99	255.64	561.61	15.90	.38	.97	.0	DRY	BAD RO CHART
166	2/11/75	19.18	105.	40.08	1.14	9067.07	256.78	413.82	11.72	.28	.71	9.7	DRY	R=O
167	2/11/75	23.20	204.	352.03	9.97	9419.10	266.75	443.37	12.56	.30	.76	79.4	WET	R/O
168	3/11/75	16.25	281.	202.26	5.73	9621.36	272.48	502.49	14.23	.34	.86	40.3	DAMP	R/O
169	7/11/75	14.10	0.	.00	.00	9621.36	272.48	192.13	5.44	.13	.33	.0	DRY	NO R/O
170	10/11/75	5.40	186.	527.99	14.95	10149.34	287.43	1300.57	36.83	.88	2.24	40.6	DRY	R/O
171	20/11/75	18.00	0.	.00	.00	10149.34	287.43	118.23	3.35	.08	.20	.0	DRY	NO RECORD
172	27/11/75	9.50	0.	.00	.00	10149.34	287.43	251.25	7.12	.17	.43	.0	DRY	NO RECORD
173	29/11/75	14.40	0.	.00	.00	10149.34	287.43	59.12	1.67	.04	.10	.0	DAMP	NO RECORD
174	29/11/75	17.50	0.	.00	.00	10149.34	287.43	44.34	1.26	.03	.08	.0	WET	NO RECORD
175	29/11/75	23.35	0.	.00	.00	10149.34	287.43	44.34	1.26	.03	.08	.0	DAMP	NO RECORD
176	30/11/75	9.40	0.	.00	.00	10149.34	287.43	177.35	5.02	.12	.30	.0	DAMP	NO RECORD
177	4/12/75	11.10	0.	.00	.00	10149.34	287.43	472.93	13.39	.32	.81	.0	DRY	NO RECORD
178	5/12/75	14.50	0.	.00	.00	10149.34	287.43	605.95	17.16	.41	1.04	.0	DAMP E 12.72	NO RECORD
179	9/12/75	13.00	0.	.00	.00	10149.34	287.43	118.23	3.35	.08	.20	.0	DRY	NO RECORD
180	10/12/75	10.45	0.	.00	.00	10149.34	287.43	206.91	5.86	.14	.36	.0	DAMP	NO RECORD
181	11/12/75	11.30	0.	.00	.00	10149.34	287.43	103.45	2.93	.07	.18	.0	DAMP	NO RECORD

SITE NUMBER: 2

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	INS	CM	RUNOFF AS % PRECIP.		COMMENTS
182	13/12/75	10.50	0.	.00	.00	10149.34	287.43	133.01	3.77	.09	.23	.0	DAMP	NO RECORD

SITE NUMBER: 3

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	PRECIPITATION INS	PRECIPITATION CM	RUNOFF AS % PRECIP.	COMMENTS	
1	6/12/73	.00	0.	.00	.00	.00	.00	.00	.00	.00	.00	.0	SNOW MELT	SAMPLED
2	19/12/73	16.00	0.	.00	.00	.00	.00	202.50	5.73	.45	1.14	.0	DRY	NO RECORD RO
3	20/12/73	10.20	0.	.00	.00	.00	.00	81.00	2.29	.18	.46	.0	WET SNOW?	NO RECORD RO
4	25/12/72	11.00	0.	.00	.00	.00	.00	153.00	4.33	.34	.86	.0	DRY	NO RECORD RO
5	26/12/73	18.00	0.	.00	.00	.00	.00	202.50	5.73	.45	1.14	.0	WET SNOW?	NO RECORD RO
6	3/ 1/74	.00	0.	.00	.00	.00	.00	.00	.00	.00	.00	.0	SNOW MELT	SAMPLED
7	8/ 1/74	.00	0.	.00	.00	.00	.00	90.00	2.55	.20	.51	.0	WET SNOW?	NO RECORD RO
8	20/ 1/74	11.30	0.	.00	.00	.00	.00	117.00	3.31	.26	.66	.0	DRY	NO RECORD RO
9	21/ 1/74	1.00	0.	.00	.00	.00	.00	292.50	8.28	.65	1.65	.0	WET SNOW?	NO RECORD RO
10	22/ 1/74	17.00	0.	.00	.00	.00	.00	157.50	4.46	.35	.89	.0	WET SNOW?	NO RECORD RO
11	26/ 1/74	21.00	0.	.00	.00	.00	.00	337.50	9.56	.75	1.90	.0	DRY EST 4.34	NO REC.-SMPL
12	18/ 2/74	21.00	0.	.00	.00	.00	.00	157.50	4.46	.35	.89	.0	DRY SNOW?	NO RECORD RO
13	24/ 2/74	2.00	0.	.00	.00	.00	.00	450.00	12.74	1.00	2.54	.0	DRY SNOW?	NO RECORD RO
14	28/ 2/74	12.00	0.	.00	.00	.00	.00	67.50	1.91	.15	.38	.0	DRY SNOW?	NO RECORD RO
15	4/ 3/74	11.00	0.	.00	.00	.00	.00	540.00	15.29	1.20	3.05	.0	DRY SNOW?	NO RECORD RO
16	16/ 3/74	8.40	172.	65.02	1.84	65.02	1.84	54.00	1.53	.12	.30	120.4	SNOW MELT?	SAMPLED
17	18/ 3/74	8.56	0.	.00	.00	65.02	1.84	45.00	1.27	.10	.25	.0	DRY	JUST R-O
18	1/ 4/74	21.30	0.	.00	.00	65.02	1.84	225.00	6.37	.50	1.27	.0	DRY	NO RO RECORD
19	3/ 4/74	20.20	943.	369.76	10.47	434.78	12.31	472.50	13.38	1.05	2.67	78.3	DRY	NO SAMPLE
20	7/ 4/74	7.52	247.	5.02	.14	439.80	12.46	99.00	2.80	.22	.56	5.1	DRY	NO SAMPLE
21	12/ 4/74	13.20	116.	3.80	.11	443.61	12.56	126.00	3.57	.28	.71	3.0	DRY	NO SAMPLE
22	14/ 4/74	13.16	146.	2.67	.08	446.28	12.64	54.00	1.53	.12	.30	4.9	DRY	
23	14/ 4/74	20.30	176.	2.40	.07	448.68	12.71	40.50	1.15	.09	.23	5.9	WET 5HR1R-O	NO SAMPLE
24	22/ 4/74	11.00	612.	219.49	6.22	668.17	18.92	396.00	11.21	.88	2.24	55.4	DRY	SAMPLED
25	30/ 4/74	1.40	0.	.00	.00	668.17	18.92	67.50	1.91	.15	.38	.0	DRY	NO R-O

SITE NUMBER: 3

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.		COMMENTS
52	20/11/74	13.20	1274.	292.60	8.29	2530.41	71.66	463.50	13.13	1.03	2.62	63.1	WET	
53	23/11/74	19.00	344.	27.18	.77	2557.59	72.43	117.00	3.31	.26	.66	23.2	DAMP	SOME SNOW
54	8/12/74	22.15	0.	.00	.00	2557.59	72.43	67.50	1.91	.15	.38	.0	DRY	
55	12/12/74	23.40	312.	63.02	1.78	2620.61	74.22	99.00	2.80	.22	.56	63.7	DRY	FROZE UP
56	20/12/74	13.00	0.	.00	.00	2620.61	74.22	103.50	2.93	.23	.58	.0	Y	
57	1/ 1/75	18.30	0.	.00	.00	2620.61	74.22	90.00	2.55	.20	.51	.0	DRY	
58	6/ 1/75	18.00	0.	.00	.00	2620.61	74.22	31.50	.89	.07	.18	.0		
59	8/ 1/75	18.00	0.	.00	.00	2620.61	74.22	135.00	3.82	.30	.76	.0	DAMP	
60	11/ 1/75	10.50	280.	17.84	.51	2638.45	74.72	76.50	2.17	.17	.43	23.3	DAMP	R/O NO SMPL
61	24/ 1/75	18.00	0.	.00	.00	2638.45	74.72	67.50	1.91	.15	.38	.0	FROZEN	
62	25/ 1/75	12.00	0.	.00	.00	2638.45	74.72	247.50	7.01	.55	1.40	.0		
63	29/ 1/75	15.30	0.	.00	.00	2638.45	74.72	225.00	6.37	.50	1.27	.0	RAIN	FROZEN
64	4/ 2/75	23.00	0.	.00	.00	2638.45	74.72	67.50	1.91	.15	.38	.0	FROZEN	
65	14/ 2/75	.00	0.	.00	.00	2638.45	74.72	45.00	1.27	.10	.25	.0	SNOW	
66	17/ 2/75	21.00	0.	.00	.00	2638.45	74.72	45.00	1.27	.10	.25	.0	FROZEN	
67	18/ 2/75	12.45	0.	.00	.00	2638.45	74.72	135.00	3.82	.30	.76	.0	FROZEN	
68	19/ 2/75	17.30	0.	.00	.00	2638.45	74.72	99.00	2.80	.22	.56	.0	FROZEN	
69	22/ 2/75	19.00	0.	.00	.00	2638.45	74.72	81.00	2.29	.18	.46	.0	FROZEN	
70	24/ 2/75	2.00	0.	.00	.00	2638.45	74.72	405.00	11.47	.90	2.29	.0	RAIN WET	EST 8.20
71	25/ 2/75	13.00	0.	.00	.00	2638.45	74.72	225.00	6.37	.50	1.27	.0	NO R/O RECD.	WET EST 4.25
72	27/ 2/75	8.00	0.	.00	.00	2638.45	74.72	54.00	1.53	.12	.30	.0	FROZEN ?	
73	7/ 3/75	8.00	0.	.00	.00	2638.45	74.72	90.00	2.55	.20	.51	.0	FROZEN ?	
74	19/ 3/75	11.45	0.	.00	.00	2638.45	74.72	99.00	2.80	.22	.56	.0	FROZEN ?	
75	22/ 3/75	9.00	0.	.00	.00	2638.45	74.72	148.50	4.21	.33	.84	.0	FROZEN ?	
76	24/ 3/75	7.45	0.	.00	.00	2638.45	74.72	36.00	1.02	.08	.20	.0	FROZEN ?	
77	25/ 3/75	10.15	0.	.00	.00	2638.45	74.72	135.00	3.82	.30	.76	.0	FROZEN ?	

SITE NUMBER: 3

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS
78	2/ 4/75	15.00	0.	.00	.00	2638.45	74.72	562.50	15.93	1.25	3.17	.0	NO R/O RECD. DRY EST8.35
79	4/ 4/75	6.15	0.	.00	.00	2638.45	74.72	112.50	3.19	.25	.63	.0	NO R/O RECD.
80	5/ 4/75	7.30	0.	.00	.00	2638.45	74.72	135.00	3.82	.30	.76	.0	NO R/O RECD.
81	6/ 4/75	10.30	0.	.00	.00	2638.45	74.72	90.00	2.55	.20	.51	.0	NO R/O RECD.
82	18/ 4/75	19.30	0.	.00	.00	2638.45	74.72	765.00	21.66	1.70	4.32	.0	NO R/O RECD. DRY EST 11.9
83	23/ 4/75	17.30	0.	.00	.00	2638.45	74.72	67.50	1.91	.15	.38	.0	TRICKLE FLOW
84	4/ 5/75	14.00	0.	.00	.00	2638.45	74.72	135.00	3.82	.30	.76	.0	TRICKLE FLOW
85	6/ 5/75	15.30	0.	.00	.00	2638.45	74.72	180.00	5.10	.40	1.02	.0	DRY EST 1.59 SAMPLED
86	12/ 5/75	14.00	0.	.00	.00	2638.45	74.72	54.00	1.53	.12	.30	.0	NO R/O
87	24/ 5/75	18.12	108.	16.54	.47	2654.99	75.19	135.00	3.82	.30	.76	12.3	DRY -R/O
88	25/ 5/75	23.04	272.	82.81	2.35	2737.80	77.53	180.00	5.10	.40	1.02	46.0	DAMP-R/O
89	26/ 5/75	7.00	140.	34.30	.97	2772.09	78.51	45.00	1.27	.10	.25	76.2	WET -R/O
90	26/ 5/75	13.40	224.	40.92	1.16	2813.01	79.66	54.00	1.53	.12	.30	75.8	WET -R/O
91	30/ 5/75	23.30	0.	.00	.00	2813.01	79.66	112.50	3.19	.25	.63	.0	DRY -R/O
92	1/ 6/75	.06	126.	18.47	.52	2831.49	80.19	54.00	1.53	.12	.30	34.2	WET
93	4/ 6/75	20.50	280.	28.01	.79	2859.50	80.98	112.50	3.19	.25	.63	24.9	DRY -R/O
94	5/ 6/75	5.00	272.	73.07	2.07	2932.57	83.05	103.50	2.93	.23	.58	70.6	WET -R/O
95	5/ 6/75	12.45	368.	50.66	1.43	2983.23	84.49	67.50	1.91	.15	.38	75.1	WET -R/O
96	10/ 6/75	22.40	524.	18.94	.54	3002.17	85.02	180.00	5.10	.40	1.02	10.5	DRY
97	14/ 6/75	8.28	216.	83.04	2.35	3085.21	87.37	180.00	5.10	.40	1.02	46.1	DRY -R/O
98	14/ 6/75	16.36	328.	67.78	1.92	3152.98	89.29	157.50	4.46	.35	.89	43.0	WET -R/O
99	15/ 6/75	19.20	180.	11.55	.33	3164.53	89.62	72.00	2.04	.16	.41	16.0	WET -R/O
100	17/ 6/75	22.30	1070.	124.12	3.52	3288.66	93.13	189.00	5.35	.42	1.07	65.7	DRY -R/O
101	19/ 6/75	3.27	739.	683.14	19.35	3971.80	112.48	958.50	27.14	2.13	5.41	71.3	WET
102	23/ 6/75	17.05	434.	29.53	.84	4001.33	113.32	130.50	3.70	.29	.74	22.6	DRY -R/O
103	13/ 7/75	23.38	128.	66.18	1.87	4067.51	115.19	256.50	7.26	.57	1.45	25.8	DRY -R/O

SITE NUMBER: 3

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS
104	19/ 7/75	7.05	274.	148.27	4.20	4215.78	119.39	472.50	13.38	1.05	2.67	31.4	DRY -R/O
105	20/ 7/75	9.35	921.	100.31	2.84	4316.09	122.23	252.00	7.14	.56	1.42	39.8	DAMP -R/O
106	24/ 7/75	6.00	606.	151.25	4.28	4467.34	126.52	148.50	4.21	.33	.84	101.9	DRY -R/O
107	27/ 7/75	16.00	211.	24.47	.69	4491.81	127.21	198.00	5.61	.44	1.12	12.4	DRY -R/O
108	2/ 8/75	17.00	144.	29.93	.85	4521.74	128.06	76.50	2.17	.17	.43	39.1	DRY -R/O
109	3/ 8/75	2.10	198.	74.18	2.10	4595.92	130.16	216.00	6.12	.48	1.22	34.3	WET -R/O
110	11/ 8/75	1.45	0.	.00	.00	4595.92	130.16	49.50	1.40	.11	.28	.0	DRY
111	13/ 8/75	20.35	219.	12.21	.35	4608.13	130.50	112.50	3.19	.25	.63	10.9	DRY -R/O
112	21/ 8/75	12.14	364.	78.91	2.23	4687.04	132.74	261.00	7.39	.58	1.47	30.2	DRY -R/O
113	23/ 8/75	.12	1773.	1039.16	29.43	5726.20	162.17	1687.50	47.79	3.75	9.52	61.6	DRY -R/O
114	25/ 8/75	17.05	0.	.00	.00	5726.20	162.17	40.50	1.15	.09	.23	.0	DAMP
115	29/ 8/75	10.58	553.	112.82	3.20	5839.01	165.36	306.00	8.67	.68	1.73	36.9	DRY -R/O
116	1/ 9/75	21.00	0.	.00	.00	5839.01	165.36	76.50	2.17	.17	.43	.0	DRY NO R/O
117	4/ 9/75	14.55	0.	.00	.00	5839.01	165.36	45.00	1.27	.10	.25	.0	DRY NO R/O
118	5/ 9/75	14.20	0.	.00	.00	5839.01	165.36	18.00	.51	.04	.10	.0	DAMP NO R/O
119	7/ 9/75	21.20	0.	.00	.00	5839.01	165.36	36.00	1.02	.08	.20	.0	DRY NO R/O
120	11/ 9/75	21.15	84.	5.25	.15	5844.27	165.51	270.00	7.65	.60	1.52	1.9	DRY R/O
121	12/ 9/75	10.50	0.	.00	.00	5844.27	165.51	13.50	.38	.03	.08	.0	DAMP NO R/O
122	12/ 9/75	20.25	0.	.00	.00	5844.27	165.51	9.00	.25	.02	.05	.0	DAMP NO R/O
123	13/ 9/75	12.35	35.	6.39	.18	5850.65	165.69	72.00	2.04	.16	.41	8.9	DAMP R/O
124	18/ 9/75	13.30	0.	.00	.00	5850.65	165.69	256.50	7.26	.57	1.45	.0	DRY NO R/O
125	20/ 9/75	2.40	120.	33.21	.94	5883.86	166.63	202.50	5.73	.45	1.14	16.4	DAMP R/O
126	21/ 9/75	18.30	0.	.00	.00	5883.86	166.63	54.00	1.53	.12	.30	.0	DAMP NO R/O
127	25/ 9/75	2.00	40.	34.19	.97	5918.06	167.60	36.00	1.02	.08	.20	95.0	DRY R/O
128	2/10/75	20.40	0.	.00	.00	5918.06	167.60	36.00	1.02	.08	.20	.0	DRY NO R/O
129	3/10/75	.30	0.	.00	.00	5918.06	167.60	63.00	1.78	.14	.36	.0	DAMP NO R/O

SITE NUMBER: 3

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	PRECIPITATION INS	PRECIPITATION CM	RUNOFF AS % PRECIP.	COMMENTS	
130	3/10/75	10.53	75.	24.67	.70	5942.72	168.30	301.50	8.54	.67	1.70	8.2	DAMP	R/O
131	19/10/75	2.43	258.	82.81	2.35	6025.53	170.64	216.00	6.12	.48	1.22	38.3	DRY	R/O
132	8/11/75	4.22	424.	141.78	4.02	6167.31	174.66	162.00	4.59	.36	.91	87.5	DRY	R/O
133	20/11/75	21.05	100.	5.35	.15	6172.66	174.81	58.50	1.66	.13	.33	9.1	DRY	R/O
134	21/11/75	.15	94.	3.45	.10	6176.11	174.91	31.50	.89	.07	.18	11.0	WET	R/O
135	23/11/75	15.00	0.	.00	.00	6176.11	174.91	22.50	.64	.05	.13	.0	DAMP	NO R/O
136	24/11/75	9.25	0.	.00	.00	6176.11	174.91	103.50	2.93	.23	.58	.0	DAMPEST 1.57	POOR RECORD
137	25/11/75	10.25	0.	.00	.00	6176.11	174.91	45.00	1.27	.10	.25	.0	DAMPEST 0.3	POOR RECORD
138	26/11/75	1.45	0.	.00	.00	6176.11	174.91	22.50	.64	.05	.13	.0	DAMP	POOR RECORD
139	26/11/75	8.20	0.	.00	.00	6176.11	174.91	54.00	1.53	.12	.30	.0	DAMPEST 0.49	POOR RECORD

SITE NUMBER: 4

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
1	19/12/73	.00	0.	.00	.00	.00	.00	326.25	9.24	.75	1.90	.0		NO R-O
2	27/12/73	.00	0.	.00	.00	.00	.00	165.30	4.68	.38	.97	.0		NO R-O
3	28/12/73	.00	0.	.00	.00	.00	.00	195.75	5.54	.45	1.14	.0		NO R-O
4	12/ 4/74	.00	0.	.00	.00	.00	.00	121.80	3.45	.28	.71	.0	FLUME CHOKED	NO R-O
5	30/ 4/74	.00	0.	.00	.00	.00	.00	369.75	10.47	.85	2.16	.0	FLUME CHOKED	NO R-O
6	3/ 5/74	.00	0.	.00	.00	.00	.00	130.50	3.70	.30	.76	.0		NO R-O
7	5/ 5/74	.00	0.	.00	.00	.00	.00	304.50	8.62	.70	1.78	.0		NO R-O
8	7/ 5/74	.00	0.	.00	.00	.00	.00	369.75	10.47	.85	2.16	.0		NO R-O
9	28/ 5/74	.00	0.	.00	.00	.00	.00	87.00	2.46	.20	.51	.0	FLUME CLEAN	JUST FLOWED
10	15/ 6/74	.00	0.	.00	.00	.00	.00	652.50	18.48	1.50	3.81	.0	SAMPLED	EST 10.76
11	28/ 6/74	4.40	308.	55.47	1.57	55.47	1.57	348.00	9.86	.80	2.03	15.9	DRY GOOD REC	NO SAMPLE
12	28/ 6/74	7.20	220.	10.90	.31	66.37	1.88	73.95	2.09	.17	.43	14.7	WET	
13	11/ 8/74	.00	0.	.00	.00	66.37	1.88	87.00	2.46	.20	.51	.0		NO R-O
14	1/ 9/74	.00	0.	.00	.00	66.37	1.88	87.00	2.46	.20	.51	.0		NO R-O
15	3/11/74	16.16	22.	8.27	.23	74.64	2.11	152.25	4.31	.35	.89	5.4	DRY	
16	5/11/74	.00	0.	.00	.00	74.64	2.11	217.50	6.16	.50	1.27	.0	DAMP	DID FLOW
17	5/ 3/75	23.40	0.	.00	.00	74.64	2.11	34.80	.99	.08	.20	.0		
18	7/ 3/75	8.35	0.	.00	.00	74.64	2.11	160.95	4.56	.37	.94	.0	DAMP	
19	19/ 3/75	9.20	0.	.00	.00	74.64	2.11	143.55	4.07	.33	.84	.0	DRY	
20	22/ 3/75	8.30	0.	.00	.00	74.64	2.11	174.00	4.93	.40	1.02	.0	DRY	
21	27/ 3/75	21.50	0.	.00	.00	74.64	2.11	160.95	4.56	.37	.94	.0	DRY	
22	2/ 4/75	16.23	0.	.00	.00	74.64	2.11	748.20	21.19	1.72	4.37	.0	DRY	
23	18/ 4/75	19.40	1424.	286.06	8.10	360.69	10.21	687.30	19.46	1.58	4.01	41.6	DRY -R/O	
24	4/ 5/75	4.35	0.	.00	.00	360.69	10.21	108.75	3.08	.25	.63	.0	DRY EST .84	
25	4/ 5/75	14.40	0.	.00	.00	360.69	10.21	65.25	1.85	.15	.38	.0	WET	

SITE NUMBER: 4

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	TOTAL FLOW CU.M	ACCUMULATED FLOW CU.FT	ACCUMULATED FLOW CU.M	PRECIPITATION CU.FT	PRECIPITATION CU.M	PRECIPITATION INS	PRECIPITATION CM	RUNOFF AS % PRECIP.	COMMENTS
26	5/ 5/75	3.15	0.	.00	.00	360.69	10.21	217.50	6.16	.50	1.27	.0	WET EST 2.86
27	25/ 5/75	14.07	30.	1.36	.04	362.06	10.25	117.45	3.33	.27	.69	1.2	DRY -R/O A.E.S. PREC.
28	26/ 5/75	17.50	172.	14.74	.42	376.80	10.67	52.20	1.48	.12	.30	28.2	WET -R/O A.E.S. PREC.
29	11/ 6/75	12.00	0.	.00	.00	376.80	10.67	226.20	6.41	.52	1.32	.0	DRY -R/O NO RECORD
30	14/ 6/75	16.30	148.	13.06	.37	389.86	11.04	26.10	.74	.06	.15	50.0	DRY -R/O
31	15/ 6/75	17.25	385.	183.26	5.19	573.12	16.23	308.85	8.75	.71	1.80	59.3	WET -R/O
32	17/ 6/75	22.30	325.	45.60	1.29	618.72	17.52	152.25	4.31	.35	.89	29.9	DRY -R/O
33	18/ 6/75	1.30	173.	166.70	4.72	785.42	22.24	704.70	19.96	1.62	4.11	23.7	WET -R/O
34	19/ 6/75	2.50	0.	.00	.00	785.42	22.24	582.90	16.51	1.34	3.40	.0	DRY EST 9.59 FLUME CHOKED
35	23/ 6/75	16.05	0.	.00	.00	785.42	22.24	256.65	7.27	.59	1.50	.0	ERY EST 3.59 FLUME CQOKED
36	11/ 7/75	13.16	63.	4.05	.11	789.47	22.36	21.75	.62	.05	.13	18.6	DRY -R/O
37	14/ 7/75	21.16	126.	16.89	.48	806.36	22.84	269.70	7.64	.62	1.57	6.3	DRY -R/O
38	19/ 7/75	7.30	505.	480.66	13.61	1287.02	36.45	504.60	14.29	1.16	2.95	95.3	DRY -R/O
39	20/ 7/75	9.40	914.	182.00	5.15	1469.02	41.60	121.80	3.45	.28	.71	149.4	DAMP -R/O
40	22/ 7/75	22.35	0.	.00	.00	1469.02	41.60	34.80	.99	.08	.20	.0	DRY
41	24/ 7/75	6.20	218.	45.68	1.29	1514.70	42.90	134.85	3.82	.31	.79	33.9	DAMP -R/O
42	26/ 7/75	16.10	237.	41.15	1.17	1555.86	44.06	91.35	2.59	.21	.53	45.1	DRY -R/O
43	2/ 8/75	16.45	0.	.00	.00	1555.86	44.06	43.50	1.23	.10	.25	.0	DRY
44	3/ 8/75	2.56	639.	63.15	1.79	1619.00	45.85	287.10	8.13	.66	1.68	22.0	WET -R/O
45	10/ 8/75	7.15	322.	5.78	.16	1624.78	46.01	208.80	5.91	.48	1.22	2.8	DRY -R/O
46	12/ 8/75	17.30	235.	121.68	3.45	1746.46	49.46	143.55	4.07	.33	.84	84.8	DAMP -R/O
47	21/ 8/75	10.55	0.	.00	.00	1746.46	49.46	243.60	6.90	.56	1.42	.0	DRY EST 3.34 NO RECORD
48	23/ 8/75	21.35	0.	.00	.00	1746.46	49.46	1117.95	31.66	2.57	6.53	.0	DRY EST 19.5 NO RECORD
49	25/ 8/75	17.20	0.	.00	.00	1746.46	49.46	47.85	1.36	.11	.28	.0	DAMP FLUMF CHOKED
50	29/ 8/75	10.40	0.	.00	.00	1746.46	49.46	356.70	10.10	.82	2.08	.0	DRY EST 5.42 FLUME CHOKED
51	31/ 8/75	19.20	0.	.00	.00	1746.46	49.46	108.75	3.08	.25	.63	.0	DRY EST .84 FLUME CHOKED

SITE NUMBER: 4

EVENT NUMBER	STARTED DAY/MO/YR	TIME	DURATION (MINS)	TOTAL FLOW CU.FT	CU.M	ACCUMULATED FLOW CU.FT	CU.M	PRECIPITATION CU.FT	CU.M	INS	CM	RUNOFF AS % PRECIP.	COMMENTS	
52	4/ 9/75	15.15	0.	.00	.00	1746.46	49.46	56.55	1.60	.13	.33	.0	DRY	FLUME CHOKED
53	7/ 9/75	21.05	0.	.00	.00	1746.46	49.46	47.85	1.36	.11	.28	.0	DRY	FLUME CHOKED
54	11/ 9/75	9.10	0.	.00	.00	1746.46	49.46	226.20	6.41	.52	1.32	.0	DRY EST 3.02	
55	13/ 9/75	5.35	0.	.00	.00	1746.46	49.46	60.90	1.72	.14	.36	.0	DAMP	
56	17/ 9/75	19.15	0.	.00	.00	1746.46	49.46	230.55	6.53	.53	1.35	.0	DRY EST 3.11	
57	19/ 9/75	7.15	0.	.00	.00	1746.46	49.46	187.05	5.30	.43	1.09	.0	DAMPEST 2.29	
58	21/ 9/75	1.25	0.	.00	.00	1746.46	49.46	30.45	.86	.07	.18	.0	DAMP	
59	0/10/75	.00	0.	.00	.00	1746.46	49.46	1513.80	42.87	3.48	8.84	.0	SITE 3 ESTIM	6.95 TOTAL R
60	1/11/75	7.50	0.	.00	.00	1746.46	49.46	100.05	2.83	.23	.58	.0	DRY	NO R/O
61	2/11/75	17.15	0.	.00	.00	1746.46	49.46	69.60	1.97	.16	.41	.0	DAMP	NO R/O
62	3/11/75	17.05	0.	.00	.00	1746.46	49.46	117.45	3.33	.27	.69	.0	DAMP	NO R/O

@FIN

APPENDIX B

RUNOFF WATER QUALITY

1973 - 75

SITE NUMBER: 1

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
20/ 8/73	S	1	2400	N.A.	N.A.	53	320	.70	.3	75	17
20/ 8/73	S	2	2200	N.A.	N.A.	42	310	.80	1.2	70	19
20/ 8/73	S	3	3200	N.A.	N.A.	49	280	.70	1.3	65	17
17/ 9/73	S	1	2600	4450	10500	160	480	.80	.5	98	52
17/ 9/73	S	2	2600	8000	15700	200	1000	.90	1.1	220	70
17/ 9/73	S	3	4000	17900	23800	220	1500	1.0	1.0	320	93
1/10/73	S	1	5000	2800	N.A.	210	600	1.0	1.0	100	30
1/10/73	S	2	5000	8100	N.A.	180	740	.88	.9	160	25
1/10/73	S	3	5000	10200	N.A.	170	710	.94	1.0	145	35
30/10/73	S	1	6000	3400	N.A.	N.A.	730	N.A.	N.A.	110	N.A.
30/10/73	S	2	9500	14600	N.A.	N.A.	1200	N.A.	N.A.	280	N.A.
30/10/73	S	3	7500	7700	N.A.	N.A.	960	N.A.	N.A.	240	N.A.
22/11/73	W	1	4600	1450	N.A.	N.A.	510	N.A.	N.A.	85	N.A.
22/11/73	W	2	6000	4700	N.A.	N.A.	660	N.A.	N.A.	100	N.A.
22/11/73	W	3	5500	2600	N.A.	N.A.	620	N.A.	N.A.	95	N.A.
30/11/73	W	1	3400	1100	6900	250	520	.69	.8	62	34
30/11/73	W	2	6000	3400	10600	350	820	.81	1.0	110	50
30/11/73	W	3	6000	4700	11500	300	850	.76	1.0	120	50
21/ 1/74	W	1	4400	4350	11000	240	820	.94	1.6	95	21

SITE NUMBER: 1

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
21/ 1/74	W	2	4400	5000	12400	260	890	1.30	2.3	100	38
21/ 1/74	W	3	3600	3450	9500	210	750	.90	1.9	90	26
20/ 2/74	W	1	4200	1600	7100	30	660	.95	.2	60	38
20/ 2/74	W	2	6000	9500	18700	670	1600	1.9	.4	160	100
20/ 2/74	W	3	5400	8200	19000	700	1700	2.0	.4	170	92
7/ 3/74	W	1	3000	1450	7500	260	700	1.0	.4	130	70
7/ 3/74	W	2	4400	6700	11700	345	840	1.0	.6	120	55
4/ 4/74	W	1	6000	9200	18000	540	N.A.	1.3	1.0	140	82
4/ 4/74	W	2	7000	6800	16000	560	N.A.	1.3	1.1	140	76
0/ 5/74	S	1	3400	4600	13200	200	600	1.0	<.01	100	52
0/ 5/74	S	2	4800	4000	15100	230	650	1.3	.2	120	58
0/ 5/74	S	3	4800	3950	15600	250	700	1.4	.1	120	62
0/ 5/74	S	4	6000	4050	23900	270	900	1.6	.4	170	81
4/11/74	W	1	2000	2950	N.A.	N.A.	400	N.A.	N.A.	90	N.A.
4/11/74	W	2	6500	14300	N.A.	N.A.	960	N.A.	N.A.	170	N.A.
4/11/74	W	3	7000	23000	N.A.	N.A.	880	N.A.	N.A.	160	N.A.
11/ 1/75	W	1	5000	7300	14400	240	620	.99	2.1	160	75
11/ 1/75	W	2	6500	9600	19400	240	620	.99	2.3	155	83
11/ 1/75	W	3	8000	14500	21800	230	660	1.1	2.6	180	73

SITE NUMBER: 1

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
21/11/75	W	1	N.A.	N.A.	N.A.	270	840	< .20	< .20	120	24

SITE NUMBER: 2

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
5/12/73	W	1	1200	2350	8000	65	290	.44	.26	65	19
27/12/73	W	1	1800	17700	23100	140	430	.35	.2	100	51
21/ 1/74	W	1	700	490	N.A.	130	190	.28	<0.1	35	24
21/ 1/74	W	2	280	270	N.A.	50	95	.1	.1	19	14
22/ 2/74	W	1	950	1650	3850	110	260	.07	.4	58	38
22/ 2/74	W	2	1000	1200	3200	97	230	.06	.4	48	30
5/ 3/74	W	1	2200	1950	7300	210	380	.62	.6	120	76
15/ 4/74	W	1	3500	35400	35600	220	1400	.78	<0.1	430	180
15/ 4/74	W	2	2800	38500	40100	140	1400	.67	.9	370	140
15/ 4/74	W	3	5500	36100	36600	210	1300	.80	.6	390	160
15/ 4/74	W	4	7500	27800	32300	270	1200	.94	.9	350	180
15/ 5/74	S	1	1000	1800	4550	30	140	.25	.1	70	40
15/ 5/74	S	2	1100	2200	5200	34	160	.25	.3	70	54
15/ 5/74	S	3	260	4800	6300	8	320	<0.01	<0.1	90	18
15/ 5/74	S	4	600	6400	7800	28	280	<0.01	<0.1	90	41
16/ 6/74	S	1	N.A.	330	4350	22	90	.17	<0.1	22	17
16/ 6/74	S	2	N.A.	550	2350	8	85	.19	<0.01	35	27
19/ 6/74	S	1	300	280	3500	6	50	.14	<0.01	37	15
19/ 6/74	S	2	300	300	3300	0	52	.15	<0.01	22	13

SITE NUMBER: 2

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
25/ 6/74	S	1	110	1950	2350	3	36	.01	<0.01	15	12
25/ 6/74	S	2	80	900	1450	1	16	.03	1.7	8	8
25/ 6/74	S	3	110	2300	3000	2	39	.01	<0.01	20	12
25/ 6/74	S	4	120	1300	2050	2	28	.04	1.6	15	14
23/ 8/74	S	1	1000	6000	13000	74	190	.24	.8	85	64
23/ 8/74	S	2	1100	7900	12200	90	200	.27	1.1	85	70
23/ 8/74	S	3	1200	10200	16200	80	190	.22	1.2	90	70
23/ 8/74	S	4	900	7800	9700	65	180	.26	.8	85	70
14/10/74	S	1	1400	5700	13900	39	380	.80	.6	120	35
3/11/74	W	1	550	2450	6500	20	260	.79	1.1	70	25
6/11/74	W	2	800	8500	12700	55	360	.75	.2	110	60
12/11/74	W	1	1600	10900	14300	80	520	.9	1.0	130	40
8/ 1/75	W	1	1800	5000	11700	270	480	.77	.9	94	37
8/ 1/75	W	2	1800	9000	14100	220	460	.67	.9	140	44
21/ 2/75	W	1	3000	1550	5500	270	460	.41	1.3	60	25
24/ 2/75	W	1	1700	4200	6600	180	350	.40	.8	75	36
24/ 2/75	W	2	1900	3300	6200	150	340	.40	.9	75	37
19/ 3/75	W	1	1650	3000	6800	150	360	.28	.3	80	32
25/ 3/75	W	1	3300	6200	11100	150	520	.38	.6	100	29

SITE NUMBER: 2

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
18/ 4/75	W	1	2200	9100	13100	140	470	.28	.3	95	32
7/ 5/75	S	1	1500	7200	10800	78	360	.48	.4	100	47
7/ 5/75	S	2	1100	3900	7000	76	350	.38	.3	100	45
7/ 5/75	S	3	950	5000	8600	58	280	.40	.3	90	36
5/ 6/75	S	1	300	1600	4450	25	160	.26	<0.05	60	28
5/ 6/75	S	2	400	7400	11700	35	260	.40	.1	85	39
12/ 6/75	S	1	775	834	6742	78	230	.51	.25	57	37
19/ 6/75	S	1	220	1650	4600	35	160	.42	.2	45	29
19/ 6/75	S	2	220	4800	6400	28	210	.30	.3	70	34
19/ 6/75	S	3	150	1550	4400	28	120	.46	.3	60	40
10/ 7/75	S	1	2550	14286	19552	110	490	.59	.32	160	88
10/ 7/75	S	2	2550	11368	16362	110	490	.60	.40	140	73
13/10/75	S	1	1150	6476	10180	54	530	.40	.60	165	40
3/11/75	W	1	1140	4134	9606	75	430	.75	1.75	110	54
3/11/75	W	2	1100	5946	9836	73	400	.40	.60	120	57
10/11/75	W	1	940	2564	13874	38	435	.48	.70	140	35
10/11/75	W	2	1060	2450	17966	42	430	.51	.80	140	40

SITE NUMBER: 3

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
6/12/73	W	1	2200	1900	5600	190	380	.36	.12	38	20
3/ 1/74	W	1	2600	900	5100	300	510	.55	.04	44	15
29/ 1/74	W	1	7500	1350	21000	2800	N.A.	2.6	2.6	100	16
29/ 1/74	W	2	900	250	2700	160	310	.39	.6	23	16
16/ 3/74	W	1	17600	3150	41800	2200	3400	2.0	1.6	340	110
3/ 4/74	W	1	3200	4050	6700	150	320	.32	.3	100	52
3/ 4/74	W	2	3200	7700	10000	86	240	.27	.3	38	26
22/ 4/74	W	1	3500	2450	24500	1300	1700	2.4	1.9	110	76
22/ 4/74	W	2	1600	2700	9900	110	300	.24	.4	50	26
5/ 5/74	S	1	5000	550	7900	370	600	.59	.6	30	14
8/ 5/74	S	1	5500	2200	9000	320	630	.66	.1	55	34
17/ 5/74	S	1	2600	1250	6600	272	580	.41	<0.01	110	30
17/ 5/74	S	2	1900	3100	6800	160	380	.06	4.5	60	26
19/ 6/74	S	1	1600	900	8700	160	400	.59	.2	120	62
19/ 6/74	S	2	300	2000	4000	N.A.	N.A.	.15	<0.01	60	30
13/11/74	W	1	11600	8100	17100	320	980	1.4	2.0	180	60
6/ 5/75	S	1	3400	5900	12300	160	660	.52	.55	130	37
19/ 6/75	S	1	2400	2100	9400	330	600	.86	.90	110	87
19/ 6/75	S	2	2000	2700	9580	200	400	.46	.50	75	43

SITE NUMBER: 3

DATE	SEASON	OUTLET	BOD,	SUSP,SOL,	TOT,SOL,	FREE NH3	KJEL,N	NO2	NO3	TOTAL P	SOL,P
19/ 6/75	S	3	650	2600	4900	87	220	1,10	2,30	70	43
4/ 8/75	S	1	340	2058	2712	35	75	,19	,15	45	35
22/ 8/75	S	1	420	253	3302	39	110	,12	<0,05	42	35
24/ 8/75	S	1	145	399	1940	51	110	,15	,15	43	32
24/ 8/75	S	2	225	1168	2710	35	110	,11	<0,05	60	36
11/ 9/75	S	1	700	230	5850	27	150	,40	,20	45	24

SITE NUMBER: 4

DATE	SEASON	OUTLET	BOD.	SUSP.SOL.	TOT.SOL.	FREE NH3	KJEL.N	NO2	NO3	TOTAL P	SOL.P
15/ 6/74	S	1	1100	420	4950	88	480	.6	.5	210	30
20/11/74	W	1	1600	3700	6700	94	340	3.0	2.3	70	30
21/ 3/75	W	1	4500	650	10040	500	750	N.A.	N.A.	55	31
21/ 3/75	W	2	4000	750	9140	490	750	N.A.	N.A.	60	21
29/ 3/75	W	1	160	50	1000	52	72	.10	<0.10	18	14
11/ 4/75	W	1	260	120	690	41	74	.06	<0.20	14	9
11/ 4/75	W	2	3200	725	7950	400	710	.50	.50	68	30
19/ 4/75	W	1	1000	2750	N.A.	160	300	.26	.45	60	38
19/ 4/75	W	1	1000	1050	N.A.	170	270	.32	.30	50	33
13/ 5/75	S	1	5800	1250	12200	390	860	.86	1.00	160	85
19/ 6/75	S	1	1000	5560	9180	130	340	.58	.60	100	78
19/ 6/75	S	1	3800	12000	15000	370	750	.66	.70	180	110

*FIN

APPENDIX C

WATER QUALITY DATA

1976-77

Date	Site	NO_3+NO_2 [1]	NH_4^+ [1]	TKN [1]	Cl^- [2]	Na [2]	TP [2]	Cond. [3]	PH [4]	T.C. [2]	TOC [2]	FOC [2]	IC [2]	Site	NO_3+NO_2 [1]	NH_4 [1]	TKN [1]	Cl^- [2]	NA [2]	TP [2]	COND. [3]	PH [4]	TC [2]	TOC [2]	FOC [2]	I.C. [2]
27/1/76	1A	0.047	9.25	12.0	550.	183.	0.075	3400.	7.4	300.	—	—	—	1B	0.96	9.3	28.	638.	166.	2.05	3955.	7.3	455.	—	—	—
25/3/"	↓	0.009	11.3	17.0	485.	265.	0.225	3200.	8.4	—	—	—	—	↓	1.92	11.3	26.5	620.	175.	1.48	4000.	7.6	—	—	—	—
7/4/"		0.005	11.0	16.8	470.	260.	0.180	3300.	8.6	260.	—	—	—		0.06	10.4	22.0	625.	155.	1.41	3900.	7.4	400.	—	—	—
19/4/"		0.005	11.6	15.0	440.	240.	0.100	3300.	7.8	—	—	—	—		0.05	8.1	24.5	800.	195.	1.79	4400.	7.2	—	—	—	—
5/5/"		0.007	11.6	19.1	515.	207.	0.055	3700.	7.4	313.	—	—	—		0.15	25.3	44.4	640.	200.	3.60	4300.	7.2	313.	—	—	—
19/5/"		0.010	12.3	—	560.	190.	0.058	3700.	7.8	340.	70.	70.	270.		0.07	22.0	35.5	730.	220.	3.78	5000.	7.4	820.	420.	390.	400.
3/6/"		0.007	12.0	14.4	625.	195.	0.076	3600.	7.2	320.	90.	—	—		0.07	13.5	34.0	900.	205.	2.20	4800.	7.0	660.	280.	—	—
29/6/"		0.005	11.8	—	525.	180.	—	3500.	7.3	288.	—	72.	—		0.04	13.5	36.8	750.	195.	0.13	4600.	7.1	550.	—	40.	—
15/7/"		0.300	13.7	29.5	550.	190.	0.080	3600.	7.2	—	—	—	—		0.10	19.0	47.0	700.	193.	2.20	4675.	7.0	—	—	—	—
18/8/"		0.095	13.3	21.3	625.	146.	0.086	3750.	7.5	316.	88.	—	228.		—	—	—	—	—	—	—	—	—	—	—	—
19/8/"		0.010	13.5	13.5	600.	160.	0.082	3650.	7.6	310.	70.	—	240.		0.19	21.0	50.0	775.	173.	4.50	5000.	1.5	710.	300.	—	410.
12/9/"		0.005	14.3	18.8	550.	198.	0.800	3650.	7.4	370.	75.	—	295.		0.08	26.0	50.0	675.	202.	3.20	4800.	7.2	760	320.	—	440.
17/9/"		0.005	—	20.0	550.	192.	0.032	3750.	—	—	—	—	—		0.005	—	54.5	650.	196.	2.90	4750.	—	—	—	—	—
8/10/"		0.010	15.2	22.5	540	194.	0.074	3700.	7.5	—	—	—	—		0.27	32.5	82.5	665.	168.	8.15	4800.	7.2	—	—	—	—
21/10/"		0.010	—	23.2	540.	196.	0.080	3800.	7.3	—	165.	—	—		0.06	—	29.5	725.	196.	2.77	4900.	7.1	—	430	—	—
15/11/"		0.100	17.0	23.0	620.	198	0.080	3950.	7.6	330.	—	70.	260.		0.10	31.0	69.0	694.	212.	7.30	4950.	7.4	670.	—	240.	670.
27/1/76	2	0.305	0.250	1.40	100.	27.0	0.37	1020.	7.8	102.	—	—	—	3	5.63	0.21	2.90	50.	29.	0.21	1420.	11.6	77.	—	—	—
25/3/"	↓	0.015	0.180	0.95	105.	31.0	0.065	1000.	8.0	—	—	—	—	↓	2.25	0.20	1.20	29.5	11.5	0.03	670.	11.5	—	—	—	—
7/4/"		0.005	0.104	0.65	96.	29.5	0.010	870.	8.0	57.	—	—	—		2.41	0.22	1.05	26.0	10.3	0.03	620.	11.2	22.	—	—	—
19/4/"		0.005	0.054	0.47	89.	25.3	0.024	900.	7.8	—	—	—	—		1.04	0.16	0.82	20.5	9.0	0.05	465.	11.1	—	—	—	—
5/5/"		0.005	0.004	0.30	90.	24.1	0.011	1000.	7.7	78.	—	10.	—		0.38	0.12	0.50	16.0	8.6	0.02	310.	10.7	13.	—		—
19/5/"		0.005	0.056	0.45	90.	—	0.036	1050.	—	83.	8.	8.	75.		0.19	0.09	0.35	13.0	7.3	0.01	295.	10.5	23.	19.	9.	4.
3/6/"		0.006	0.008	0.44	90.	22.0	0.060	1000.	7.6	77.	5.	—	—		0.13	0.10	0.29	11.5	7.1	0.01	240.	10.3	9.	8.	—	—
29/6/"		0.005	0.160	1.30	89.	23.0	0.510	920.	7.7	120.	—	16.	—		0.42	—	—	—	23.	—	445.	9.4	38.	—	—	—
15/7/"		0.100	0.126	0.65	78.	22.5	0.150	720.	7.7	—	—	—	—		0.48	0.03	0.34	13.0	7.0	0.02	250.	9.3	—	—	—	—
19/8/"		0.010	0.084	0.50	79.	23.0	0.040	860.	—	76.	15.	—	61.		0.005	0.002	0.18	11.8	6.5	0.02	245.	—	19.	9.	—	10.
12/9/"		0.005	0.118	0.55	85.	23.5	0.040	940.	7.7	105.	25.	—	80.		0.005	0.002	0.40	15.0	7.0	0.02	280.	8.8	24.	7.	—	17.
17/9/"		0.005	—	0.68	71.	23.5	0.029	820.	—	—	—	—	—		0.005	—	0.40	15.0	6.6	0.14	320.	—	—	—	—	—
8/10/"		0.010	0.006	0.01	68.	22.0	0.001	800.	7.8	—	—	—	—		0.01	0.006	0.19	15.0	6.0	0.06	315.	8.2	—	—	—	—
21/10/"		0.005	0.126	0.40	73.	24.0	0.032	900.	7.7	—	13.	—	—		0.005	0.002	0.20	16.0	6.7	0.05	330.	8.5	—	3.	—	—
15/11/"		0.100	0.100	0.80	72.	23.0	0.040	870.	8.0	71.	—	12.	71.		0.10	0.10	0.40	18.0	4.0	0.04	350.	8.1	38.	—	9.	29.

1 Values are expressed in mg-N/L

2 Values are expressed in mg/L

3 Values are expressed in mmhos/cm

4 Values are expressed in PH units

Date	Site	NO_3+NO_2 [1]	NH_4^+ [1]	TKN [1]	Cl^- [2]	Na [2]	TP [2]	Cond. [3]	PH [4]	T.C. [2]	T.O.C. [2]	F.O.C. [2]	I.C. [2]
27/1/76	4	0.65	0.85	3.2	120.	335.	0.250	5800.	11.7	50.	—	—	—
25/3/"	↓	0.73	0.74	1.75	60.	145.	0.060	2750.	11.9	—	—	—	—
7/4/"		0.05	0.63	1.70	50.	120.	0.045	2400.	11.8	24.	—	—	—
19/4/"		0.04	0.74	1.74	48.5	115.	0.052	2200.	11.6	—	—	—	—
5/5/"		0.09	0.70	1.67	45.	100.	0.036	2000.	11.7	24.	—	19.	—
19/5/"		0.30	0.42	1.32	42.	99.5	0.027	1800.	11.5	19.	18.	16.	1.
3/6/"		0.19	0.44	1.42	34.5	70.	0.036	1250.	11.4	17.	14.	—	—
29/6/"		0.39	0.40	1.95	30.0	66.	0.032	1040.	10.9	29.	—	14.	—
18/8/"		0.01	0.55	0.65	11.5	8.3	0.045	590.	—	63.	8.	—	55.
19/8/"		0.20	0.30	0.27	10.5	8.1	0.042	590.	—	69.	9.	—	55.
12/9/"		0.02	0.60	1.15	11.0	8.7	0.175	580.	8.0	74.	9.	—	65.
17/9/"		0.92	—	1.10	10.5	8.1	0.550	600.	—	—	—	—	—
8/10/"		0.36	0.50	1.26	27.0	49.5	0.062	700.	10.4	—	—	—	—
21/10/"		0.005	0.82	1.10	21.5	48.5	0.045	800.	11.2	—	4.	—	—
15/11/"	↓	0.10	0.50	1.00	25.0	47.0	0.040	755.	10.8	12.	—	8.	4.
7/10/76	10	55.5	0.700	—	330.	—	—	3000.	—	—	—	—	—
21/10/"	↓	63.5	0.198	1.22	330.	97.5	0.08	3100.	7.56	—	55.	—	—
15/11/"		77.0	0.100	2.6	315.	99.0	0.56	3125.	7.60	178.	—	22.	178.
7/10/76	12	20.8	1.20	—	255.	—	—	2100.	—	—	—	—	—
21/10/"	↓	—	—	1.80	—	86.0	0.24	2100.	7.54	—	32.	—	—
15/11/"		34.0	0.20	0.60	265.	87.0	0.08	2200.	7.80	148.	—	22.	126.
8/10/76	14	30.0	0.30	1.90	230.	63.0	0.68	2150.	7.52	—	—	—	—
21/10/"	↓	28.0	0.03	0.56	255.	67.0	0.042	2150.	7.56	—	40.	—	—
15/11/"		27.0	0.10	0.60	232.	65.0	0.040	2150.	7.80	130.	—	22.	108.

Date	Site	NO_3+NO_2 [1]	NH_4^+ [1]	TKN [1]	Cl^- [2]	Na [2]	TP [2]	Cond. [3]	PH [4]	T.C. [2]	TOC [2]	FOC [2]	IC [2]
7/10/76	6	0.06	3.2	—	—	—	—	2800.	—	—	—	—	—
21/10/"	↓	—	—	14.0	—	—	0.65	2800.	7.57	48.	—	—	—
15/11/"		0.10	1.9	4.3	404.	120.	0.08	2900.	7.90	102.	—	24.0	78.
7/10/76	7	26.4	2.2	—	305.	—	—	2900.	—	—	—	—	—
21/10/"	↓	—	—	5.25	—	—	0.6	2800.	—	—	—	—	—
15/11/"		—	0.4	—	—	—	—	3050.	—	—	—	—	—
8/10/76	8	22.5	0.030	0.68	105.	44.5	0.063	1650.	6.96	—	—	—	—
7/10/"	↓	18.8	0.074	—	105.	—	—	1600.	—	—	—	—	—
21/10/"		22.6	0.038	0.48	105.	45.5	0.038	1650.	7.22	—	0.	—	—
15/11/"		27.0	0.100	1.00	103.	46.	0.40	1525.	5.70	130.	—	18.	112.
7/10/76	9	36.0	0.32	—	290.	—	—	2400.	—	—	—	—	—
21/10/"	↓	32.0	—	2.3	330.	116.	2.20	2450.	7.45	—	40.0	—	—
15/11/"		34.0	0.10	1.2	340.	119.	0.32	2475.	7.30	128.	—	22.0	106.
7/10/76	11	28.0	0.800	—	128.	—	—	1700.	—	—	—	—	—
21/10/"	↓	18.0	0.168	1.40	108.	34.5	0.19	1650.	7.62	—	8.0	—	—
15/11/"		34.0	0.100	0.60	100.	32.0	0.08	1650.	7.8	126.	—	20.0	126.
7/10/76	13	32.0	0.600	—	265.	—	—	2300.	—	—	—	—	—
21/10/"	↓	31.5	—	2.35	255.	83.5	0.51	2350.	7.26	—	10.	—	—
15/11/"		33.0	0.100	0.80	277.	84.0	0.08	2400.	7.50	150.	—	26.	124.

1 Values are expressed in mg-N/L

2 Values are expressed in mg/L

3 Values are expressed in mmhos/cm

4 Values are expressed in PH units

Date	Site	NO_3+NO_2 [1]	NH_4^+ [1]	TKN [1]	Cl^- [2]	Na [2]	TP [2]	Cond. [3]	PH [4]	T.C. [2]	T.O.C. [2]	F.O.C. [2]	I.C. [2]
15/3/77	1A	0.025	17.4	22.9	540.	211.	0.115	3700.	7.64	310.	40.	25.	270.
4/4/ "	↓	<0.005	18.2	21.8	525.	204.	0.225	3900.	7.31	—	—	72.	—
5/5/ "	↓	0.025	17.5	26.5	520.	195.	0.176	4000.	7.17	331.	45.	—	286.
18/5/ "	↓	0.010	20.4	22.5	712.	190.	0.105	4000.	7.06	—	—	—	—
26/5/ "	↓	0.060	20.8	25.0	612.	220.	0.070	4000.	7.13	371.	81.	—	290.
6/6/ "	↓	0.030	17.6	22.5	570.	181.	0.100	3900.	7.28	358.	75.	—	283.
22/6 "	↓	0.015	19.0	22.5	540.	188.	0.130	3800.	7.09	359.	73.	—	286.
15/3/77	1B	0.285	42.5	162.	540.	180.	26.0	4750.	7.20	1300.	840.	570.	460.
4/4/ "	↓	0.180	77.5	118.	475.	174.	19.0	4850.	7.18	—	—	459.	—
4/4/ "	↓	0.225	78.5	129.	488.	176.	20.9	4950.	7.14	—	—	573.	—
5/5/ "	↓	0.100	70.0	122.	600.	220.	17.0	5500.	7.15	990.	510	—	480
18/5/ "	↓	0.015	71.2	116.	662.	205.	14.8	5400.	7.16	—	—	—	—
26/5/ "	↓	0.035	43.0	110.	600.	235.	12.0	5200.	7.12	825.	300.	—	525.
6/6/ "	↓	0.030	65.0	96.	540.	192.	9.5	4900.	7.30	782.	308.	—	474.
22/6/ "	↓	0.045	70.0	98.	525.	175.	7.8	4750.	7.09	790.	298.	—	492.
15/3/77	2A	0.005	0.080	0.67	73.	22.	0.085	870.	7.81	75.	4.	1.	71.
4/4/ "	↓	0.125	0.018	0.28	75.	22.	0.023	880.	7.84	—	—	7.	—
5/5/ "	↓	0.245	0.120	0.52	63.	17.	0.066	920.	7.65	79.	6.	—	73.
18/5/ "	↓	0.010	0.330	0.33	69.	19.	0.011	950.	7.56	—	—	—	—
26/5/ "	↓	0.005	0.170	0.45	70.	19.	0.028	950.	7.57	87.	4.	—	83.
6/6/ "	↓	0.005	0.128	0.44	63.	19.	0.016	940.	7.73	89.	5.	—	84.
22/6/ "	↓	0.100	0.170	0.56	63.	19.	0.058	940.	7.52	90.	5.	—	85.
15/3/77	3A	<0.005	0.008	0.24	14.	6.3	0.022	310.	8.11	28.	1.	1.	27.
15/3/ "	↓	<0.005	<0.002	0.23	15.	6.6	0.057	350.	8.18	—	1.	1.	30.
4/4/ "	↓	0.35	<0.002	0.37	15.	6.1	0.051	380.	8.17	—	—	6.	—
5/5/ "	↓	0.16	0.008	0.25	14.	5.3	0.014	380.	8.04	35.	4.	—	31.
18/5/ "	↓	0.005	0.020	0.18	15.	5.6	0.012	410.	8.18	—	—	—	—
26/5/ "	↓	0.020	0.002	0.28	16.	5.6	0.037	410.	7.98	40.	4.	—	36.
6/6/ "	↓	0.030	0.016	0.24	16.	6.0	0.022	395.	8.04	39.	5.	—	34.
22/6/ "	↓	<0.005	0.004	0.20	15.	5.7	0.012	395.	7.93	39.	4.	—	35.
15/3/77	4A	3.00	0.126	0.49	10.	6.9	0.045	660.	7.86	69.	0.0	0.0	69.
4/4/ "	↓	2.50	0.208	0.53	10.	6.8	0.049	680.	7.88	—	—	5.	—
26/5/ "	↓	3.63	0.012	0.20	10.	6.5	0.014	680.	7.75	70.	2.	—	68.
6/6/ "	↓	3.12	0.058	0.22	10.	6.7	0.024	690.	7.86	73.	6.	—	67.
14/3/77	6	0.42	1.30	3.88	395.	119.	0.082	2850.	7.58	212.	22.	20.	190.
4/4/"	↓	0.12	2.52	4.85	390.	120.	0.071	2950.	7.58	—	—	86.	—
18/5/ "	↓	0.90	9.50	20.00	325.	103.	1.200	2600.	7.13	—	—	—	—
26/5/ "	↓	0.02	11.20	15.30	375.	138.	0.60	2700.	7.30	560.	120.	—	440.
6/6/ "	↓	1.50	7.10	12.50	365.	118.	0.312	2750.	7.38	282.	72.	—	210.
26/6/ "	↓	0.49	6.70	10.50	405.	108.	0.09	2800.	7.35	—	—	—	—
15/3/77	7	61.5	0.046	2.35	325.	106.	0.09	3100.	7.45	192.	12.	8.	180.
4/4/ "	↓	66.0	0.044	2.05	310.	109.	0.071	3150.	7.34	—	—	69.	—
5/5/ "	↓	9.0	0.116	2.90	313.	102.	0.356	3200.	7.34	220.	33.	—	187.
18/5/ "	↓	72.5	1.700	2.35	310.	108.	0.330	3200.	7.63	—	—	—	—
26/5/ "	↓	39.5	1.36	3.50	—	120.	0.425	—	—	—	—	—	—
6/6/ "	↓	—	0.660	2.90	305.	—	0.202	3000.	—	—	—	—	—
26/6/ "	↓	52.0	—	2.80	—	—	0.078	3100.	7.90	—	—	—	—
15/3/77	8	20.0	0.002	0.31	42.	27.	0.056	1160.	7.36	128.	6.	5.	122.
4/4/ "	↓	18.0	0.014	0.47	40.	23.	0.072	1100.	7.19	114.	2.	—	112.
5/5/ "	↓	—	0.200	2.00	63.	23.	0.108	1080.	7.37	192.	26.	—	166.
18/5/ "	↓	3.4	0.150	1.00	55.	24.	0.046	1070.	7.30	—	—	—	—
26/5/ "	↓	8.9	0.170	0.82	54.	28.	0.072	1190.	7.36	145.	10.	—	135.
6/6/ "	↓	12.8	0.146	0.54	55.	31.	0.040	1220.	7.52	130.	10.	—	120.
26/6/ "	↓	13.1	0.188	0.72	55.	31.	0.032	1200.	7.37	142.	10.	—	132.
15/3/77	9	29.0	0.320	3.10	290.	102.	0.310	2300.	7.48	162.	14.	4	148.
4/4/ "	↓	29.0	1.00	4.95	280.	101.	0.036	2300.	7.18	176.	34.	—	142
5/5/ "	↓	22.7	0.058	1.72	313.	106.	0.076	2400.	7.22	124.	18.	—	106.
18/5/ "	↓	21.5	0.060	1.56	425.	115.	0.250	2500.	7.20	—	—	—	—
26/5/ "	↓	20.1	0.070	2.75	350.	132.	0.068	2500.	7.36	172.	10.	—	162.
6/6/ "	↓	20.2	0.064	1.39	330.	109.	0.065	2450.	7.49	170.	18.	—	152.
22/6/ "	↓	21.5	0.056	2.25	340.	99.	0.042	2500.	7.27	178.	20.	—	158.
15/3/77	10	67.0	0.200	1.60	290.	84.	1.50	2900.	7.72	184.	12.	4	172.
4/4/ "	↓	60.5	0.540	2.35	295.	—	0.49	2950.	7.87	—	—	—	—
5/5/ "	↓	57.5	0.206	1.92	265.	78.	—	2850.	7.66	—	—	—	—
18/5/ "	↓	75.0	0.090	1.38	285.	82.	0.234	2900.	7.42	—	—	—	—
6/6/ "	↓	56.5	0.076	1.25	270.	85.	0.465	2800.	7.59	176.	18.	—	158.
22/6/ "	↓	56.0	0.072	1.20	280.	88.	0.175	2850.	7.47	—	—	—	—

1 Values are expressed in mg-N/L

2 Values are expressed in mg/L

3 Values are expressed in mmhos/cm

4 Values are expressed in PH units

Date	Site	NO_3+NO_2 [1]	NH_4^+ [1]	TKN [1]	Cl^- [2]	Na [2]	TP [2]	Cond. [3]	pH [4]	TC [2]	TOC [2]	FOC [2]	IC [2]
15/3/77	11	49.0	0.740	1.50	90.	33.	0.34	1600.	7.61	116.	0.0	0.0	116.
4/4/"	↓	—	—	—	—	—	—	—	—	—	—	—	—
5/5/"	↓	15.0	0.452	1.52	73.	26.	0.18	1550.	7.49	106.	8.	—	98.
18/5/"	↓	57.0	0.300	1.16	82.	29.	1.32	1600.	7.45	—	—	—	—
22/6/"	↓	39.0	0.056	1.40	88.	29.	0.74	1550.	7.52	158	40.	—	118.
15/3/77	12	—	—	2.80	200.	—	0.675	1900.	—	—	—	—	—
4/4/"	↓	36.0	0.096	1.25	225.	83.	0.115	2100.	7.27	146.	16.	—	130.
5/5/"	↓	41.0	0.014	0.56	245.	86.	0.024	2250.	7.28	132.	6.	—	126.
18/5/"	↓	55.0	0.040	0.45	265.	90.	0.069	2250.	7.25	—	—	—	—
26/5/"	↓	41.0	0.024	1.00	255.	93.	0.300	—	7.62	—	—	—	—
6/6/"	↓	41.5	0.020	1.10	245.	91.	0.050	2200.	7.45	134.	18.	—	116.
22/6/"	↓	37.5	0.002	0.90	260.	91.	0.240	2150.	7.33	140.	12.	—	128.
15/3/77	13	32.00	1.22	3.30	290.	92.	0.51	2400.	7.61	152.	8	6.	144.
4/4/"	↓	—	—	—	—	—	—	—	—	—	—	—	—
5/5/"	↓	37.2	0.24	1.56	227.	94.	0.54	2550.	7.37	156.	14.	—	142.
18/5/"	↓	43.0	0.10	0.93	312.	98.	0.12	2250.	7.31	—	—	—	—
26/5/"	↓	34.5	0.076	0.80	291.	96.	0.028	2550.	7.43	156.	6.	—	150.
6/6/"	↓	37.8	0.05	1.04	290.	97.	0.04	2500.	7.37	150.	12.	—	138.
22/6/"	↓	35.0	0.03	1.16	300.	99.	0.12	2500.	7.27	142	6.	—	136.
15/3/77	14	32.5	0.84	3.20	240.	76.	1.06	2150.	7.70	208.	28.	10.	180.
4/4/"	↓	30.5	1.44	7.55	235.	74.	0.24	2200.	7.27	171.	47.	—	124.
5/5/"	↓	32.0	0.28	2.70	213.	67.	0.086	2100.	7.51	128.	16.	—	112.
18/5/"	↓	31.3	0.21	2.60	240.	68.	0.36	2150.	7.31	—	—	—	—
26/5/"	↓	30.0	0.16	3.00	235.	72.	0.027	2200.	7.60	134.	14.	—	120.
6/6/"	↓	27.5	0.086	1.19	230.	69.	0.064	2150.	7.49	134.	20.	—	114.
22/6/"	↓	29.4	0.19	2.50	225.	70.	0.05	2100.	7.40	142.	18.	—	124.
26/5/77	15A	36.0	0.040	1.86	338.	130.	0.024	3200.	7.22	225.	10.	—	215.
6/6/"	↓	38.0	0.002	3.00	325.	114.	0.044	3100.	7.33	214.	26.	—	188.
22/6/"	↓	33.2	0.010	2.50	330.	104.	0.055	3100.	7.17	258.	54.	—	204.
26/5/77	15B	19.6	0.038	1.08	312.	83.	0.028	2650.	7.20	176.	12.	—	164.
6/6/"	↓	5.4	0.002	1.39	325.	100.	0.124	2800.	7.25	188.	16.	—	172.
6/6/"	↓	23.5	0.034	1.55	320.	96.	0.085	2700.	7.26	188.	16.	—	172.
22/6/"	↓	16.8	0.004	1.04	290.	90.	0.030	2550.	7.14	204.	46.	—	158.
22/6/"	↓	16.8	0.004	0.93	310.	91.	0.019	2550.	7.11	178.	12.	—	166.
26/5/77	15C	21.4	0.116	1.24	325.	97.	0.070	2750.	7.09	184.	0.0	—	184.
6/6/"	↓	21.8	<0.002	0.73	315.	94.	0.025	2700.	7.15	186.	14.	—	172.
22/6/"	↓	21.6	0.038	1.36	325.	92.	0.014	2700.	7.05	182.	18.	—	164.
26/5/77	16A	27.3	0.016	0.38	260.	83.	0.030	2350.	7.26	152.	12.	—	140.
6/6/"	↓	26.3	0.006	0.48	260.	81.	0.047	2300.	7.34	152.	20.	—	132.
22/6/"	↓	22.7	0.002	0.68	270.	83.	0.026	2300.	7.21	150.	20.	—	130.
26/5/77	16B	18.3	0.100	0.62	291.	85.	0.010	2250.	7.20	140.	4.	—	136.
6/6/"	↓	18.6	0.032	0.66	275.	83.	0.069	2200.	7.34	138.	14.	—	124.
22/6/"	↓	16.5	0.006	1.16	260.	82.	0.012	2150.	7.16	146.	14.	—	132.
26/5/77	16C	9.3	0.010	0.28	76.	22.	0.009	1050.	7.49	78.	1.	—	77.
6/6/"	↓	9.4	<0.002	0.21	86.	23.	0.006	1020.	7.58	76.	9.	—	67.
6/6/"	↓	8.6	0.024	0.30	75.	—	0.042	1030.	7.66	79.	4.	—	75.
22/6/"	↓	6.5	0.002	0.46	80.	23.	0.005	1020.	7.45	81.	4.	—	77.

1 Values are expressed in mg-N/L

2 Values are expressed in mg/L

3 Values are expressed in mmhos/cm

4 Values are expressed in pH units

APPENDIX D

WATER TABLE ELEVATIONS

1976-77

Date	1A[1]	1B	1W	2A	2W	3A	3W	4A	4W	6	7	8	9	10	11	12	13	14	15A	15B	15C	16A	16B	16C
27/1/76	28.88	29.19	29.15	27.86	27.85	28.14	28.20	31.25	31.76															
25/3/"	30.08	30.15	30.14	28.24	28.24	28.84	28.73	33.55	33.79															
7/4/"	29.99	30.09	30.12	28.06	28.06	28.54	28.45	33.16	33.30															
19/4/"	30.07	30.18	30.18	28.08	28.08	28.59	28.45	33.18	33.30															
5/5/"	30.03	30.14	30.14	28.08	28.07	28.52	28.44	33.10	33.26															
19/5/"	29.96	30.09	30.09	28.10	28.09	28.61	28.47	32.95	33.13															
2/6/"	29.68	29.87	29.87	28.02	28.00	28.48	28.41	32.38	32.58															
29/6/"	29.35	29.59	29.59	27.87	27.87	28.44	28.45	31.69	31.84															
15/7/"	29.36	29.67	29.66	28.05	28.03	28.44	28.39	31.57	31.74															
18/8/"	29.24	29.61	29.57	27.82	27.82	28.39	28.35	31.11	31.28															
11/9/"	28.72	28.98	28.98	27.59	27.58	28.00	28.00	30.80	30.97															
16/9/"	28.58	28.74	28.75	27.49	27.49	27.87	27.92	30.58	30.95															
9/10/"	29.43	29.78	29.79	28.12	28.11	28.63	28.58	31.09	31.26	28.19	28.0	28.77	28.58	28.28	28.18	27.94	28.46	28.42						
21/10/"	29.47	29.88	29.88	28.14	28.14	28.62	28.79	31.17	31.33	27.97	27.81	28.87	28.81	28.53	28.06	27.68	28.58	28.60						
15/11/"	29.06	29.30	29.30	28.06	28.05	28.37	28.36	31.60	31.77	28.36	28.03	28.46	28.48	28.43	28.30	28.38	28.27	28.29						
14/3/77	29.52	29.78	29.79	28.25	28.25	28.85	28.60	33.25	33.70	28.61	28.94	29.01	28.54	28.72	28.68	28.53	28.74	28.75						
4/4/"	29.57	29.93	29.94	28.15	28.14	28.66	28.55	33.05	33.28	28.04	29.27	28.90	28.90	28.79	28.57	28.61	28.50	28.54						
20/4/"	29.30	29.78	29.79	28.06	28.05	28.43	28.40	32.56	32.71	29.33	28.82	28.54	28.51	28.39	28.19	28.32	28.22	28.25						
5/5/"	29.36	29.68	29.68	28.02	28.01	28.40	28.38	—	—	28.90	28.94	28.53	28.51	28.39	28.17	28.33	28.21	28.53						
18/5/"	29.00	29.23	29.22	27.90	27.90	28.27	28.33	—	—	28.47	28.09	28.28	28.28	28.18	28.01	28.10	28.06	28.11						
25/5/"	29.01	29.12	29.14	27.86	27.86	28.35	28.37	31.77	31.98	28.37	28.44	28.38	28.38	28.25	28.09	27.79	28.09	28.16	28.45	28.40	28.15	28.16	28.21	
6/6/"	28.79	28.97	28.97	27.73	27.72	28.22	28.32	31.54	31.72	28.40	27.91	28.18	28.21	28.10	27.91	27.89	27.99	28.03	28.29	28.25	28.01	28.01	28.06	
22/6/"	—	—	—	27.65	27.68	28.28	28.27	—	—	28.17	27.89	—	28.20	28.12	27.96	27.93	28.04	28.11	28.29	28.25	28.06	28.06	28.11	
12/7/"	—	—	—	28.00	27.98	28.43	28.36	31.07	31.28	28.43	27.98	27.98	28.40	28.31	28.61	—	28.24	28.26	28.50	28.45	28.21	28.21	28.26	

1 All values are expressed in metres above an arbitrary datum.

INTERNATIONAL JOINT COMMISSION
GREAT LAKES REGIONAL OFFICE
100 Ouellette Avenue
Windsor, Ontario N9A 6T3