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An Assessment of the Effects of

RUNOFF FROM CATTLE FEEDLOTS

on the Water Quality of Receiving Streams

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September 1973

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Social Sciences Division

Canada Centre for Inland Waters

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FOREWORD

Effective water resource management cannot be realized without adequate knowledge of the impact of land use on water quality. One area of land use and its water impact where a dearth of information exists, at least in Ontario, concerns cattle feedlots. In order to assist in overcoming this "information gap," this study was commissioned by the Social Sciences Division of the Canada Centre for Inland Waters and carried out by a student in partial fulfillment of his master's thesis. It is intended to serve as a pilot study to determine the impact of cattle feedlots on the water quality of nearby streams. The opinions expressed in this report are those of the author and do not necessarily reflect those of the sponsoring party.

Reservations

This paper is presented as an unpublished report which must be qualified by certain reservations--reservations which concern the methodology, data gathering, and conclusions of the study. Due to the restricted area for study and the method of selecting sites for study within this area, the results cannot be considered either representative or typical of the situation in Ontario. In addition, the method of sampling, the level of quality control on samples obtained, and the analysis of samples could have led to significant deviances from actual water state. In view of these reservations, it is felt that definitive conclusions on the basis of this study regarding the impact of cattle feedlots on stream water quality are not justified.

The above problems are due, at least in part, to the dearth of prior information available on the subject--information which could have assisted in defining a more relevant study framework and to the lack of resources available for undertaking the study.

Value of Study

Despite the above reservations, it is felt this study has value for water quality research and management. The descriptive nature of the report gives a good indication of the problems involved--both human and otherwise--of conducting a study on this subject. It is indicative of the many variables involved which affect study design and implementation such as site sample size, criteria for site selection, water quality variables to measure, water sampling design and procedures, etc. It is also indicative of the number and types of variables which determine the impact of cattle feedlots on the quality of ground water and surface water as well as streams. Thus, as a pilot project, it should prove useful in the development of a framework for future studies in this area, although no attempt to provide such a framework has been included in this report.

Social Sciences Division
Canada Centre for Inland Waters
Burlington, Ontario

SUMMARY

The purpose of this project was to assess the effect of runoff from cattle feedlots on the water quality of nearby streams. Increasing public concern over all types of environmental pollution has precipitated research into various forms of agricultural runoff. Livestock waste runoff has become a major issue due to the development of feedlot style production where large numbers of cattle are confined for long periods of time in small areas. This type of production was initiated on a large scale first in the United States mid-west during the 1950's. Since that time, numerous cases of water pollution linked to the feedlots have been reported and much research has been devoted to finding methods of waste disposal and treatment.

In Ontario, feedlots are considerably smaller than in the United States; however, the growing demand for beef is causing a rapid increase in the number of cattle produced. While research into the effects of livestock waste in the United States may supply some answers to officials in Ontario, different conditions of climate, vegetation, and topography make much of the information invalid and require the research be carried out under the particular conditions found in the beef producing regions of southern Ontario.

Research into the characteristics of animal waste and their potential for polluting streams has been investigated by various groups in Ontario, however little analysis has

been made of water quality in streams near feedlots.

This project was designed to assess the effects of feedlot runoff on water quality during spring and summer. A sample of seventeen feedlots distributed through six counties in the western Lake Ontario region were selected according to specific criteria and water sampling stations were located on the adjacent streams, both upstream and downstream from the feedlots. Water quality was monitored at regular intervals during the period of March through May and analyzed for concentrations of phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, BOD_5, and volatile residue. For the summer analysis a sample of five feedlots was used and water quality was measured during and after storm runoff.

Analysis of samples indicated that incidents of waste runoff adversely affecting water quality do occur during spring runoff and that the major factors influencing waste runoff are distance from feedlot to the stream and the presence of drainage tile between feedlot and stream. Concentrations of the various water quality properties measured diminished with runoff during the spring period.

Analysis of summer samples was severely restricted as the result of little rainfall. In those cases where runoff did occur from the feedlot area, the effect upon stream water quality was negligible.

Results of this study indicate that continuous monitoring of the water quality of feedlot streams should be undertaken along with a more in depth study of some of the factors that were found to contribute to runoff.

ACKNOWLEDGMENTS

The writer would like to express his thanks to the numerous people who provided assistance during the preparation of this report. In particular, to Louis Pando of the Social Science Research Section, Canada Centre for Inland Waters; William Traversy and Don McGirr of the Water Quality Division, Canada Centre for Inland Waters; Steve Black of the Water Research Division, Ontario Ministry of the Environment; and Ralph McCartney of the Ontario Ministy of of Agriculture and Food who provided much information and advice. William Traversy and Steve Black also provided help with laboratory analysis of samples.

Dr. Edward Spence of the Department of Geography, York University made many helpful suggestions as to research design and methodology and was always available to discuss problems encountered during the study. Bill Scott, Senior Lab Technician in the York geography laboratory and the cartographic staff of the Department of Geography gave a great deal of assistance in the time consuming analysis of water samples and preparation of maps.

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CHAPTER I

INTRODUCTION

1.1 Purpose

The purpose of this study is to determine whether or not runoff of livestock wastes from cattle feedlots in southern Ontario affects the quality of water in nearby streams This purpose has been approached through the monitoring of several aspects of water quality on streams adjacent to a sample of feedlots in south-central Ontario. Monitoring of stream quality was carried out during the spring and summer of 1973 in order to assess the effects of both spring runoff and summer rains in transporting livestock wastes to nearby streams. Water samples were collected at predetermined locations, both upstream and downstream from each feedlot, and analyzed for various properties indicative of waste presence. Those water quality properties considered included orthophosphate (P), nitrite-nitrate nitrogen (N), ammonia (N), BOD_5, and volatile residue. The study is intended as a pilot project to identify the magnitude of the problem and to determine the need for a more comprehensive analysis.

Research into the various problems associated with animal waste management in Ontario is receiving increased attention today because of a growing public concern over all types of environmental pollution and conflicts relating to the management of our water resources. Livestock waste disposal has become a major issue due to two more specific factors: the increasing concentration of cattle numbers which results in large accumulations of waste in small areas; and the expanding non-farm rural population which is complaining of farm odours and water pollution about their new homes.

In the past, when there were relatively few animals spread over a wide area, the disposal of waste was a natural process resulting from the pasture style of operation and what pollution did occur was viewed as 'natural'. Today. however, the economics of farming demand that beef producers confine their cattle in feedlots to facilitate the most rapid weight gain possible. It is also necessary, due to the small profit made on each animal, to feed the maximum number of cattle that resources will allow. In Ontario at present, the average size of feedlots is approximately 200 head and each steer produces about 50 pounds of waste per day (Black, S. A., et al., N. D., p. 3). The potential for both air and water pollution from such waste accumulation has been recognized by government agencies throughout North America. Since the mid 1950's research, particularly in the United States, has been aimed at analyzing the characteristics of livestock waste and formulating methods both to disperse and treat it.

Numerous cases of water pollution caused by feedlot runoff have been documented in the United States, however such is not the case in Ontario. While reports on the contaminants found in and around Ontario feedlots have been published, there is as yet little evidence to show that those contaminants ever reach surface water supplies.

Conditions differ greatly between the beef producing regions of the American mid-west and that of Ontario. The average number of cattle contained in an American feedlot is much greater than for the average Ontario feedlot. Waste disposal in the United States is different from that in Ontario because of the large quantities accumulated and the shortage or absence of land onto which the waste can be dispersed. Topography in the feedlot regions of the United States is relatively flat compared to that found in Ontario and stream density is low. These factors contribute to the accumulation of waste products in the feedlot area. Climatic, soil, and vegetation factors also combine to create a far different situation in the United States compared to that in Ontario. Rainfall in the U.S. regions tends to be concentrated during a short period of the year and causes runoff of waste that has accumulated and dried over the long dry season. In Ontario, snowmelt and more uniform rainfall cause runoff to occur more generally throughout the year. For these reasons, it cannot be assumed that feedlots in the province are in fact causing pollution of streams and lakes comparable to that documented for the United States.

In any measurement of feedlot runoff a great many variables must be taken into account. Not only do environmental conditions determine the amount of waste that is removed from the feedlot area, but the operating procedures of the farmer also have a great influence on waste runoff. The frequency with which the farmer removes waste from the feedlot area and spreads it on fields, the amount of manure applied per acre, the time of year at which it is applied, the use of commercial fertilizers, the nutrient demands of the crops in the area, and the presence of permanent grass or drainage tile in the area between the feedlot and stream are just some of the many variables involved. It may be that the difficulty in isolating variables is the reason for a lack of interest in the study of waste runoff. Most of the publications put out by the Ontario Department of the Environment relating to livestock waste are studies of the potential of livestock waste to pollute water courses rather than studies of livestock waste that actually reaches surface streams or lakes. Partly as a result of these studies, there is considerable concern on the part of many cattlemen that their operations may be contributing significantly to the pollution of nearby streams and that regulations may be invoked which will affect their methods or scale of production.

It is hoped that this analysis of runoff from feedlot areas as affecting water quality in nearby streams will be a contribution to a more rational approach to pollution analysis and will serve to either confirm or allay the fears of the people involved.

We, in Ontario, are fortunate that livestock waste disposal problems in areas such as the American South-West have created an awareness of the problem at a time when our livestock industry is in the early stages of the transition to concentrated production. While feedlots in the United States have already grown to an average capacity of several thousand head with a maximum capacity of over 100,000 head (Rademacher, 1969, p.194), most Ontario feedlots contain only several hundred head. Thus we may not only benefit from some of the research already carried out in the United States, but develop methods for controlling waste pollution while the production system is still amenable to change that will not result in serious disruption either to the type of farming or the quantity of production.

1.2 The American Experience

Concern over livestock waste disposal in the United States began to appear in journals almost twenty years ago. By that time, the beef industry had already become well established in two major regions: the Missouri and Colorado River basins, and confined feeding had long since replaced range feeding. The problems of air and water pollution became evident as a result of the combination of several factors. The increase in population and an increase in the per capita consumption of beef products resulted in an increase in the number of cattle in most feedlots and the establishment of new operations. Also, there was an increase in human settlement in the livestock regions, in some cases in close proximity to feedlots. As a result, there was a greater demand for water for domestic and recreation purposes. These demands were in conflict with the use to which cattlemen were putting the water. This conflict between expanding communities and expanding feedlots led to complaints and court action over feedlot odours and poor water quality (Loehr, 1969, p. 19).

The extent of pollution in livestock regions is indicated by several of the documented cases. In Kansas, for example, 22 of 36 fish kills reported during the period 1967-1968 were caused by feedlot runoff--one such kill resulted in the death of 500,000 fish (Rademacher, 1969, p. 194). Cattle too have suffered the consequences of polluted water with numerous becoming sick and dying after consuming water contaminated by the waste of cattle operations upstream (Rademacher, 1969, p.194). The pollution of surface waters that has resulted in the Missouri basin is equalled by the contamination of groundwater supplies. A study of 6,000 sub-surface water samples collected from throughout the state of Missouri showed that 42 per cent contained more than five parts per million nitrate as nitrogen. In some counties in the state, over 50 per cent of the samples indicated potential danger to livestock and humans because of the high nitrogen levels. Ammonia and organic carbon have also been found in groundwater near feedlots (Rademacher, 1969, p.195).

It has been reported that there are over two billion tons of livestock waste produced annually in the United States by more than one million cattle and that half of this figure is produced in feedlots (Bernard, 1970, p. 8; Heald and Loehr, 1970, p. 122). The heavy concentration of such wastes is indicated by the large number of cattle marketed from each of the basin states. Iowa, for example, marketed four million beef cattle in 1967, representing a waste population equivalent of 40 million (Rademacher, 1969, p. 163). The trend to ever larger feeding operations is indicated by the 100,000 head feedlot in Greeley, Colorado.

State authorities now recognize the lack of planning that has resulted in cattle operations located in areas highly susceptible to surface runoff and the uncontrolled release of wastes directly to streams. The fact that many of these operations have only been in existence for a short period of time indicates the initial lack of concern for the pollution characteristics of such operations.

There has been a hardening of attitude developing over the past several years towards livestock waste pollution and both state and federal agencies are in the process of trying to solve the problem. The enactment of the Federal Water Pollution Control Act, Public Law 660, in 1956, and its revision into the Clean Water Restoration Act of 1966 demonstrated the interest of the federal government in stopping water pollution. However, as in Canada, water quality comes under state jurisdiction and state legislators are more subject to the pressures brought to bear by powerful industries within the state. As a result of this and other factors, adoption of the standards laid down in the Clean Water Restoration Act and further action at the state level has been slow (Biniek, 1969, p. 364).

Engineering studies have resulted in many suggestions as to treatment methods that might be used to reduce the level of contamination in waste runoff. Anaerobic holding systems, anaerobic digestion, complete treatment, drying and or incineration, liquid aeration, and aerobic composting are the major areas of research interest. However, these methods invariably entail a capital investment which might put the economic viability of many feedlots into question--and this, at a time of growing beef shortages, must be a prime consideration.

It is difficult to predict what effects the recent instability in feed supply will have upon the production of beef; but, it seems likely that such a volatile situation will force many small producers out of business, leaving the market to the large feedlot corporations that have the resources to survive until the situation stabilizes or alternative feeds are developed. This will continue the trend toward further concentration of the industry and consequently the wastes within certain watersheds. In spite of increasing prices for beef products in recent years, the annual per capita consumption of beef in the United States continues to rise. Between 1951 and 1971, the per capita consumption of all red meat increased 22 per cent with most of this gain coming in the last ten years (Kottman, 1971, p. 9). Thus, increasing demand too suggests that the quantity of waste produced as a by-product will increase and continue to be a source of pollution in an area where control is difficult.

1.3 The Ontario Situation

As in the United States, during recent years there has been a significant increase in the number of beef cattle raised on Ontario farms. High prices paid for slaughter cattle in the early 1950's initiated an expansion of the beef industry and many farmers gave up the cultivation of mixed grain crops in favour of corn and cattle. Between 1951 and 1971, the number of beef cattle rose from 1,120,824 to 2,498,086 (Ontario Ministry of Agriculture and Food, 1971) with most cattle now confined for a large part of their lives in feedlots. Ontario's increase in cattle production can also be accounted for by the rapid rise in population--4,597,000 in 1951 to 7,703,106 in 1971 (Statistics Canada 1951 and 1971), and per capita consumption of beef products, which rose from 61.6 pounds in 1955 to 92.5 pounds in 1972. There is, however, a constraint on cattle production in the province. Most cattlemen are in the business of only fattening replacement cattle rather than raising their own calves. At present, 70 per cent of all replacement cattle and calves are brought in from western Canada and there is often a shortage of such replacements (Townshend, 1970, p. 195). The number of replacement cattle arriving in Ontario from western Canada increased from 277,449 head in 1956 to 416,221 head in 1971 (Can. Dept. of Agric., 1956 and 1971). Ontario cattlemen who have, since the 1950's, acted merely as middlemen buying cattle in the form of calves, feeders, and stockers and holding them until they have gained sufficient weight to go to market, are being encouraged by the Department of Agriculture to establish fully integrated cow-calf and feeder operations. The government now offers guaranteed loans for the purchase of cows for breeding. This program, it is hoped, will result in self-sufficiency for Ontario in beef production and provide more security for cattlemen by extricating them from the decreasing margin position that they have been in.

At present, there is no legislation which can be used by authorities to restrict the operation of any feedlot or other type of farm that is thought to be a polluter as long as the farm in question is being run in accordance with 'normal' operating practices. Thus far, almost all cases of air and water pollution investigated by the Department of the Environment have been corrected through the mutual agreement of the Department and the farmers involved. A "Suggested Code of Practice" has been prepared by the Air Management Branch of the Ontario Department of the Environment (1970) which outlines how new farm structures should be located and built, how renovations to older buildings should be made, and how animal wastes should be disposed of. While the code is not law, certificates of compliance with the code are awarded and farm loans for non-certified projects are difficult to obtain. In a few cases of farm pollution, the owners have shown complete indifference to both suggestions in the code of practice and warnings from the Department of the Environment and, according to Department personnel, it appears that court action will be required to halt pollution at those sites and set a precedent for future cases.

Government research into feedlot pollution has been restricted to analysis of the characteristics of solid and liquid waste in the area of the feedlot rather than the study of waste movement into surface streams. It is interesting to note that government researchers state that most feedlot operations are situated in such a way that the drainage does not cause pollution (Jensen, 1972, p. 1), a fact borne out in the search for feedlots for this study.

1.4 Development and Distribution of Beef Operations in Ontario

The present distribution of beef cattle in Ontario has developed as the result of several factors. The dairy industry, which became important in the late 1800's, was centred in the counties from York to the Ottawa Valley in order to be near the populated markets. There was less interest in beef in this area and therefore the beef cattle operatiors developed in counties farther from the centres of population.

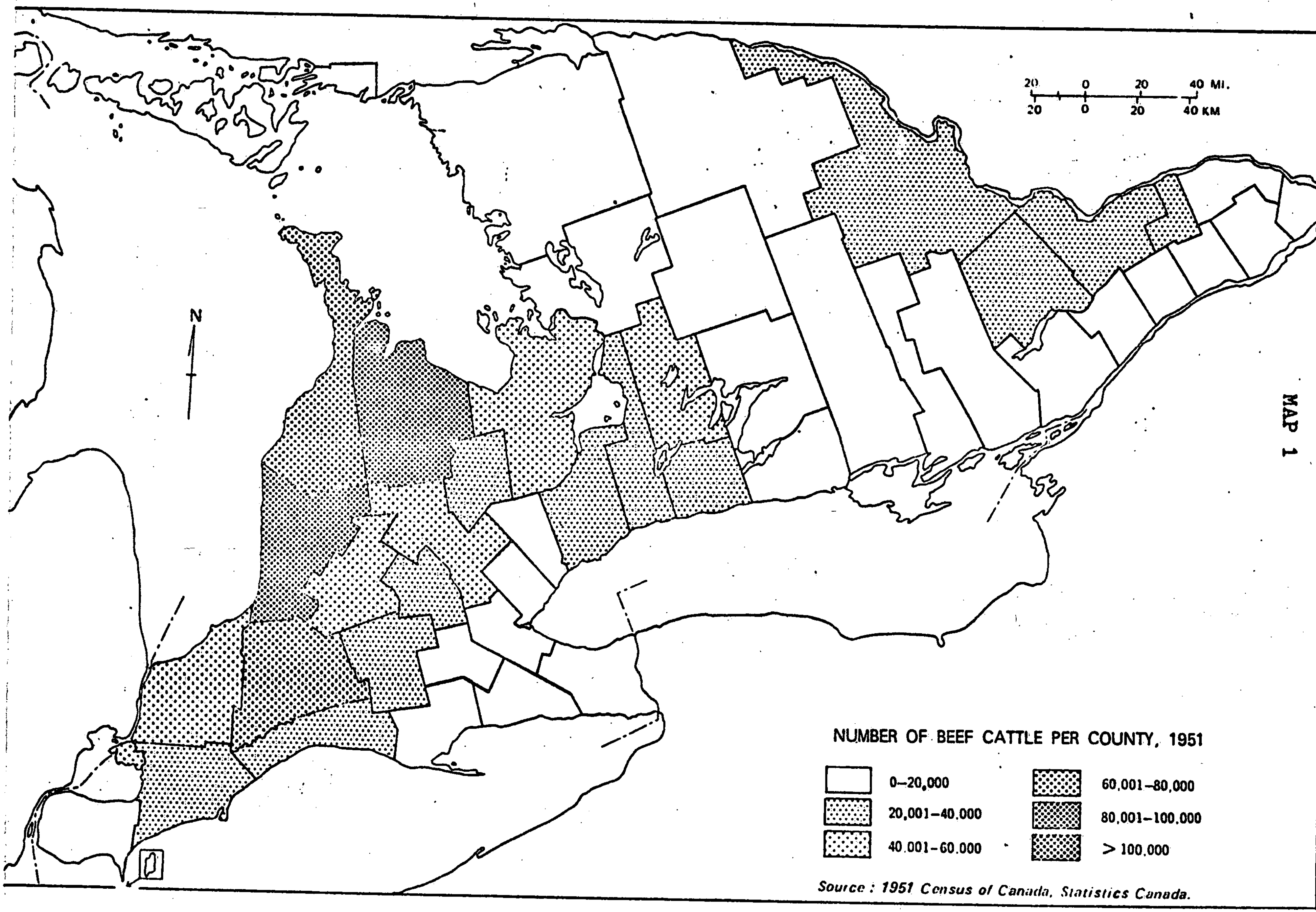
The large quantities of feed required to fatten beef cattle made it necessary to locate in the west of the province where conditions were most suitable for high yield grain cultivation. In the north-west, conditions were less satisfactory for some grain crops, however the area is good for growing hay and there is extensive improved pasture. Because of the different food requirements of the various cattle types, both of these regions were popular with cattlemen. Steers achieve their best growth potential when fed on high protein grain feed and for this reason they came to be concentrated in the western counties while beef cows, with a greater dependence upon pasture, came to be concentrated more in the northern counties (McDonald, 1972, p. 76).

There are few cattle feedlots today that were created as specialized operations. Almost without exception, beef feedlots in Ontario evolved out of mixed farming operations. The greater demand for beef has caused a gradual increase in prices. This in turn has caused increases in prices paid for feed grains. Thus, crops such as oats, barley, and winter wheat are being replaced by shelled and fodder corn, both for sale and for feeding to the increased number of cattle on the farm. Of the hundred feedlots visited for purposes of this study, few had more than ten beef cattle prior to 1960.

Maps 1 through 5 have been prepared to illustrate the changes in beef cattle numbers for each county in the census years from 1951 to 1971. Data on the counties for each year are listed in Appendix I. The term 'total beef cattle' represents the total of steers, beef cows, beef heifers, and all calves. Calves were not divided into beef and dairy because only a small percentage of the total number are raised for dairy purposes. It is difficult, with the importation of beef calves from western Canada, to accurately assess how many dairy calves are in each county. The maps show that the centre of the beef raising industry over the past twenty years has been located in the west and north-west regions of southern Ontario, in the counties of Simcoe, Grey, Bruce, Huron, Perth, Wellington, and Middlesex. The numbers of beef cattle are much lower in the counties east of Toronto.

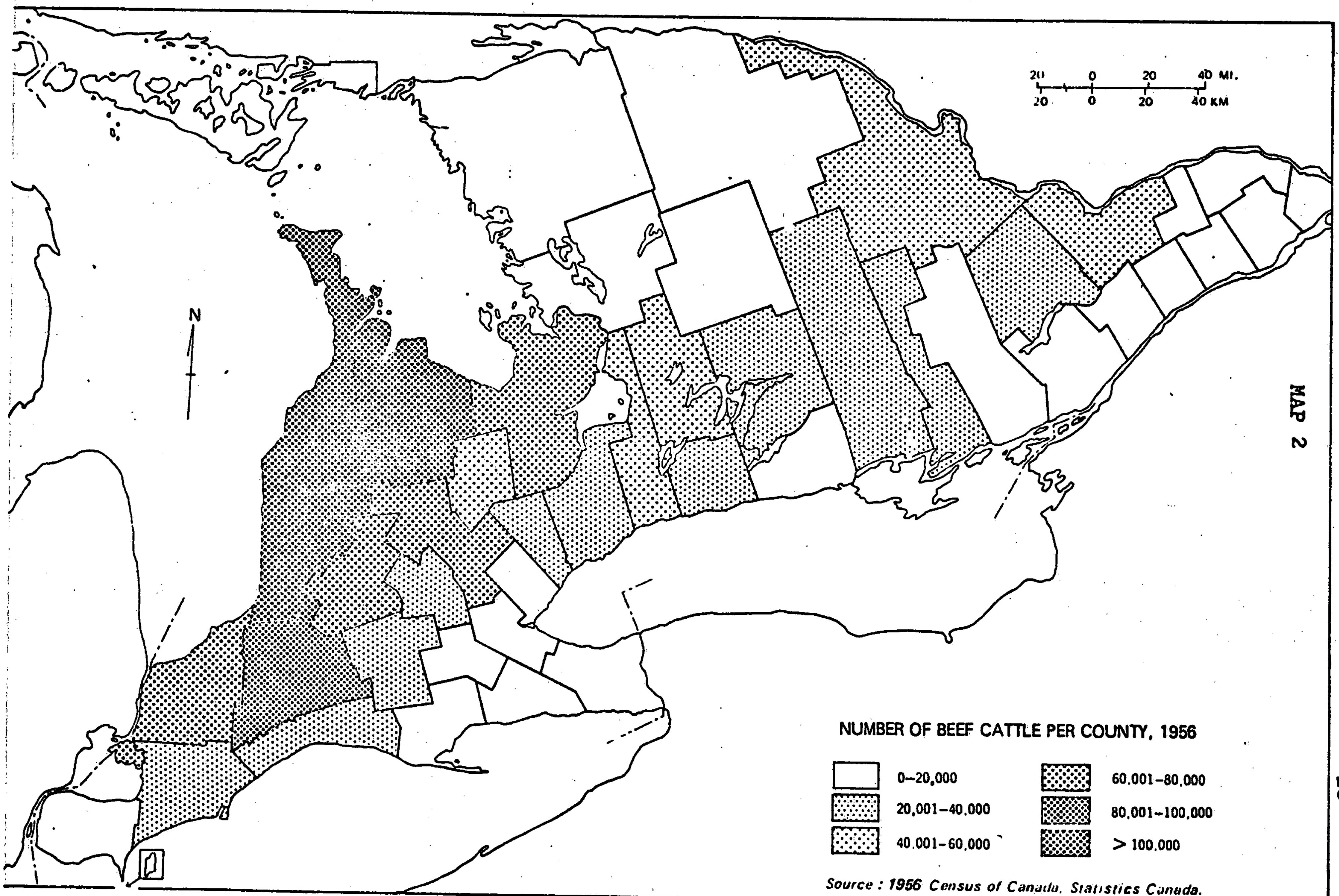
The totals listed in Appendix I show a considerable increase in numbers between 1951 and 1956. Prior to the rapid increase in cattle numbers, there was a significant increase in prices paid for slaughter cattle. The price in 1950 was $24.50 per hundredweight and increased to $32.60 within a year. This higher price no doubt caused many farmers to invest more money in cattle. The price fluctuations in the early 1950's might also account for the decrease in the number of farms in Ontario. Following the high of $32.60 paid in 1951, prices dropped to between $19.00 and $20.00 for the four-year period 1953 to 1957. During the period 1951 to 1961, the number of farms in Ontario decreased from 150,000 to 120,000 (Ontario Ministry of Agriculture and Food, 1971). Part of this decrease in farm number could conceivably have been caused by the bankruptcy of farmers who over-invested in cattle and necessary farm modifications in the hope that the high 1951 prices would persist and who later lost their investments when the prices dropped. In such a situation, there would likely be an incorporation of many small uneconomical operations into fewer large volume feedlots. In the region used for this study, many feedlot operators were renting land for cultivation from neighbours who had given up farming. The high cost of feed makes it imperative to grow as much corn as possible but the high cost of land prevents most owners from purchasing adjacent land to stabilize their expanded operations. Thus, the number of cattle kept at any feedlot is not only determined by the cost of feed on the market but also by the availability of rental land.

Map 6 shows the number of farms per county that reported cattle on feed during 1971 (Appendix II). As with data for cattle numbers, the highest values are located in the west and north-west regions of southern Ontario. It was hoped that a map of feedlot numbers could be included as the most relevant representation of potential feedlot locations. However, according to many people with various positions in the agriculture and cattle business, there are no data kept on feedlot numbers. As a last resort, the agricultural representatives in each county were contacted and asked for the numbers of feedlots in their counties. In some cases unfortunately, the estimates given are in contradiction to published statistics of cattle and farm numbers. Therefore, a map of feedlots has not been included and Map 6 is presented as an approximation of what is the likely feedlot distribution. The number of feedlots would be considerably smaller than the number of farms reporting cattle on feed since there is no minimum number of cattle required in the latter case.


N
20 0 20 40 MI.
20 0 20 40 KM
NUMBER OF BEEF CATTLE PER COUNTY, 1951
0–20,000
20,001–40,000
40,001–60,000
60,001–80,000
80,001–100,000
> 100,000
Source: 1951 Census of Canada, Statistics Canada.

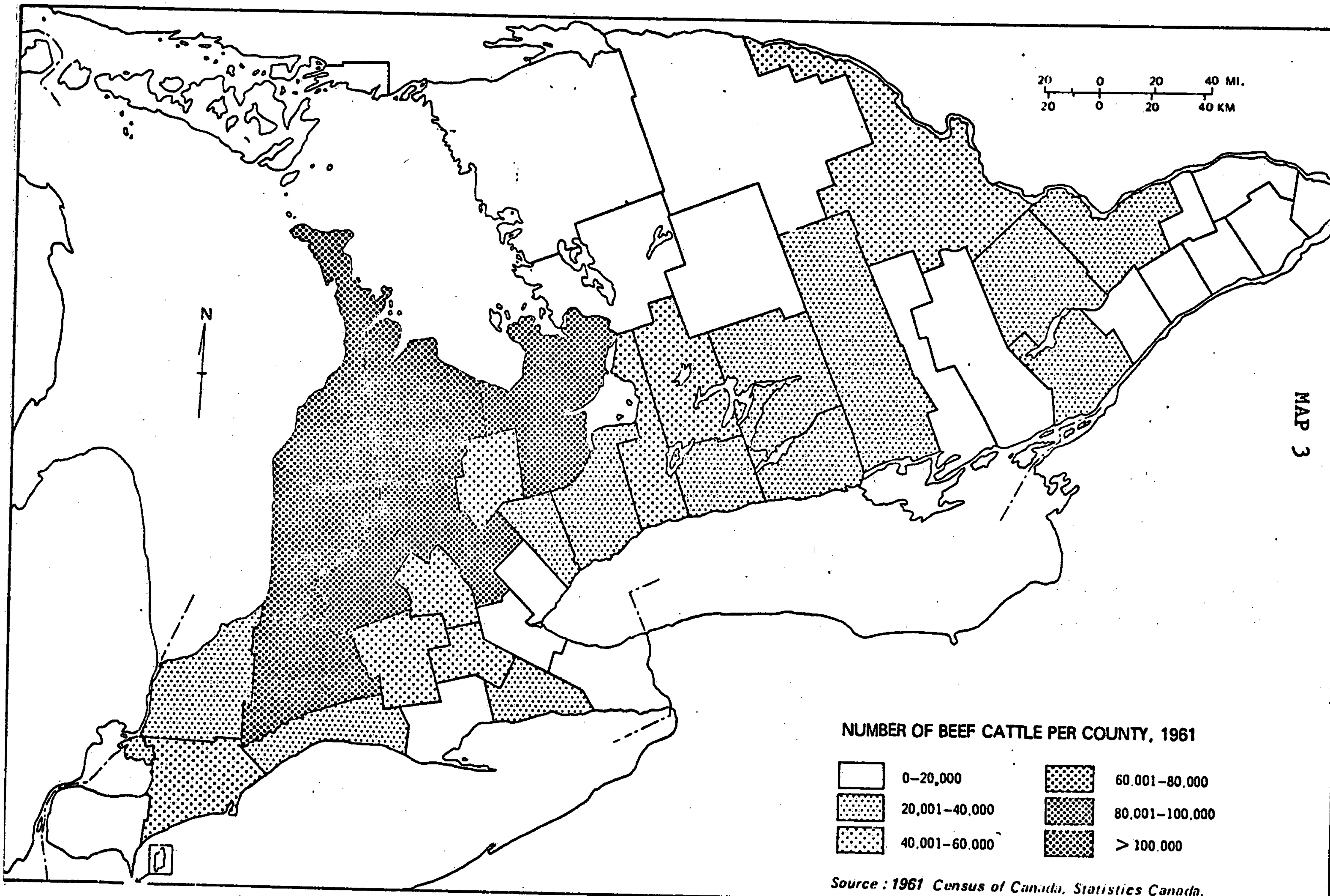
MAP 1

MAP 2

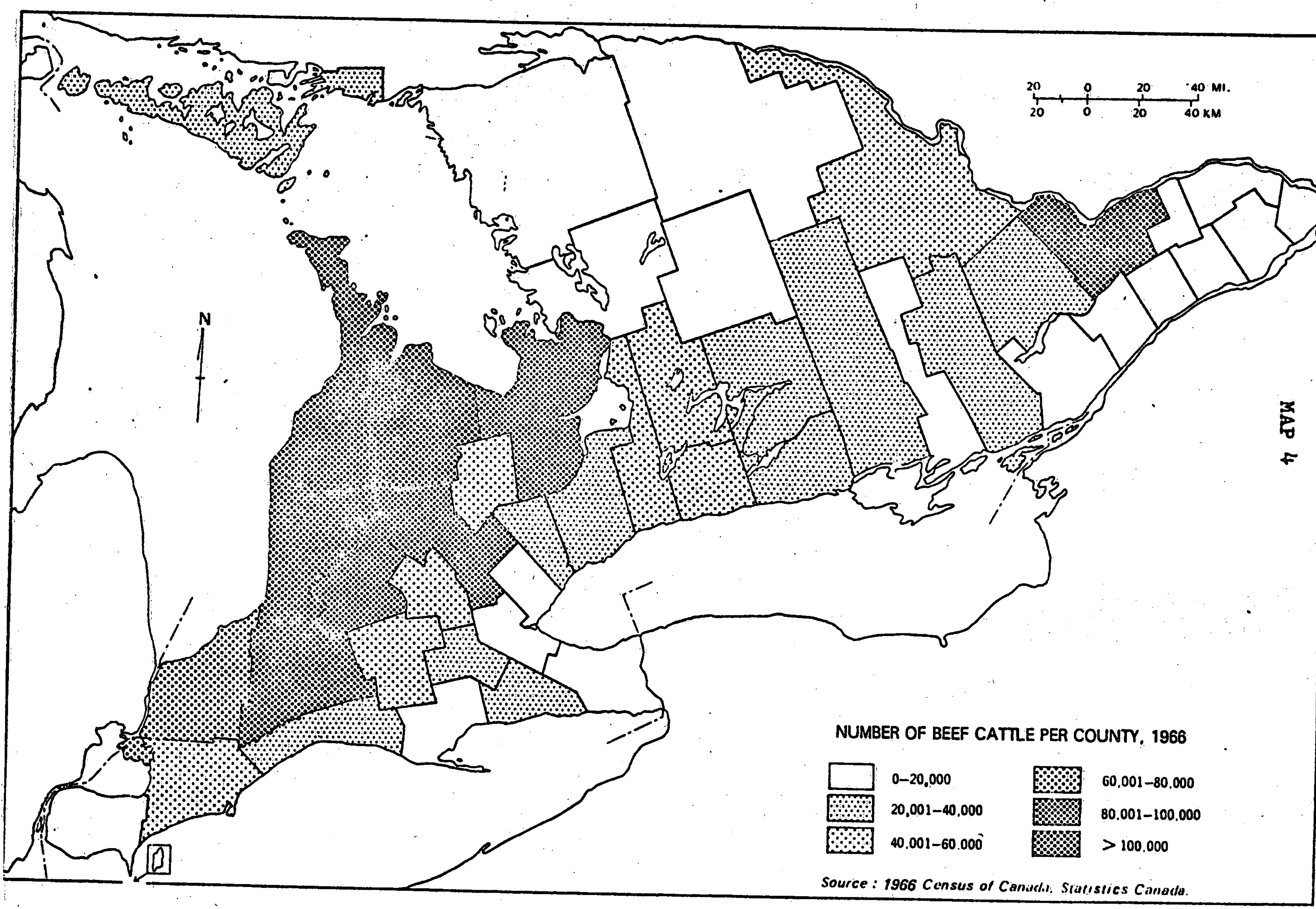


20 0 20 40 MI.
20 0 20 40 KM
N
NUMBER OF BEEF CATTLE PER COUNTY, 1956
0–20,000
20,001–40,000
40,001–60,000
60,001–80,000
80,001–100,000
> 100,000
Source : 1956 Census of Canada, Statistics Canada.

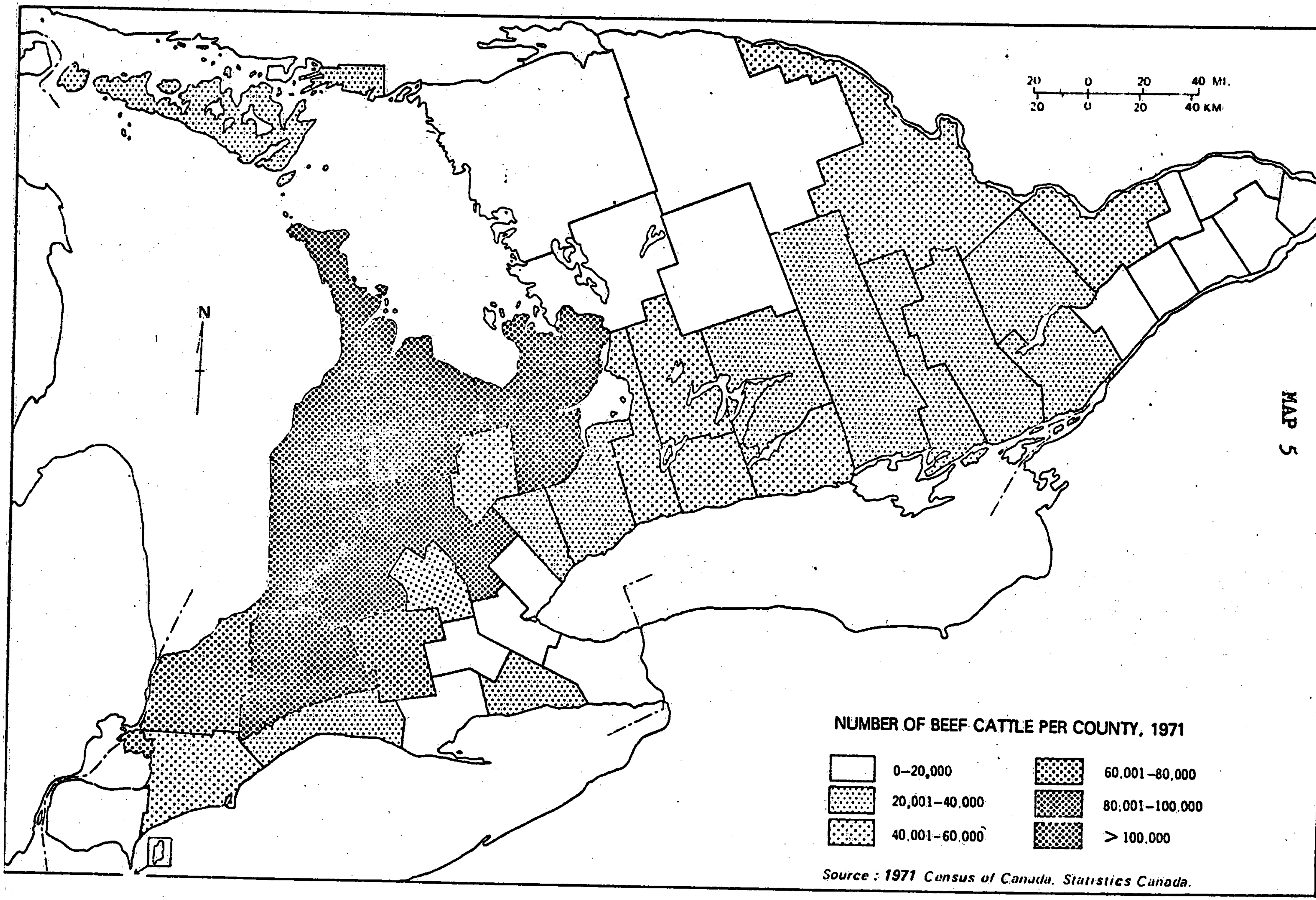
MAP 3

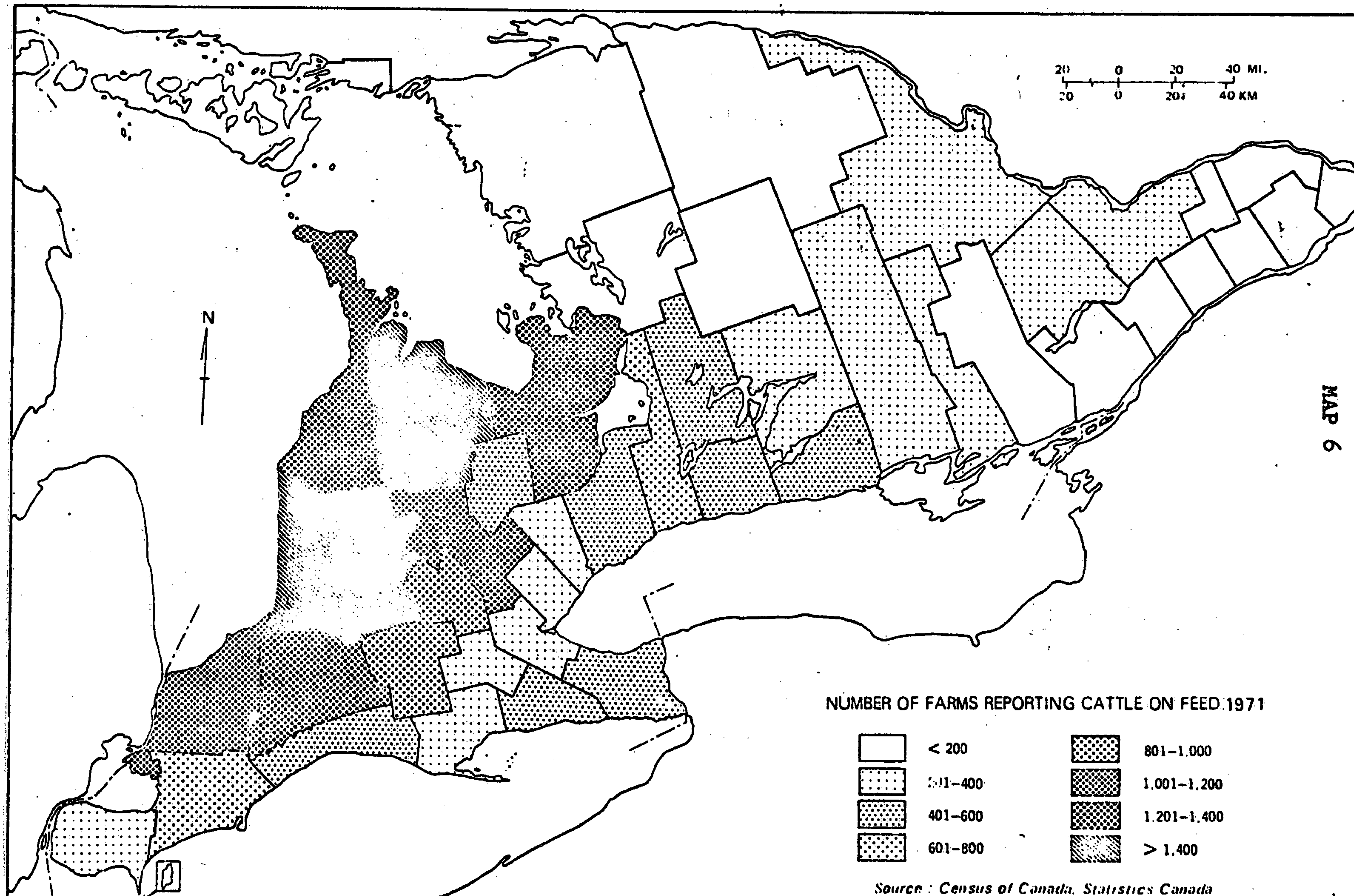

20 0 20 40 MI.
20 0 20 40 KM
N
NUMBER OF BEEF CATTLE PER COUNTY, 1961
0–20,000
20,001–40,000
40,001–60,000
60,001–80,000
80,001–100,000
> 100,000
Source : 1961 Census of Canada, Statistics Canada.

MAP 4


NUMBER OF BEEF CATTLE PER COUNTY, 1966
0–20,000
20,001–40,000
40,001–60,000
60,001–80,000
80,001–100,000
> 100,000
Source : 1966 Census of Canada, Statistics Canada.
20 0 20 40 MI.
20 0 20 40 KM
N

MAP 5


20 0 20 40 MI.
20 0 20 40 KM
N
NUMBER OF BEEF CATTLE PER COUNTY, 1971
0–20,000
20,001–40,000
40,001–60,000
60,001–80,000
80,001–100,000
> 100,000
Source : 1971 Census of Canada, Statistics Canada.


20 0 20 40 MI.
20 0 20 40 KM
N
NUMBER OF FARMS REPORTING CATTLE ON FEED 1971
< 200
01–400
401–600
601–800
801–1.000
1.001–1.200
1.201–1.400
> 1.400
Source : Census of Canada, Statistics Canada

MAP 6

CHAPTER II

RESEARCH DESIGN AND METHODOLOGY

1.1 Purpose

The primary purpose of the study is to determine whether or not runoff of livestock wastes from cattle feedlots in southern Ontario affects the water quality of nearby streams. The research project was designed with the intention of answering the following questions:

1. What is the effect of waste runoff in terms of the observable fluctuations in water quality characteristics at the point of waste entry?
2. What changes in water quality characteristics occur downstream from the point of waste entry?
3. What seasonal changes in concentration occur during spring and summer?
4. What site factors seem to facilitate or inhibit runoff of the various waste components?

The present study is intended as a pilot study which may later be expanded to a wider area. The information collected here will be useful in indicating the degree of water quality variations associated with feedlot runoff, identifying problems associated with the attitudes of individuals and organizations that must be dealt with, and the field conditions relating to problems in sample collection and analysis. It is also hoped that this study will serve to identify those problems of greatest concern which require further, more detailed analysis.

A review of published literature on livestock waste runoff reveals that little work has been done outside of the immediate area of the feedlot. There is a striking lack of monitoring of stream quality. As a result, the methodology used in this project was developed without reference to other studies and according to the situations anticipated without benefit of any background information.

The feedlots selected for the study are located in counties in the western Lake Ontario region. In order to discover the effects each feedlot had on the water quality of the adjacent stream four sampling stations were selected to show the condition of water upstream from the feedlot, at the nearest point downstream from the point of waste entry, and at locations one-quarter and one-half mile downstream from the feedlot. The monitoring of stream quality was to be carried out periodically according to a schedule during both spring (March through May) and summer (June through July). Water samples were analyzed for concentrations of orthophosphate (P), nitrite-nitrate nitrogen (N), ammonia (N), BOD_5, and volatile residue. In addition, bacterial analysis was carried out periodically on samples from each stream. The following sections of this chapter describe the criteria used in the final selection of feedlots and the methods of analysis which were thought would best provide answers to the questions set forth at the beginning of this chapter.

2.2 Selection of Feedlots for Spring Runoff Analysis

Twenty feedlots were selected for use in the spring runoff section of the study. Since only one individual was involved in the collection of samples and frequent sampling was desired, the distribution of feedlots was restricted to an area of approximately a sixty mile radius from Toronto. Because a random sample of feedlots would not be realistic with such a small sample number, a certain degree of standardization was used to obtain a more meaningful representation. The selection of feedlots was made after consideration of many variables which could affect the amount of runoff reaching a nearby stream. These variables can be catagorized under three headings: physical geographic, construction characteristics, and operational practices. The physical geographic variables considered were distance from feedlot to stream, the ground cover between feedlot and stream, the topographic slope from feedlot to stream, the soil characteristics, and the stream discharge. The construction characteristics considered were the type of feedlot floor, the extent of roof covering, the presence of holding ponds or other waste disposal facilities, and the presence of drainage tile in the vicinity of the feedlot. The operational practices considered were the number of cattle per unit area; the use of straw bedding; the frequency of manure removal; the amount, location, and season of manure spreading; and the operator's attitude toward runoff and agricultural pollution in general.

Of these three groups of variables considered, the physical factors were thought to be most important in the selection of study feedlots, particularly in light of the view of researchers in the Ministry of the Environment that most feedlots are situated in such a way as to minimize stream contamination. It would be difficult to assess the effect of each physical factor in isolation from the others, since they are interrelated. However, it is clear that other factors being equal, the greater the distance from the stream, the less likelihood there will be of waste runoff to the stream. Infiltration, evaporation, and chemical change would bring about a decrease in both the amount and concentration of waste runoff. Ground cover between feedlot and stream also affects runoff. A continuous vegetative cover is usually to be associated with higher infiltration rates and limited runoff to streams. The topographic slope from the feedlot to the stream also plays an important role in determining the rate of runoff and the amount of infiltration. In this regard also, soil characteristics are a major consideration, particularly with respect to infiltration rates. According to the United States Bureau of Soils, the approximate permeability in gallons per day per square foot of soil for sand is over 10 while that for clay is 10^{-4} (Linsley and Franzini, 1964, p. 634). Stream discharge must also rank as a factor of importance since the volume of flow will determine the amount of dilution of the waste runoff that takes place.

Construction variables have been analyzed by various groups in the province and the major considerations are the type of flooring in the feedlot yard and the extent of roofing over the yard. Flooring is either bare soil or concrete with the latter coming into universal acceptance throughout the province. Concrete floors do cause liquids to flow out of the yard if they are excessive; however, the highly concentrated waste is prevented from infiltrating to and contaminating groundwater supplies. Also, concrete flooring allows for easier waste removal from the yard. The degree of roofing is important in that the greater the covering, the less rain and snow will fall in the yard and natural runoff will be less. Few of the farms visited had taken measures such as the building of holding ponds to prevent the immediate runoff of wastes. However, since a great deal of discussion has been generated over the value of a holding pond as a treatment facility in the reduction of certain contaminants, one of the few sites with a holding pond was included in the study group. A factor which clearly has a potential effect on water quality is the presence of field drainage tile in the area between the feedlot and the stream. These drainage lines not only carry excess moisture from the field but also all of the contaminants present in such water. The tiles overcome the effects of physical factors in preventing runoff from reaching the stream.

Operational factors are the most difficult to discuss in terms of their effects on runoff since they may change from day to day. The number of cattle kept in the feedlot is clearly of importance since it determines the amount of waste produced. The use of straw bedding is important in that the straw absorbs the liquid waste and allows for much easier handling of the waste. However, the amount of straw applied is highly variable from one feedlot to another and it is frequently in short supply. The removal of manure from the yard is also a highly variable factor. Few owners follow a precise schedule of yard cleaning, preferring to wait instead until the manure reaches a certain depth. Often rainfall makes the manure unmanageable and it is left in the yard until it partially dries. Disposal of the manure is accomplished either by piling it in the immediate area of the feedlot until it can be applied as fertilizer to the fields or by taking it directly to the fields and spreading regardless of the time of year. Since large volumes of waste are involved the latter method of disposal is usually used.

The attitude of the owner toward water pollution and the possible runoff of waste from his own feedlot is often a difficult thing to ascertain. The owner's statements may be influenced by the researcher or complaints of neighbours or a host of other reasons. However, the general appearance of the farm and feedlot as well as his activities viewed over a period of time allow one to judge with some accuracy whether or not the owner is concerned with operating in a safe manner with regard to pollution.

It was found that in the region used for the study there was considerable uniformity with regard to several of the variables and therefore they could be assumed to be constant. Since all of the feedlots had evolved out of mixed farming operations, there were no extreme differences found in soil type. Most soils were either clay loam or silty clay loams with similar permeabilities (10^{-2} gpd/ft.^{2}) (Linsley and Franzini, 1969, p. 634). As for construction type, no feedlots were found that had roofs covering the feedlot yard. In almost all cases, the feedlots were made up of an open-front barn and adjoining yard with concrete flooring throughout. The operational features or management of all feedlots was quite similar with the use of straw bedding to absorb waste moisture whenever the straw was available, manure removal once or twice a week and the spreading of manure whenever ground conditions and crops allowed.

The factors used in the selection of sample feedlots were primarily physical--distance, ground cover, and slope. Also, examples of holding ponds and drainage tile were included in the sample group. Two operational variables were used: number of cattle (although an average herd size of 200 head was sought) and the feedlot owner's attitude toward maintenance of his operation and his attitude toward potential water pollution. In standardizing those features which were quite common in the study region, it was hoped that the factors considered as variables would prove more manageable for purposes of analysis leading to a rational assessment of the effect of each.

In order to obtain a basis for the selection of sample feedlots, the researcher visited over 100 feedlot operations in the counties of York, Peel, Simcoe, Dufferin, Wellington, Wentworth, Brant, and Haldimand during February. The feedlot locations were obtained from three sources: the Ontario Beef Improvement Association, Ontario Department of Agriculture County Representatives, and feedlot operators themselves.

Considerable difficulty was encountered in the initial survey of feedlots that was used as the basis for the final selection of feedlots. Conversations with various people within the Ontario Ministry of Agriculture and Food indicated that there is a great reluctance to divulge information, even facts of the most harmless nature which are available from Statistics Canada. According to some people who were willing to discuss the situation, secrecy has long been characteristic of the Department although a rationale for such secrecy was never offered. As a result of the reluctance of many people to give more than a bare minimum of the information requested, there was always a certain amount of suspicion that data directly related to the topic was on hand but would not be supplied unless specifically asked for. At the county level, officials in the six counties ultimately used in the study (Peel, South Simcoe, Dufferin, Wellington, Brant, and Wentworth) were extremely helpful in providing the names and locations of farmers and discussing the beef production situation in their areas. Agricultural representatives in the two other counties of

Halton and Haldimand refused to co-operate in any way saying that should they divulge the names of farmers, they would be betraying the confidence of those farmers. After discussing the major features of each feedlot with the agricultural representative of that county, the feedlots were located on 1:50,000 scale topographic maps in order to get a general impression of the drainage characteristics of each. This enabled the researcher to quickly eliminate some of the feedlots listed by the agricultural representatives as being of little importance to the purpose of this study. The farmers visited were at first reluctant to take part in any water quality study until they were convinced that it was a university rather than a government study and that their farms would not be identified. At only two of the more than 100 farms visited did the owners say that they would rather not take part in the study. Once the purpose of the study was made clear, the feedlot operators were quite agreeable to answering questions of farm history, and the functioning of their feedlots.

While there are many feedlots in the counties used, and it was hoped that twenty suitable operations would be located, only seventeen were ultimately selected. Of this sample number, it was later found that one feedlot had no measureable runoff due to the topography of the area and the stream at another feedlot was eliminated by the filling of a new conservation reservoir during the early stage of the project. Thus while the results from seventeen feedlots will be discussed, there were only fifteen operations from which samples were repeatedly collected. Site data for each of the feedlots selected is contained in Table 1 and the general locations of the operations are presented in Map 7.

2.3 Selection of Feedlots for Summer Runoff Analysis

In addition to the study of water quality variations associated with runoff from feedlots during the spring season, a smaller sample of feedlots was selected as a basis for the study of runoff associated with summer rainfall. The purpose of analyzing water quality in streams after summer rainstorms was to assess the effectiveness of rain in removing feedlot wastes. During dry periods the accumulated wastes often have very low moisture content and are in a powdered form resulting from the continual trampling by the cattle. They are therefore more likely to be taken into suspension by runoff.

Runoff during summer is affected by various soil and vegetative conditions not present during spring. These conditions are dynamic and determine to a large extent the volume of runoff that will occur on any given occasion. For example, moisture content of each soil type is determined by antecedent conditions of precipitation and evaporation. The rate at which runoff will infiltrate the soil is also dependent upon the rate at which water is applied to the soil surface. During an intense summer storm, time is not sufficient for the usually slow process of infiltration to

Table 1

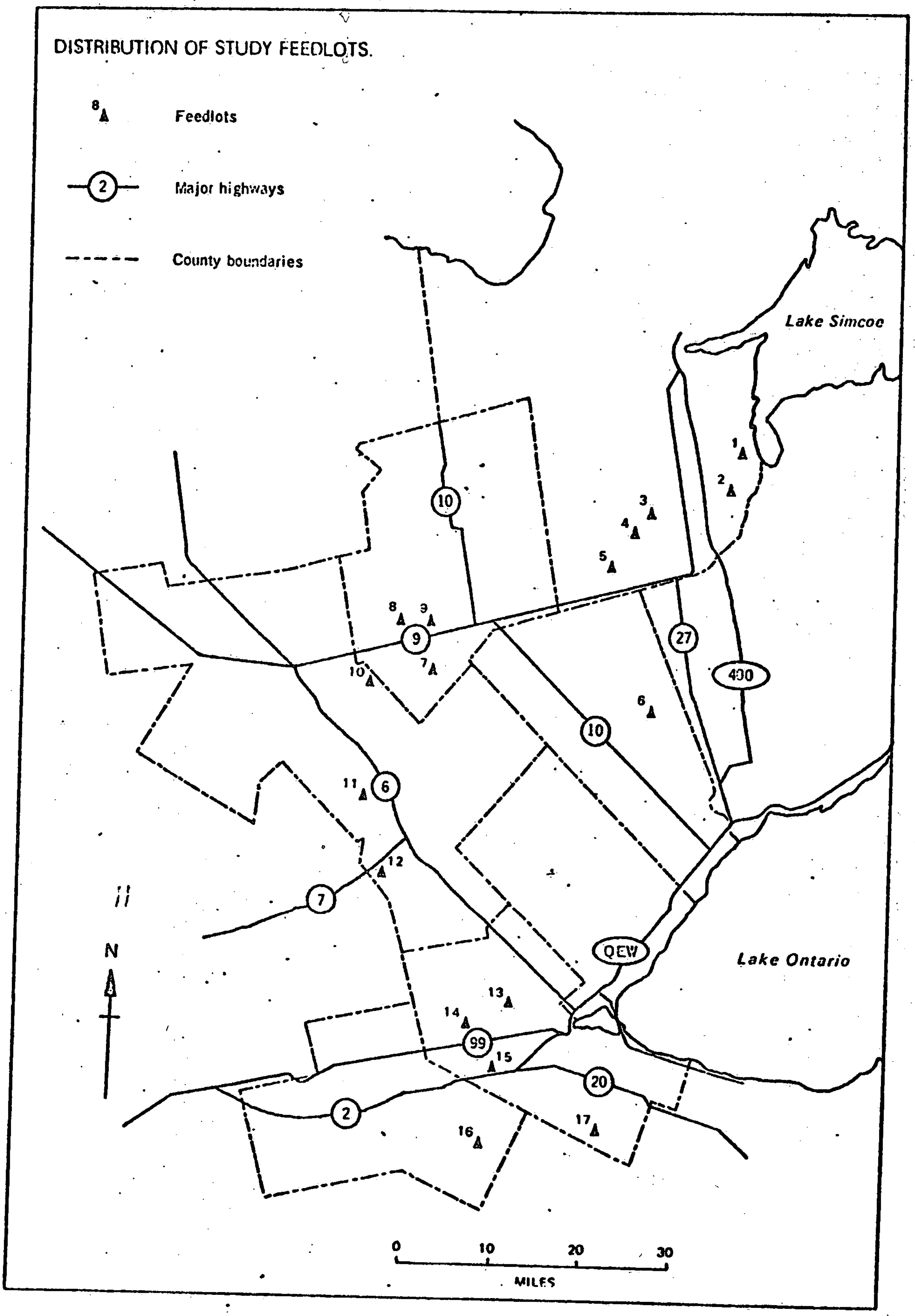
INFORMATION ON SELECTED FEEDLOTS FOR SPRING 1973

Feedlot Number	Feedlot Area (yds.²)	Number of Cattle	Distance to Stream (yds.)	Slope	Feedlot Floor	Drainage Tile	Soil Drainage	Soil Type
1	990	70	0	4°	Soil		Good	silty clay loam
2	1,100	140	100	15°	Concrete		Good	loam
3	2,010	280	200	20′	Concrete		Poor	silt loam
4	1,210	150	300	20′	Concrete		Imperfect	silt loam
5	1,300	170	140	3°	Concrete		Good	silty-clay loam
6	1,530	300	200	50′	Concrete		Imperfect	clay loam
7	940	90	90	3°-30′	Concrete	Present	Good	clay loam
8	2,240	220	290	4°	Soil + Concrete	Present	Good	clay loam
9	1,168	150	120	40′	Concrete	Present	Imperfect	clay loam
10	1,555	80	0	4°	Soil	Present	Good	clay loam

Table 1--Continued

Feedlot Number	Feedlot Area (yds.²)	Number of Cattle	Distance to Stream (yds.)	Slope	Feedlot Floor	Drainage Tile	Soil Drainage	Soil Type
11	2,800	300	120	3°	Concrete	Present	Good	loam
12	1,320	170	5	30′	Concrete		Good	loam
13	2,120	350	200	4°20′	Concrete	Present	Good	sandy loam
14	1,667	350	100	18°	Concrete		Good	complex
15	1,880	160	160	3°	Concrete	Present	Imperfect	silt loam
16	1,089	180	30	30°	Concrete	Present	Good	silt loam
17	1,595	150	60	10°	Soil		Good	silt loam

MAP 7



DISTRIBUTION OF STUDY FEEDLOTS.
Feedlots
Major highways
County boundaries
Lake Simcoe
Lake Ontario
N
0
10
20
30
MILES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
10
9
27
400
10
6
7
QEW
99
20
2

take effect and a major part of the rainwater flows away over the wet ground as surface runoff. Heavy rains, furthermore, compact the soil and reduce its surface openings and prolonged rains cause soils to swell, reducing pore spaces. On the other hand, vegetation usually reduces the surface impact of the rain, creates additional pore space in the soil, and absorbs a certain amount of the runoff dependent upon previous moisture conditions. Vegetation may also absorb some of the nutrients contained in the runoff. Obviously, the effects are greatest during the growing season and vary according to the type of vegetation present. Each of these variables could be analyzed in detail as they relate to waste runoff. The purpose here, however, is to find how the combination of all factors present during summer affect the transport of waste products from feedlots to the streams.

Feedlots chosen for this stage of the study were selected from the group of seventeen feedlots used for the spring runoff study. In addition to the characteristics considered during the initial selection, it is necessary to take into account changes in site conditions at each farm, changes in the operation of each farm, and also the results of the analysis of spring runoff at each site.

The major site consideration that was taken into account was the stream discharge existing in early June. Of lesser importance was the distance from feedlot to stream. While no accurate assessment can be made as to the effect of a sudden heavy or prolonged rainfall on stream discharge due to the moisture holding characteristics of the basin, it is reasonable to assume that a stream that has gone dry by late May will only flow after a rain of unusually long duration. With this in mind, the distance between the feedlot and the stream assumes a greater importance during summer months because extended dry periods prior to any rainfall increase the moisture holding capacity of the soil thus reducing the possibility of feedlot liquids reaching the stream. The absence of any stream flow is relevant in itself of course, however the analysis of stream samples where waste contributions do occur is the purpose of the study and it was expected would yield more information than any study of sites where conditions prevent such waste transfer.

Other factors that must be taken into account involve the operation of each feedlot during the summer months. On the basis of discussions with county agricultural representatives, it was found that the normal cycle of cattle breeding and fattening is such that most animals are born in the spring and reach maturity after two and one-half years. Thus cattle are removed from the feedlots for slaughter in early summer with some farmers emptying their lots completely by late August and refilling them with yearlings in late September. For this reason, several feedlots of interest were not included in the summer study and those that were used had fewer cattle than earlier in the year.

Results of the spring runoff study were used as in indication of which feedlots were likely to have runoff during the summer that would affect the quality of the receiving streams. In consideration of the few occasions upon which samples would be collected from each site during the summer, it would be more advantageous to use feedlots that had in the past shown at least a minimal effect upon water quality rather than to expect a radically new situation to occur. With these considerations in mind, the feedlots selected for the summer study were numbers 1, 2, 6, 11, and 15, each of which is quite different in site characteristics from the rest. The general site characteristics have been summarized previously in Table 1.

Feedlot 1 had the fewest cattle of the group selected (60), however, it is located directly adjacent to the stream. The lot has a dirt floor in contrast to the rest of the feedlots and little cleaning of the yard is done. Much of the waste flows directly to the lower edge of the lot and into the stream. The operation is an example of minimal care and inadequate facilities.

Feedlot 2, with 100 head of cattle, is situated on the crest of a hill and while the spring study showed little effect upon water quality, the potential for such runoff seems clear. The stream involved has a small marshy area above and below the feedlot and the area between the feedlot and the stream is grass covered.

Feedlot 6 has holding ponds above and below the lot which consistently gave higher readings than the downstream stations. The stream had no flow by May 24 but the drainage area is considerably larger for this stream than for most others which could result in a resumption of flow during heavy rains. The area between the feedlot and holding pond is grass covered. One of the major reasons for selecting this feedlot was the number of cattle involved--approximately 200 which was greater than the summer average for the total feedlot group.

Feedlot 11, with 250 head of cattle, was the largest of the group. Analysis of early samples indicate waste does run into the stream during spring runoff. The feedlot is well maintained and a corn field occupies the area between lot and stream.

Feedlot 15 contained 100 head of cattle and corn field separates the lot from the stream. There was some correlation between the feedlot location and waste values in the stream during spring with high values above the lot as well. Tile drainage appears to facilitate the movement of waste toward the stream.

2.4 Data Collection and Methods of Analysis

In an attempt to isolate water quality variations associated with feedlot runoff, as well as the effect of downstream transport of the waste runoff, four sampling stations were located along the stream associated with each feedlot. The first sampling station in each case was located at a point far enough upstream from the feedlot to avoid the effects of any waste runoff but as close as possible to it in order that runoff from sources between Station One and the feedlot were avoided. In most cases, the distance was approximately one hundred feet but in several cases was as great as one-quarter mile. The reason for such variation is explained in the analysis of results (Chapter III). The second sampling station was located within one hundred feet downstream of the point at which the drainage from the feedlot area entered the stream and was the station at which maximum values for each of the measured properties were anticipated. Station Three and Four were located one-quarter and one-half mile downstream from the point of waste entry from the feedlot. These stations were used to measure the effects of downstream movement of the feedlot drainage.

During the period from February to June, the stations at each feedlot were to be monitored at two week intervals. The seventeen feedlots were arranged in groups of 5, 5, and 7 according to geographic region and each group was covered in the space of one day and involved between 80 and 200 miles of travel. It was then necessary to return the samples as quickly as possible to both York University and Ontario Department of the Environment laboratories for analysis.

Collection of samples during the summer for the analysis of the effects of rainfall was to begin at the five selected feedlots in early June and continue until early August. The stream monitoring locations used during the spring were again used during summer. Standard rain gauges were set out at each of the five feedlots and an attempt was made to reach each feedlot as soon as possible after the beginning of rainfall in that area. Samples were to be collected before runoff began or, in the case of a dry stream, as soon as streamflow commenced, and again several times as stream discharge increased and later decreased. Discharge was measured with each sample collection.

Analysis of water samples consisted of measurements for orthophosphate nitrite-nitrate nitrogen, ammonia nitrogen, five-day biochemical oxygen demand, volatile residues, and in some cases, total and fecal coliforms. Each of these properties is a characteristic of livestock waste and has the potential for serious impact on water quality (Black, et al., N.D., p. 16).

Determination of phosphorus concentration in water samples has become an integral part of almost all water quality studies today. Researchers have come to appreciate the significance of phosphorus as a vital factor in biological processes. Phosphorus determinations are extremely important in assessing the potential biological productivity of surface waters, and in many areas limits have been established on the amounts of phosphorus that may be discharged to receiving water bodies (Sawyer, 1960, p. 330). Phosphorus is present on farms in liquid wastes and in fertilizers. High proportions of phosphorus in fertilizer applied to fields are rapidly fixed to inorganic soil particles and do not readily enter solution. This phosphorus is discharged into streams as the result of erosion and studies indicate that it will enter solution when soluble concentrations are less than 10 mg./1. However, all phosphorus is subject to biological assimilation which may result in the growth of algae (Keup, 1968, p. 377).

Nitrogen is an important factor in water quality studies because it too is of great significance to the potential productivity of biological systems. Another reason for the interest in testing nitrogen concentrations stems from the fact that high nitrogen content has been found to be responsible for the deaths of animals and infants through a condition called methemoglobinemia. The study of nitrogen in water is complex because of the several valence states that it can assume and the fact that changes in valence can be brought about by living organisms. For purposes of this study, two forms of nitrogen were monitored--ammonia (NH_3^+) and the combination of nitrites (NO_2^-) and nitrates (NO_3^-). Ammonia is produced by bacteria from unassimilated protein matter in livestock waste. The ammonia may be used by plants directly to produce plant protein, it may be volatized, or it may be transformed again by bacteria to form nitrites. These in turn are oxidized to form nitrates (Sawyer, 1960, p. 291).

The biochemcial oxygen demand (BOD) of water is a measure of the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. BOD analysis is widely used to determine the pollutional strength of waste water in terms of the oxygen that the water will require if discharged into a natural watercourse in which aerobic conditions exist. "The test is one of the most important in stream pollution control activities" (Sawyer, 1960, p.270). BOD testing is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water. Since a five-day incubation period is usual with BOD analysis, the measure is usually expressed in the form BOD_5. The method of analysis used was that described in Standard Methods (1969, p. 415).

Since there is a considerable amount of organic matter present in livestock waste runoff, measurement of the organic matter present in streams is a logical property to use in order to determine if there is waste input into the water from the feedlot. In this study, values for volatile residue are expressed as per cent of the total residue in the sample in order to avoid errors caused by collection of samples with little total residue and thus little absolute volatile residue. The method of analysis used was that described in Standard Methods (1969, p. 423).

Bacterial analysis of samples from each feedlot was carried out periodically at the laboratory of the Ministry of the Environment. In each case, the sample was taken from Station Two--that closest to the point of waste entry and values for both total and fecal coliforms were obtained. Since fecal coliforms originate only in waste, their presence is a positive indicator of some kind of animal waste in a sample.

In discussions with laboratory officials at the Canada Centre for Inland Waters, it was agreed that analysis of phosphorus, ammonia, and nitrite-nitrate nitrogen should be carried out as quickly as possible after the samples had been taken in order to avoid changes in property concentrations over time. For this reason, the use of Hach field analysis kits was approved. The kits used were models PO-19A which measures orthophosphate as P; NI-8 which measures ammonia as N; and NI-10 which measures the total nitrite and nitrate level as N. All of the kits are colorimeter type. Accuracy of results for phosphorus and nitrogen was to be periodically checked by taking some of the stream samples to the C.C.I.W. laboratory for analysis using a Technicon autoanalyzer. Several tests were made to check BOD_5 results also.

2.5 Problems Associated with Field Conditions and Sample Analysis

The difficulty encountered in obtaining a sample number of twenty feedlots has been pointed out earlier. Of the more than one hundred feedlots examined during February, only a small number were situated in close proximity to a surface stream and some of these were discarded on the basis of other criteria. As a result, the study was carried out using a total of seventeen feedlots during the spring period.

Locating four sampling stations along each stream was in some cases not possible due to the presence of other drainage channels joining with the study stream or the presence of marshes or large flooded areas at some point the length of stream that was to be studied.

Temperature and precipitation were responsible for two serious occurrences during the period of the study. Table 2 shows the mean monthly temperature and total monthly precipitation at four stations of the Atmospheric Environment Service. Temperatures recorded for the month of March, 1973 are considerably higher than the 30-year average at each location. These temperatures are the result of several very warm periods that occurred early in the month. During those periods runoff occurred, thus reducing the amount of water held in storage that would normally be released during a period of several weeks late in the month. As a result, the waste liquids carried in the runoff were removed over a longer period of time and likely in reduced concentration.

The table does not portray the dry July weather as clearly as it does March temperatures; however, the Bradford-Springdale and Orangeville stations do indicate the lack of rainfall that occurred within the study region. This problem of dry weather at a time when the analysis of storm runoff was the goal is discussed in the next chapter.

Several problems developed with regard to the analysis of samples--the major one being discrepancies between values

Table 2

TEMPERATURE AND PRECIPITATION DATA
FOR SELECTED STATIONS IN THE STUDY REGION

Bradford-Springdale

	Temperature Mean (inches) 1968-1972	1973	Precipitation Mean (inches) 1968-1972	1973
January	23.0	23.8	1.82	1.25
February	27.6	16.1	1.75	1.41
March	34.8	37.8	1.99	2.64
April	52.2	44.2	2.27	2.80
May	65.0	52.6	2.20	2.53
June	74.2	66.5	2.61	1.60
July	79.2	68.9	2.94	0.34
August	78.2	69.5	3.29	3.83

Hamilton Airport

	Temperature Mean (inches) 1941-1970	1973	Precipitation Mean (inches) 1941-1970	1973
January	21.3	25.0	2.67	1.48
February	22.6	19.0	2.09	2.53
March	31.3	38.0	2.21	5.22
April	44.4	44.0	3.21	2.66
May	54.6	52.0	2.53	3.07
June	64.6	67.0	2.24	2.48
July	69.0	70.0	2.83	2.89
August	67.6	68.3	2.80	0.33

Table 2--Continued

TEMPERATURE AND PRECIPITATION DATA
FOR SELECTED STATIONS IN THE STUDY REGION

Orangeville

	Temperature Mean (inches) 1941-1970	1973	Precipitation Mean (inches) 1941-1970	1973
January	17.5	21.4	2.04	1.74
February	18.5	15.0	2.00	1.69
March	25.7	36.0	2.25	3.86
April	40.2	42.3	2.54	3.02
May	51.3	49.6	3.13	3.86
June	61.6	63.9	2.44	3.07
July	65.7	66.9	2.83	1.81
August	63.9	68.7	3.04	4.56

Toronto International Airport

	Temperature Mean (inches) 1941-1970	1973	Precipitation Mean (inches) 1941-1970	1973
January	20.6	24.0	2.19	1.35
February	21.6	18.0	1.95	1.43
March	30.3	38.0	2.36	4.77
April	43.5	44.0	2.54	2.45
May	54.0	52.0	2.86	3.46
June	64.7	65.0	2.41	2.67
July	69.3	69.0	2.95	2.46
August	68.0	69.8	2.88	2.52

Source: Atmospheric Environment Service--
Department of the Environment

recorded for phosphorus in the field and those recorded in the laboratory. Stream samples were taken to the C.C.I.W. laboratory on two occasions during the spring. On both occasions, the values recorded using the Hach kit in the field were much greater than those recorded in the laboratory using an autoanalyzer. The discrepancies did not occur in samples checked during the month of June nor were discrepancies ever recorded when measuring prepared samples of unknown concentration. Several explanations for the differences were suggested, such as the time elapsed between field and laboratory testing (approximately three hours), temperature differences between field and laboratory, and interference in the sample which caused false colorimeter readings. However, the problem could not be resolved by the researcher and laboratory personnel at C.C.I.W. The Hach company, replying to a request for their opinion, suggested that the autoanalyzer was registering either a sample colour or turbidity or both that do not register when making visual colour comparisons using the kit.

Since the differences could not be accounted for, it is necessary to point out the possible inaccuracy of phosphorus concentrations recorded during March and April which are listed in the following tables.

Values recorded using the Hach kit for nitrite-nitrate nitrogen were consistently in agreement with the autoanalyzer results at all times throughout the study.

Analysis of ammonia nitrogen using a Hach kit was not entirely satisfactory since the maximum concentration that can be measured using the kit is only 3 ppm. In the tables of results following, it can be seen that in several instances, the ammonia concentration was in excess of this level.

In some instances in the following chapter, BOD_5 concentrations are described as being in excess of a stated figure. This results from a problem characteristic of BOD analysis. The concentration of BOD in each sample must be estimated and a suitable dilution factor used in order that the analysis will be in the proper range. With each increase in dilution however, there is a resulting decrease in accuracy so that a minimum amount of dilution is preferred. Analysis of several samples using different dilution factors would eliminate this problem but the collection and transport of these additional samples becomes difficult if many sampling stations are being used as was the case in this study.

Bacterial analysis is a useful tool in water quality studies. Unfortunately, the number of laboratories that do such analysis are few. As a result, it was only through the generosity of personnel in the Ministry of the Environment that the writer was able to submit a certain number of samples for analysis. It is for this reason that measurements of bacteria are recorded on such a limited basis.

CHAPTER III

ANALYSIS OF WATER QUALITY DATA

3.1 Introduction

The purpose of this chapter is to describe the changes in water quality that took place at each site as the result of livestock waste runoff. The chapter is divided into two parts: the first to show the changes in water quality that took place during the period March through May as the result of spring runoff; the second is to show the water quality changes that occurred as the result of storm runoff during June and July. The first section is made up of the results of analysis for spring and is preceded by a description of how the monitoring was carried out and what significance levels of the various water properties have. For each case presented, the reasons that the feedlot was thought to be a source of runoff are mentioned in addition to relevant facts not described in Table 1. The results of analysis for each of the water quality properties is then covered and an assessment is given of the effects that the feedlot in question has upon the water quality of the study stream. The data itself is listed in table form following the discussion.

At the end of the section, a summary of the findings from all of the feedlot streams as a group is presented in order to describe trends that occur through the tables of data and to describe what factors could be found to account for the changes in water quality.

The same format is used in the section following which deals with changes in water quality that result from runoff caused by summer rain. However, the main point of interest in each case is the amount and duration of rainfall that occurred. Cases are listed in order of the dates on which the rainfall and runoff occurred.

3.2 Water Quality Variation During Spring Runoff

As indicated earlier there is a great deal of similarity between feedlots with respect to physical, constructional, and operational characteristics. For this reason, only those factors which are unique to the feedlot in question or which exert an obvious influence on runoff have been mentioned in the discussion of runoff and stream water quality. For a more complete description of each feedlot the reader should refer to Table 1.

Along with a description of the feedlot site or some of its characteristics is an explanation of why sites of sample collection (stations) sometimes deviated from the intended locations. As stated, there were to be four sampling stations: one close to but upstream from the feedlot, one immediately downstream from the feedlot, and two others located 0.25 and 0.5 miles downstream from the feedlot. Problems such as level topography with questionable runoff points, drainage from other streams, and accessibility necessitated changes in some of these locations.

In the interpretation of quantitative results, and evaluation as to what any particular level of property concentration has on overall stream quality, a large degree of subjectivity was necessarily involved. Many conditions operative in a feedlot area, such as infiltration and chemical change, were not measured since they were beyond the scope of the study. Thus these effects can only be guessed. As to what a significant level of contamination is, there are few answers since the use to which the water is to be put, time of measurement, source of contamination, and other factors determine the acceptability of contaminating properties. In these analyses, the criteria set by the Ontario Ministry of the Environment were used when reference was made to unacceptable contamination. The only properties covered by the Ministry for water in agriculture and livestock use are nitrate plus nitrite (20 mg./1 permissible), total and fecal coliforms (100,000 and 100/100 ml. permissible), and algae (no heavy growth of blue-green algae). Reference is made in the analyses to 'high' and 'low' concentrations as they relate to average values found in the group as a whole.

No analysis of aquatic invertebrae or algae was undertaken; however, their presence or absence was noted as an additional indicator of water quality. They are of particular interest because they are often the result of sporadic loadings of pollutants whose presence is no longer detectable by other means.

3.2.1 Water Quality at Feedlot 1

This feedlot was chosen because it is situated directly adjacent to a small stream with liquid and semi-aqueous wastes running unimpeded into the stream channel. Between April and August, the large amount of waste flow results in complete blockage of the stream. A small holding tank installed last year to prevent runoff from the yard has proved ineffective but no improvement on the tank is contemplated. The owner is presently involved in several business ventures including the operation of another larger feedlot. Because of this, little attention is paid to the feedlot.

Discharge of the stream reached a maximum of 3.2 cubic feet per second during the month of March which indicates both the small basin area and the short length of the stream (approximately three-quarters of a mile), with the fourth sampling station located at the junction of the study stream and a larger stream which runs throughout the year. Station One is located 75 feet above the feedlot while Station Two is 50 feet downstream. Stations Three and Four are a further 0.25 and 0.5 miles below the feedlot.

Values for each of the measured characteristics, save volatile residue, were higher at this feedlot than at any of the other feedlots considered in the study. In most cases, there was a definite correlation between the location of the feedlot (Station Two) and the highest contaminant values observed along the stream profile.

Phosphorus, for all the sets of observations, increased from Station One to Station Two and then decreased to Station Four. Since there are no other sources of waste input and there is little sediment present, it may be concluded that the measured phosphorus has its origins in the feedlot runoff. Values decreased on each sampling date from March to late May.

Nitrogen, in the form of total nitrite and nitrate, shows a decrease from Station One through Station Four with no increase at Station Two. Land use is uniform from above Station One to Station Three (non-manured, bare, corn field), thus it is unlikely that dissolved nitrogen from field run-off caused differential effects. Nitrogen levels show no uniform or significant decrease from the first to the last sampling date. The absence of $NO_3^- + NO_2^-$ increase at Station Two is somewhat surprising in light of the increase in ammonia (NH_4^+) at that point. Since NH_4 breaks down chemically into nitrite and nitrate in time, some $NO_3^- + NO_2^-$ increase might be expected.

Ammonia shows a trend similar to that of phosphorus with a low value at Station One, a maximum on all dates at Station Two, and decreases to Station Four. There is a general decrease in NH_4^+ values from March to May.

BOD_5, which may be more indicative of animal waste presence than any other measurement used, shows a maximum on each day at Station Two closest to the feedlot. Values then decrease through Stations Three and Four. There is also a decrease in values from March 20 to May 24.

Volatile residue, measured as a percentage of the total residue, shows no correlation between maximum values and feedlot location although values are lower downstream from both Stations One and Two.

Bacterial analysis of a sample taken at Station Two on May 24 showed a total coliform level of 2,300/100 ml. and fecal coliform level of 840/100 ml.

While the stream does not exhibit high nutrient levels downstream from the feedlot, there is extensive development of benthal material. Surface algae is absent during summer.

The values for all properties measured except nitrogen clearly indicate that the feedlot is a source of runoff and that the runoff has an adverse effect upon water quality. Waste runoff is indicated at Station Two in almost all instances and the degree of contamination is greatest on March 20, decreasing through the spring to May 24.

Table 3

W A T E R Q U A L I T Y D A T A

FEEDLOT NUMBER 1

Stream Discharge

March 20	3.2 $ft.^3/sec.$
April 5	0.8
May 3	0.3
May 24	0.2
June 15	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 20	1	16.7	4.7	4.7
April 5	3.7	4.3	0.7	0.77
May 3	0.1	0.43	0.43	0.3
May 24	0.0	0.2	0.25	0.12

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 20	7.0	2.6	4.2	2.8
April 5	7.4	6.8	4.4	0.0
May 3	5.0	5.0	2.1	0.1
May 24	5.3	3.6	0.1	0.02

Table 3--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 1

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 20	0.2	>3.0	0.7	0.2
April 5	0.2	0.9	0.4	0.1
May 3	0.2	1.0	0.6	0.4
May 24	0.1	0.2	0.2	0.2

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 20	0.3	>38.4	13.5	3.5
April 5	1.0	>38.0	14.0	>7.7
May 3	0.7	27.0	15.0	4.0
May 24	0.4	21.0	8.0	1.0

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 20	19.23	33.33	15.77	14.16
April 5	28.32	27.06	23.27	22.52
May 3	36.0	28.77	29.98	28.40
May 24	27.5	30.1	28.0	25.9

3.2.2 Water Quality at Feedlot 2

This farm was selected because it is situated on the crest of a hill, overlooking a small stream. Manure is piled on the slope below the barn and it was thought that the steep gradient (15), combined with the short distance to the stream (100 feet), would result in sufficient runoff from the stored manure to affect the quality of the stream.

Station One was located 100 feet above the area of the feedlot because the direction of drainage flow was not obvious. Station Two was 50 feet below this area and Station Three was one-quarter mile below Station Two. A fourth sampling location was omitted due to the junction of the study stream with a much larger drainage ditch. Several factors could affect or mask runoff values at this feedlot location, the major ones being a marsh area above Station One, a small spring between Stations One and Two, and a marsh area above Station Three.

The owner of this operation has several sources of income other than the feedlot; however, the sale of cattle contributes significantly to overall income. The feedlot appears to be operated in an efficient manner with adequate attention paid to the comfort of the animals and cleanliness of the yard.

Maximum stream discharge at this site was 5.9 cubic feet per second measured on March 20. It was impossible to take any measurements at Station Three on this date as the stream widened below Station Two and was heavily iced. Discharge diminished rapidly through early April and reached zero by

June 15.

Phosphorus values were variable throughout the spring runoff period with no maximum values ever recorded at Station Two. Maximum values (5.3 - 1.67 ppm.) were found in March with a decrease through April and May until only trace amounts (0.1 ppm.) were observed in late May. There was no observable cause for the high (2.67 ppm.) reading at Station Three on April 5.

Nitrogen levels, while being low, show an interesting increase from Station One through Three on three of the four sampling days. The fact that the maximum values do not occur at Station Two suggest that runoff from corn fields which run alongside the stream from the feedlot to Station Three may have some effect on the level of nitrogen contained in the stream. Certainly, the feedlot is not shown to be a significant contributor. At the low levels of concentration found (0.1 - 3.0 ppm.), it is not surprising that a seasonal decrease is absent.

Ammonia values showed no trend in concentration and never exceed the level to be expected in uncontaminated waters.

BOD_5 concentrations were low throughout the spring period (0.1 - 1.1 ppm.). Maximum levels were not related to the location of the feedlot and there was only a slight decrease in values from March until late May.

Volatile residue indicates no runoff from the feedlot. On only one day, when no third station value was obtained, was there a maximum reading located at Station Two.

Bacterial analysis of a sample collected at Station Two on May 24 showed total coliforms to be 90 per 100 ml. and fecal coliforms to be 40 per 100 ml.

Benthic deposits were not noticeable in this stream and surface algae was absent.

The measurements obtained from this stream indicate that there is little or no inferior runoff from the feedlot and manure pile at this site. While the location of the feedlot and the storage of wastes indicate that the potential for waste runoff is significant, there are several factors which may prevent any degradation of stream quality. Those factors already mentioned (marsh and spring) are possibly important as sources of nutrient absorption and dilution respectively. Surrounding fields downstream from the feedlot are fertilized with manure which may result in higher readings some distance away from the feedlot. Heavy growths of reeds and long grasses developed along the length of the stream in late spring and these may extract significant quantities of nutrients from the runoff entering the stream and from the stream itself.

Thus, it can be concluded that there is no stream contamination as the result of feedlot runoff and that except for bacteria content, this is a relatively clean stream.

Table 4

WATER QUALITY DATA

FEEDLOT NUMBER 2

Stream Discharge (at Station Two)

March 20	5.9 $ft.^3/sec.$
April 5	2.2
May 3	0.95
May 24	0.7
June 15	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3
March 20	5.3	1.67	Frozen
April 5	0.5	0.2	2.67
May 3	0.17	0.1	0.1
May 24	Trace (0.1)		

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3
March 20	1.6	1.4	Frozen
April 5	0.58	1.6	3.0
May 3	0.58	0.9	1.0
May 24	0.14	1.8	2.2

Table 4--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 2

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3
March 20	0.1	0.1	Frozen
April 5	0.2	0.1	0.2
May 3	0.2	0.1	0.1
May 24	0.1	0.1	0.1

BOD_5 (mg./l)

Date	Sample Stations 1	2	3
March 20	0.9	0.7	Frozen
April 5	0.6	0.4	1.0
May 3	0.3	0.3	1.0
May 24	0.2	0.2	1.1

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3
March 20	9.8	18.9	Frozen
April 5	24.0	23.3	23.8
May 3	37.4	38.6	41.7
May 24	24.3	22.5	25.1

3.2.3 Water Quality at Feedlot 3

Since a comparison of the amount of runoff from feedlots located in areas of differing topography was one of the goals of the study, this feedlot was selected as an example of a feedlot situated in an area of level topography with heavy clay loam soil. The average gradient from this feedlot to surrounding ditches is twenty minutes. When the feedlot was visited on March 20, there was a uniform snow cover of approximately eight inches and no runoff had yet occurred. Sporadic periods of warm weather occurred between that date and the date when samples were again collected in that region. The ditches at the later date (April 5) contained only several inches of still water while the fields were clear of snow and spotted with flooded patches. According to the owner, water had filled the ditches for several days but it was common for them to empty rapidly and for the fields to retain a large amount of moisture beyond the date at which farmers in other areas could begin to work their fields. Some fields within a two mile radius of the feedlot were completely flooded to a depth of up to one foot.

It is possible that under these conditions, waste both in the vicinity of the feedlot and that spread on frozen fields remains to a large degree on the fields rather than running off in drainage ditches.

At no time during late spring or summer did rain cause runoff at this site and it is unlikely that such runoff would occur during a summer with excessive rainfall.

There is no water quality data presented for Feedlot 3 since both the volume and duration of runoff were of too little magnitude to collect samples. It seems highly unlikely that livestock waste runoff from this feedlot occurs in sufficient amounts to adversely affect the water quality in area streams at any time.

3.2.4 Water Quality at Feedlot 4

This feedlot is in the same area as Feedlot 3 with similar gradient and soil. However, the distance between feedlot and stream in this case is greater by 100 yards. The feedlot is cleaned regularly and manure is spread on adjacent fields when conditions permit. The owner is unconcerned with any thought of runoff from the feedlot to the stream since the distance and slope involved result in standing water around the feedlot.

Only two sample collection stations were used at this feedlot because the study stream joins another stream directly below Station Two. Station One was located 0.25 miles upstream from the feedlot in order to avoid any feedlot influence caused by the level topography. Stream discharge was measured first on April 5, because heavy snow and thick ice prevented measurement in mid March. For this reason also, water quality data are absent for March 20. Stream discharge on April 5 was 91.8 cubic feet per second.

Phosphorus values were consistently low (<0.3 ppm.). There is no clear increase in concentration from Station One to Station Two, nor is there any decrease in level from first analysis date to last.

Nitrogen levels are relatively constant between the two sampling points, indicating no additional loading near the feedlot. The nitrogen values clearly decrease through the spring season from a maximum of 5.8 ppm. on April 5, to a minimum of 0.6 ppm. on July 18. This decrease through time in an area of corn cultivation with winter spreading of manure suggests field runoff of nitrogen in solution.

Ammonia is uniform in concentration at both points on all dates with only one exception. The value of 1.8 ppm. at Station Two on April 5 is at that location one would expect a high level. However, the value recorded 16 days later is only 0.3 ppm. This rapid change combined with the values of NO_3^- + NO_2^- on April 5--5.8 ppm. at Station One and 5.6 ppm. at Station Two--suggest that the 1.8 ppm. value for ammonia is questionable and may not indicate waste runoff.

BOD_5 levels are consistently low and show no change from Station One to Station Two, nor do they change significantly through time.

Benthic material was not present at either sampling point and surface algae was minimal.

It is apparent that there is no observable waste runoff from this feedlot. Values for each of the factors measured indicate that the distance of 300 yards and the lack of any gradient inhibit the flow of liquid from the feedlot; that nitrate values are derived from manure or commercial fertilizer that has been applied to surrounding fields.

Table 5

WATER QUALITY DATA

FEEDLOT NUMBER 4

Stream Discharge (at Station Two)

March 20	Frozen
April 5	91.8 ft.^{3}/sec.
May 3	42.0
May 24	4.5
June 15	1.2
July 18	0.5

Phosphorus (P) (ppm)

Date	Sample Station 1	Sample Station 2
March 20	Frozen	
April 5	0.07	0.27
May 3	0.1	0.2
May 24	Trace	
July 18	Trace	

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Station 1	Sample Station 2
March 20	Frozen	
April 5	5.8	5.6
May 3	3.0	3.6
May 24	1.2	1.1
July 18	.8	.6

Table 5--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 4

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2
March 20	Frozen	
April 5	0.2	1.8
May 3	0.2	0.3
May 24	0.2	0.2
July 18	0.2	0.1

BOD_5 (mg./l)

Date	Sample Stations 1	2
March 20	Frozen	
April 5	0.3	0.3
May 3	1.1	1.0
May 24	1.0	1.0
July 18	0.8	0.9

Volatile Residue
as % of Total Residue

Date	Sample Stations 1	2
March 20	Frozen	
April 5	28.6	23.2
May 3	35.8	41.6
May 24	26.3	22.3
July 18	24.1	23.8

3.2.5 Water Quality at Feedlot 5

This feedlot is one of a group of three feedlots operated by the same man. In addition to his own cattle, the owner also has a yard set aside for the care of bulls belonging to other farmers in the area. The three feedlots are located on the same stream but only the feedlot located furthest upstream and closest to the stream was used because topography and distance made runoff from the other two feedlots seem unlikely although some of the results put this assumption into question. Station One was located 150 feet above the area of runoff. Station Three was located one-quarter mile below Station Two with a second feedlot between the two stations. Station Four was one-quarter mile below Station Three and below the junction with a small stream which runs close to a third feedlot which is located more than a quarter mile away from the study stream.

Stream discharge was 7.2 cubic feet per second in mid March and decreased to zero by mid June.

Phosphorus values show an increase at Station Two on only one date. However, the values for March 20 and April 5 show an increase in phosphorus level through the length of the stream which may suggest the addition of phosphorus at the second and third feedlots or from other sources not related to the feedlots. The concentration of phosphorus decreases through time reaching a trace level (<.1 ppm.) on May 24.

Nitrogen concentrations were similar in trends to those found for phosphorus. On three dates, there is an increase downstream from the study feedlot indicating additional sources of runoff. Nitrogen values also decrease through time.

Ammonia concentrations are all quite low although the values at Station Four are slightly higher than those at the other stations. Values of less than 0.3 ppm. using the Hach analysis method cannot be considered indicative of waste runoff.

BOD_5 values are low (1 mg./1 or less); however, there is a slight increase at Station Four on three dates and an increase throughout the length of the stream on one date.

While the above measures show higher levels at Station Four, volatile residue is at its lowest level at this point on each date. On each date there is a slight increase in percentage content at Station Two.

Bacterial analysis at Station Two on May 24 showed total coliforms at 80 and fecal coliforms at 30 per 100 ml.

While there are indications that the feedlots along this stream have some effect on water quality, such effect is quite small. It may be that field runoff is of much greater significance than that of the feedlot since there is algae present above the first feedlot as well as below it. There is also amorphic organic matter on the stream bed above Station One.

Table 6

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 5

Stream Discharge (at Station Two)

March 20	7.2 $ft.^3/sec.$
April 5	2.8
May 3	1.35
May 24	0.8
June 15	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 20	3.3	5.0	7.7	—
April 5	1.3	0.1	5.3	9.3
May 3	0.2	0.27	0.1	0.23
May 24	Trace			

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 20	3.8	4.0	3.6	—
April 5	4.0	3.8	4.0	5.6
May 3	1.1	1.8	2.0	3.0
May 24	0.53	0.53	1.0	2.6

Table 6--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 5

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 20	0.0	0.1	0.2	—
April 5	0.3	0.1	0.3	0.4
May 3	0.1	0.1	0.2	0.3
May 24	0.2	0.2	0.2	0.2

BOD_5 (mg./1)

Date	Sample Stations 1	2	3	4
March 20	0.8	1.0	1.0	—
April 5	0.5	0.4	0.2	0.6
May 3	0.4	0.4	0.4	0.9
May 24	0.3	0.7	0.8	0.9

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 20	11.2	11.4	12.5	—
April 5	29.2	31.1	30.2	26.8
May 3	38.9	39.6	50.1	33.3
May 24	22.4	23.4	22.6	20.6

3.2.6 Water Quality at Feedlot 6

This feedlot was of interest because large holding ponds have been created by the owner both above and below the feedlot and there was a larger than average number of cattle. The feedlot is part of an integrated operation with two other yards--one for cows and calves and one for yearlings. Station One was located at the outlet of a pond upstream from the feedlot area. The water from this pond flows a short distance to the holding pond which receives runoff from the area of the feedlot. Station Two was located at the outflow from this second pond. Station Three was three-eighths of a mile and Station Four was three-quarters of a mile below Station Two.

Streamflow was only 5.1 cubic feet per second during the period of maximum flow and decreased to zero by May 24. The small discharge and rapid decrease is caused in part by the holding pond which has a large capacity and contains little water prior to winter resulting in containment of much of the spring snowmelt.

Phosphorus exhibits greatest concentrations on March 20, the earliest date of analysis and decreases to almost trace levels by May 5. The level of phosphorus in water leaving the outlet of the pond is not high on any date and suggests either an absence of phosphorus in runoff from the feedlot or the effect of containment by the pond. The value of 15.0 ppm. at Station Three is likely the result of chemical interference.

Nitrogen concentrations show a distinct trend on each date of sampling. Maximum values were obtained at Station One and decrease downstream to Station Four. Only on May 24 was there an exception with a maximum value recorded at Station Two. The level of nitrogen also decreases through the spring season. The maximum values found at Station One may be accounted for by the combination cornfield and pasture above the station.

Ammonia values are similar to those of nitrite-nitrate with respect to the locations of maximum and minimum readings. Station One was again the site of greatest concentration and Station Four the site of least concentration. This supports the contention that cattle using the upstream pasture affect the quality of the stream. Ammonia values also decrease through time, although the concentrations found on the final date of sampling are relatively high--0.9 and 1.2 ppm. at Stations One and Two respectively.

BOD_5 is at a maximum at either Station One or Station Two on each day and decreases to minimum levels at Station Four. As with most other feedlot sites, there is no clear trend of change of BOD_5 levels from one day to another through the season.

Volatile residue levels in this stream support some of those trends found with the other measured stream characteristics. Maximum values are found at either Station One or Two on each date, decreasing to minimums at Station Four.

The values obtained for this stream indicate that there is a relationship between the highest values recorded and either the presence of cattle or the impoundment of runoff or a combination of both. In theholding pond at Station Two, there are algae around the perimeter and amorphic organic matter covers the bottom. In the pond above Station One, there is amorphic organic matter on the bottom but algae are almost absent. The stream below Station Two flows through occasionally used pasture land, contains little algae, and no benthic accumulation is visible.

Table 7

W A T E R Q U A L I T Y D A T A

FEEDLOT NUMBER 6

Stream Discharge (at Station Two)

March 20	5.1 $ft.^3/sec.$
April 5	1.9
May 3	0.3
May 24	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 20	1.0	1.0	15.0	3.0
April 5	3.7	0.53	0.73	1.57
May 3	0.37	0.4	0.13	0.03

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 20	3.0	1.6	1.2	1.2
April 5	2.2	1.4	0.18	0.7
May 3	0.22	0.9	0.34	0.18

Table 7--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 6

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 20	1.3	0.9	0.9	0.7
April 5	0.5	0.4	0.6	0.4
May 3	0.9	1.2	0.4	0.2

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 20	3.7	5.0	4.4	3.2
April 5	2.5	2.5	2.0	1.4
May 3	3.3	3.0	1.6	1.9

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 20	24.9	29.0	23.3	16.8
April 5	38.1	44.8	41.6	37.8
May 3	48.4	26.1	15.5	13.1

3.2.7 Water Quality at Feedlot 7

This feedlot, as with Number 6, is one of three yards operated by the owner. It is used for 'finishing' feeder cattle while the other two are for calves and yearlings. The feedlot is cleared of waste only when the cattle have difficulty moving about in the yard. Manure in a liquid state forms flows which extend half the distance from the feedlot to the stream during early spring. Drainage tile from the feedlot facilitates the flow of liquids to the stream bank and the outflow can be seen entering the stream in mid March. Station One was located 75 feet above this point of waste entry; Station Two was located 50 feet below it; and the other two stations were one-quarter and one-half mile further downstream.

Streamflow was 62.0 cubic feet per second on March 15 and decreased to 2.4 c.f.s. on July 16. The stream under normal conditions, flows throughout the year.

Phosphorus levels are highest at Stations One and Two and decrease to low levels (<1ppm.) downstream. There is also a decrease in concentration from March through July. On three dates, the level of phosphorus at Station One is greater than 1 ppm. This is caused neither by livestock waste nor field runoff as the upstream region is almost entirely marsh and woodland.

Nitrogen levels are also higher at Station One than at Station Two and cannot be accounted for by agricultural or livestock runoff. There is no trend toward lower values downstream from the feedlot. It is possible that fertilizer on cornfield that borders the stream below Station Two contributes nitrogen and thus sustains the nitrate level. Values decrease in May at all stations and remain low through summer.

Ammonia has higher than normal values on only two dates with maximums at either Station One or Station Two. Values decrease on each succeeding sample date, reaching trace levels by early May.

BOD_5 values are relatively low and vary little either from one station to another or from one date to the next.

Bacterial analysis shows the presence of 280 fecal coliforms per 100 ml. sample on March 15. This decreases to 30 per 100 ml. by May 24.

This feedlot, when viewed during March and April, shows visible signs of waste runoff. However, the values obtained for each of the measured characteristics show no such waste pollution occuring. Not only are measured values low, but obnoxious benthic deposits indicative of waste pollution are also absent and surface algae is present only in small amounts both above and below the feedlot. The sole indicator of waste presence is the fecal coliform level of 280 per 100 ml. on March 15. This decreases to 30 per 100 ml. by May 24.

Table 8

WATER QUALITY DATA

FEEDLOT NUMBER 7

Stream Discharge	(at Station Two)
March 15	62.0 ft.^{3}/sec.
March 29	45.0
April 30	16.2
May 16	4.1
July 16	2.4

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 15	1.3	14.0	0.0	0.67
March 29	3.3	3.0	0.67	0.0
April 30	1.5	1.57	0.0	0.13
May 16	0.03	0.03	Trace	
July 16	Trace			

Nitrogen $(NO_3^- + NO_2^-)$ (ppm)

Date	Sample Stations 1	2	3	4
March 15	1.2	1.8	2.2	1.2
March 29	2.2	2.0	1.2	1.0
April 30	4.3	0.3	0.34	0.52
May 16	0.28	0.22	0.18	0.54
July 16	0.26	0.24	0.21	0.40

Table 8--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 7

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 15	0.8	0.6	0.5	0.3
March 29	0.2	0.6	0.2	0.3
April 30	0.1	0.2	0.1	0.2
May 16	Trace (0.1)			
July 16	Trace			

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 15	0.7	1.5	1.2	1.0
March 29	1.3	1.4	1.5	1.3
April 30	0.9	0.9	0.8	0.9
May 16	0.9	1.0	1.2	0.7
July 16	1.0	1.1	0.8	0.6

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 15	44.1	40.6	37.9	36.1
March 29	36.0	30.9	30.7	40.4
April 30	38.8	43.5	43.2	45.3
May 16	42.2	52.4	51.3	49.3
July 16	36.4	39.1	37.7	40.2

3.2.8 Water Quality at Feedlot 8

The stream at this site was selected because of the high probability of waste content present and the likelihood that observable decreases in nutrient content would occur in the stream before it joined the Grand River. The stream is created each spring as the result of surface runoff from cultivated fields in the area and tile drainage from both the fields and the feedlot. Thus, the first sampling site on the stream is located below the feedlot and is labelled Station Two. Stations Three and Four are located at quarter-mile intervals downstream, the Fourth being at the junction of the stream with the Grand River.

Stream discharge is small due to the area of the watershed, having a maximum of only 1.4 c.f.s. on March 14 and decreasing to zero by April 30. The short period of streamflow resulted in samples being taken on only two dates.

Phosphorus values are consistently high with a maximum of 18.3 ppm. at Station Two on March 29. There is an increase in concentration at two stations on the second date of sampling. Values are erratic from one station to the next on both dates.

Nitrogen values duplicate those of phosphorus with regard to increase and decrease at each station, although there is a general decrease in concentrations at each station on the second sampling date.

Ammonia concentrations are positive indicators of animal waste presence and are at a maximum at Station One and Two on each date. It is unfortunate that the method of analysis used provides a maximum of only 3 ppm. since it was clear that some samples were far in excess of that level. The concentrations measured support the nitrogen findings and also show the effect of time and distance with values decreasing to only 0.6 and 0.8 ppm. in the second quarter mile. These concentrations of ammonia may be the cause of erratic values of nitrite-nitrate nitrogen since the breakdown of NH_4^+ will produce increases in the level of $NO_3^- + NO_2^-$.

$\underline{BOD_5}$ for March 15 was in excess of the range of analysis at all three stations, thus no downstream decrease in concentration can be observed. On March 29, diluted samples show a maximum of 12.0 mg./1 at Station Two, decreasing to 3 mg./1 at Station Four. The difference between the values at Station Four on March 29 and March 15 indicate that all of the values recorded on March 15 are considerably in excess of those found on March 29.

Volatile residue values are similar to those found at other feedlot sites representing approximately one-third of total residue. Due to the short period of streamflow, there is neither benthic material nor surface algae present.

Bacterial analysis of a sample taken at Station Two on March 15 showed a total of 60,000 coliforms per 100 ml. and 18,900 fecal coliforms per 100 ml. It is clear that waste from the feedlot is present in large concentrations and that the water is unfit for either agricultural or livestock use. While the bacteria content of this water is extremely high and nutrient levels are moderate to high for a stream in an agricultural area, it has already been pointed out that this stream is the smallest of those studied and originates in and around a feedlot receiving farm runoff exclusively.

Table 9

W A T E R Q U A L I T Y D A T A

FEEDLOT NUMBER 8

Stream Discharge	(at Station Three)
March 15	1.4 $ft.^3/sec.$
March 29	0.2
April 30	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 15	—	8.3	8.7	4.3
March 29	—	18.3	6.67	11.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 15	—	9.2	10.0	7.6
March 29	—	8.0	3.2	6.4

Table 9--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 8

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 15	—	>3.0	>3.0	0.6
March 29	—	>3.0	>3.0	0.8

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 15	—	>6.8	>6.8	>7.4
March 29	—	12.0	10.0	3.0

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 15	—	19.2	36.0	30.0
March 29	—	37.8	37.6	36.0

3.2.9 Water Quality at Feedlot 9

This feedlot was of interest because the owner was very concerned that liquids leaving the feedlot were reaching the stream 120 yards distant and had attempted to hold all of the waste solids behind wooden barriers. At the same time, drainage tile in the cornfield between the feedlot and stream facilitated the movement of liquids on the field to the stream. On the first day of sampling, the feedlot was flooded to a depth of more than one foot and both liquids and solids could be seen flowing through the barriers which had been erected.

The land in this area is quite flat and almost all of it is used for the growing of corn. Because of the topography, Station One was located 50 yards upstream from the feedlot. Station Two was located 75 yards below both the feedlot and the outlets of the drainage tile. Station Three was a quarter mile further downstream. A fourth station was omitted due to the junction of the stream with a larger drainage ditch.

Stream discharge decreased from 212.0 c.f.s. on March 15 to 1.2 c.f.s. on July 16. However, the small discharge during summer is mainly the result of decreased current, rather than a small stream cross-section. The level topography and clay loam soil result in the persistence of a relatively large stream with almost zero current.

Phosphorus is present in notable amounts only during March, with only trace levels found after that. There is no indication that the feedlot contributes to the phosphorus level. Indeed, the level at Station Two is lower on each day than the levels found above and below the feedlot.

Nitrogen values are low (<1.7 ppm.) and also show no indications of runoff from the feedlot. However, on each date there is an increase in values from Stations One to Three. This is likely brought about through runoff of nitrogen from the surrounding fields.

Ammonia is notably present from March 15 through April 30, after which time it decreases to minimal levels. There is no indication of ammonia runoff from the feedlot.

BOD_5 is the sole indicator that the feedlot exerts some effect upon stream quality. On four of the five sampling dates, BOD_5 values increased in the area of the feedlot and then decreased farther downstream. The amount of variation is small (0.1 - 1.1 mg./l), however, the trend is consistent over a five month period.

Bacterial analysis showed counts of 860 total and 340 fecal coliforms at Station Two on March 15 which also suggests the runoff of waste water from the feedlot. Fecal coliforms on April 30 had decreased to only 10/100 ml. as surface runoff ceased.

After April, surface algae began to form along the length of the stream and became dense in places by July. In areas of slow moving water, there were light coverings of benthal material across the bed of the stream.

Stream quality at this site is good in all respects except bacterial content. As with all streams, the highest values are recorded during March when surface runoff from all sources enter the stream and, along with benthic load, is flushed from the area. The consistent presence of maximum BOD_5 values at Station Two, along with a large number of fecal coliforms indicates that liquid waste from the feedlot does enter the stream but with little effect on overall stream quality.

Table 10

WATER QUALITY DATA

FEEDLOT NUMBER 9

Stream Discharge	(at Station Two)
March 15	212.0 $ft.^3/sec.$
March 29	172.0
April 30	32.0
May 16	6.0
July 16	1.2

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3
March 15	11.7	1.0	3.3
March 29	2.0	1.67	5.67
April 30	0.0	0.07	0.13
May 16	Trace (0.1)		
July 16	Trace		

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3
March 15	1.0	1.0	1.1
March 29	1.4	1.4	1.7
April 30	0.2	0.22	0.26
May 16	0.24	0.18	0.3
July 16	0.18	0.2	0.24

Table 10--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 9

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3
March 15	0.5	0.5	0.4
March 29	0.4	0.4	0.3
April 30	0.6	0.5	0.6
May 16	0.1	0.1	0.1
July 16	0.1	0.1	0.1

BOD_5 (mg./l)

Date	Sample Stations 1	2	3
March 15	1.0	1.8	1.1
March 29	0.8	2.0	0.9
April 30	0.7	1.0	0.7
May 16	1.5	1.2	1.7
July 16	1.1	1.3	1.2

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3
March 15	38.3	36.5	55.4
March 29	34.8	35.5	32.8
April 30	56.4	60.1	53.6
May 16	53.4	50.6	53.1
July 16	42.5	40.3	45.8

3.2.10 Water Quality at Feedlot 10

This feedlot contains fewer cattle than most others; however, it was one of the few feedlots with a soil rather than a concrete floor and it also abuts the stream channel. The major interest on this farm is cash cropping of corn with cattle providing a small portion of the total income. Nevertheless, the feedlot receives adequate attention with waste removed to the lower end of the yard to provide a clean floor in the immediate area of the barn.

The stream at this site is similar to that at Feedlot 9 in that it flows through an area of level topography and cornfield borders the stream for several miles both up and downstream from the feedlot. Station One was located 60 feet upstream from the feedlot; Station Two was 100 feet downstream and Stations Three and Four were one-quarter and one-half mile below the feedlot. No sample was collected from Station Four on March 15 because a large volume of water from another drainage ditch was running into the study stream below Station Three on this date.

Phosphorus values are at noticeable levels on only the first two dates with high readings recorded at Station Three and Four on March 29.

Nitrogen concentration increases slightly at Station Two on all of the sampling dates and indicates the presence of nitrite or nitrate running into the stream from the feedlot. The maximum nitrogen level (2.6 ppm.) was recorded on March 15, the first sampling date, and while the level is reasonably constant throughout the study period, there is a gradual decrease of 0.6 ppm. from the first date to the last.

Ammonia values are quite low even at their maximum (0.3 ppm.) but two trends are apparent. There is a decrease from Station One through Station Four on two of the four days with the other two days showing constant levels. There is also a decrease in values through time.

BOD_5 is reasonably constant in value from one date to the next although not always at the same stations. Values are lowest either at Station One or Station Two on each date and increase downstream from those points with maximum values found at Station Four on each date. The maximum value recorded was 1.5 mg./l and indicates only light contamination.

Bacterial analyses were made of two samples. These showed total coliforms of 1,700 and fecal coliforms of 730/100 ml. on March 15 which decreased to 280 and 10 on April 30. This amount of bacteria, particularly of fecal type, is a strong indication of waste from the study feedlot although it decreases rapidly through the season. Surface algae appeared in mid May and grew to cover what remained of the stream in June. Benthic material was not visible.

It would appear that both BOD_5 and bacterial analysis confirm the fact that livestock waste does enter this stream from the feedlot, and that the level of fecal contamination during March makes the water unfit for any agricultural use. All measures other than bacterial, however, indicate only slight pollution and little connection between such pollution and the feedlot.

Table 11

WATER QUALITY DATA

FEEDLOT NUMBER 10

Stream Discharge (at Station Two)

March 15	42.0 $ft.^3/sec.$
March 29	17.1
April 30	7.1
May 16	1.47
July 16	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 15	0.0	1.0	1.67	—
March 29	0.9	0.7	5.0	16.7
April 30	0.3	0.2	0.0	0.0
May 16	0.0	0.0	0.0	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 15	2.2	2.6	2.6	—
March 29	2.0	2.2	2.4	2.4
April 30	2.0	2.2	2.2	2.1
May 16	1.6	2.0	2.0	2.0

Table 11--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 10

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 15	0.3	0.3	0.2	—
March 29	0.2	0.2	0.1	0.0
April 30	0.2	0.0	0.2	0.0
May 16	0.1	0.1	0.2	0.1

BOD_5 (mg./1)

Date	Sample Stations 1	2	3	4
March 15	0.6	1.1	1.4	—
March 29	0.9	1.5	1.4	1.4
April 30	0.6	0.6	0.8	1.2
May 16	1.0	0.9	1.2	1.2

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 15	27.4	35.7	29.4	—
March 29	23.2	22.1	18.3	19.0
April 30	34.4	31.3	42.7	42.6
May 16	51.2	48.1	53.0	49.5

3.2.11 Water Quality at Feedlot 11

This is one of the most efficiently run feedlots found in the study region. Large investments have been made over the past several years on new feeding facilities, barn and silos. Cleaning of the yard is carried out several times a week with the waste removed to a flat area away from the slope to the stream. In spite of the regular cleaning, liquids can be seen flowing half the distance to the feedlot during March. There are several lines of drainage tile in the field between the feedlot and stream and these likely facilitate the movement of waste liquid to the stream.

The stream runs through cultivated fields (mostly corn) for several miles above the feedlot. Station One was located 0.20 miles above the feedlot in order to avoid any contact with yard wastes running off through drainage lines. Station Two was 200 feet downstream from the feedlot and Stations Three and Four were 0.25 and 0.5 miles below the feedlot. Between Stations Three and Four, there are ten homes with septic tanks near the stream. These homes are a potential source of sub-surface sewage movement.

<u>Phosphorus</u> was present in the stream samples only on March 11 and March 29. Following March 29, the concentration of phosphorus drops to zero at all stations. The values found on both March 11 and 29 show the lowest concentrations at Station One, increases beginning at Station Two and reaching maximums at Station Three and then decreasing at Station Four. The levels are higher than those found at

most other sites and certainly much more ordered, indicating the strong influence of the feedlot. It is interesting to note that the decreased values found on March 29 are uniform through the length of the stream.

Nitrogen values vary between 2.0 and 4.2 ppm. and show no trends through either space or time. Where phosphorus reached zero in April, nitrogen remained in the stream at a constant level through the last date of analysis. Land-use ranges from cornfield at Stations One and Two where manure and commerical fertilizer are applied to woodland at Station Three and residential at Station Four.

Ammonia values were relatively high (0.7 - 1.2 ppm.) at three stations on March 11 and at one station on March 29. There is no connection between these high values and the location of the feedlot. All values after March 29 are in the low 'clean' water range.

BOD_5 concentration is greatest on the first sampling date and decreases thereafter. Maximum concentrations are above average for the streams studied and occur in places of field runoff as much as in the livestock region of the stream.

Bacterial analysis of a sample collected at Station Two on March 11 showed 76,000 total coliforms and 2,000 fecal coliforms per 100 ml. By April 30, these figures had dropped to 3,000 and 60 respectively. These, however, are still beyond the recommended limits set for water for agricultural and livestock purposes by the Ministry of the Environment.

During May and June there was no noticeable build-up of benthic material; however, algae was dense throughout the length of the stream.

Obviously, there is farm runoff occuring in the area of this feedlot. The factors measured indicate that both field runoff (nitrogen, BOD_5) and cattle wastes (phosphorus, bacteria) are contributing to inferior water quality. Values other than bacteria, however, are not excessive in terms of water quality standards set for agricultural use by the Ontario Ministry of the Environment.

Table 12

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 11

Stream Discharge (at Station Four)

March 11	139.0	$ft.^3/sec.$
March 29	54.0	
April 30	9.8	
May 16	2.2	
July 16	0.0	

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 11	6.0	7.67	15.0	12.7
March 29	6.0	6.3	14.0	11.7
April 30	0.0	0.0	0.0	0.0
May 16	0.0	0.0	0.0	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 11	3.9	3.0	2.8	3.0
March 29	3.9	4.2	3.3	3.8
April 30	2.2	2.0	2.1	2.4
May 16	4.2	3.2	3.4	2.8

Table 12--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 11

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 11	0.9	0.7	0.3	0.8
March 29	0.2	0.2	1.2	0.1
April 30	0.1	0.2	0.2	0.2
May 16	0.3	0.3	0.2	0.2

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 11	4.7	5.3	3.5	3.1
March 29	1.6	1.5	2.2	3.5
April 30	1.3	1.4	0.6	0.5
May 16	1.5	0.7	0.6	0.6

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 11	18.7	18.4	19.2	20.6
March 29	31.7	32.9	32.0	25.0
April 30	43.5	37.4	45.6	42.5
May 16	38.9	39.2	42.4	38.2

3.2.12 Water Quality at Feedlot 12

As with several other feedlots in the study, this feedlot was situated on the banks of a relatively small stream (48.5 c.f.s. max.). Although manure is scraped from the yard regularly, it is left near the stream. Several factors exist at this site which may confuse any study of runoff. Station One was located 200 feet above the feedlot in a stretch of fast flowing water. Station Two was situated 0.25 miles downstream from the feedlot and in a broad slow flowing and marshy area. The location of Station Two was placed here because a second, smaller feedlot was located below the study feedlot and, although it is set a considerable distance back from the stream, any runoff from it had to enter the stream above Station Two. Station Three was located 0.25 miles below Station Two and at the lower end of the marshy area. Station Four was a further 0.25 miles downstream. Pasture borders the stream and marsh from Station One to Four. As time passed at this site, there was an increase in the growth of marsh biota and a decrease in current--a situation with great potential for affecting nutrient values.

Phosphorus was found to be present in significant amounts on only the first two sampling dates after which the concentration fell to zero in almost all instances. The values found on March 11 show an increase at Stations Two and Three and a decrease at Station Four. Values for March 29 are erratic with no relationship to the feedlot (Station Two).

Nitrogen concentrations on each date show no feedlot influence and the ranking of station values changes from one date to the next. It is clear that there is a decrease in concentration after March 29 to very low levels.

Ammonia shows significant levels only during the month of March when the highest readings were found at Stations One and Two. There is a decrease through the marsh and a slight increase again on one date at Station Four in a pasture area.

BOD_5 also is at maximum levels during early March and shows an increase below the feedlot and a decrease below the marsh. Values decrease after March to insignificant levels.

There is very little indication from the values obtained that the feedlot exerts any influence upon this stream. Nor can it be said that the marsh area consistently absorbs or adds nutrients to the stream since, for each factor measured, the ranking of concentrations along the stream change at each station from one date to the next.

However, while this feedlot appears to have no effect on stream quality according to the above characteristics, bacterial analysis showed the highest concentrations of coliforms found in any of the study streams--120,000 total coliforms/100 ml. and 30,000 fecal coliforms/100 ml. These levels, found at Station Two on March 11, are positive indicators of livestock waste drainage. A second sample analyzed on April 30 showed decreases to 1,000 total and 30 fecal coliforms/100 ml.

According to the values obtained for each characteristic, it appears that the feedlot has little effect upon water quality save for the runoff of bacteria. Bacteria, however, is present in extreme quantities in early March and poses a definite health threat to man and animals.

Table 13

WATER QUALITY DATA

FEEDLOT NUMBER 12

Stream Discharge (at Station Two)

March 11	48.5 $ft.^3/sec.$
March 29	22.4
April 30	11.1
May 16	6.0
July 16	1.8

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 11	2.3	5.0	14.7	10.0
March 29	16.7	0.4	4.3	6.7
April 30	0.0	0.0	0.1	0.1
May 16	0.0	0.3	0.0	0.0
July 16	0.0	0.0	0.0	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 11	2.8	3.0	0.8	2.1
March 29	2.0	1.2	4.0	2.0
April 30	0.0	0.0	0.0	0.21
May 16	0.76	0.1	0.15	0.32
July 16	0.2	0.0	0.1	0.22

Table 13--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 12

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 11	1.5	1.6	1.0	0.4
March 29	0.4	0.3	0.0	0.2
April 30	0.2	0.1	0.2	0.1
May 16	0.1	0.2	0.2	0.1
July 16	0.1	0.1	0.1	0.1

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 11	1.3	3.8	1.1	1.4
March 29	0.7	0.5	1.3	0.4
April 30	0.5	1.8	0.5	0.3
May 16	0.1	0.2	0.2	0.1
July 16	0.1	0.1	0.2	0.1

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 11	31.6	17.2	14.9	24.9
March 29	36.2	32.5	23.8	31.1
April 30	44.2	41.0	39.8	39.5
May 16	35.1	18.7	20.5	22.6
July 16	33.7	20.2	19.1	20.7

3.2.13 Water Quality at Feedlot 13

This feedlot, unlike others that have been adapted from mixed farming operations, was constructed solely for the purpose of finishing feeder cattle. To facilitate care of the yard, features such as a sloped concrete floor with drains and raised platform for the scraping of wastes directly into spreader or truck have been built into the feedlot. Obvious, too, is the interest of the owner in frequent and safe disposal of wastes. The feedlot floor rarely has more than several inches of waste on it and during winter, manure is spread on those fields farthest from the stream.

This stream is the largest of those selected for the project and accurate measurement of discharge during March was difficult due to fast current and ice conditions. Because the point of potential waste entry was difficult to determine, Station One was located 1,000 feet upstream from the feedlot and Station Two was 200 feet downstream from the feedlot. Stations Three and Four were located 0.25 and 0.5 miles downstream from Station Two. No sample was taken from Station Four on March 6 because an area of 30 acres was flooded at that point. Ammonia and BOD_5 were not analyzed on March 6 as the laboratory equipment was not available.

Values recorded at this site for phosphorus, nitrogen, ammonia, and BOD_5 were low even on the first date of analysis and indicate no runoff from the feedlot or any other source that degrades the quality of water at any of the stations. Phosphorus and nitrogen show irregular variations within a low range and there is also a decrease at this low range from March 6 to July 20. Ammonia and BOD_5 also show irregular variations at a low level of concentration, however there is no decrease through time.

Bacterial analysis showed total and fecal coliform counts of 52,000 and less than 1,000 per 100 ml. respectively on March 6. These measures decreased to 300 total and less than ten fecal on March 27. More accurate measures of fecal coliforms were not made due to apparent laboratory priorities and time restrictions on this date.

In addition, the stream is aesthetically attractive with no visible benthic accumulation and an almost entire absence of algae. Subsequent to the heavy runoff during March and April, the water is clear and fish are present.

Table 14

WATER QUALITY DATA

FEEDLOT NUMBER 13

Stream Discharge (at Station Two)

March 6	> 400.0 $ft.^3/sec.$
March 27	376.0
April 25	119.0
May 10	53.6
July 20	11.2

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 6	2.3	2.0	3.0	—
March 27	0.6	0.23	0.13	0.9
April 25	0.43	0.27	0.37	0.17
May 10	0.0	0.0	0.3	0.0
July 20	0.0	0.0	0.1	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 6	1.2	1.0	1.2	—
March 27	1.0	5.2	0.66	0.58
April 25	0.56	0.5	0.38	0.52
May 10	0.26	0.27	0.26	0.34
July 20	0.12	0.1	0.19	0.14

Table 14--Continued

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 13

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 6	—	—	—	—
March 27	0.1	0.0	0.2	0.1
April 25	0.1	0.1	0.2	0.2
May 10	0.2	0.2	0.2	0.2
July 20	0.1	0.2	0.2	0.1

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 6	—	—	—	—
March 27	1.2	0.6	0.7	0.4
April 25	0.9	1.1	1.0	1.3
May 10	1.0	1.1	1.1	1.0
July 20	0.9	1.0	0.9	0.7

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 6	—	30.9	—	—
March 27	47.0	48.1	46.6	33.2
April 25	41.4	37.6	39.0	26.7
May 10	39.5	40.2	45.3	42.1
July 20	38.3	36.1	38.2	35.3

3.2.14 Water Quality at Feedlot 14

This feedlot is situated on the crest of a hill and runoff to the nearby stream has been of considerable concern to the owner, who has received complaints from the Department of the Environment several times in the past. The feedlot is kept only moderately clean with large amounts of waste occasionally left in the yard. Disposal of manure is made to surrounding fields during winter and these fields are quite susceptible to erosion during spring because of the rolling topography. Manure in aqueous flows can be seen during March and April and extend one-third of the distance from the feedlot to the stream.

The stream is relatively small, and flows only until mid May. Station One was located 200 feet upstream from the feedlot because drainage appeared to flow over a broad area. Station Two was 100 feet downstream from the feedlot drainage area; Station Three was 0.25 miles below the feedlot and Station Four was 100 feet downstream from Station Three. Station Four was located close to Station Three because a second stream joined the study stream between the two stations. The study stream is bounded by cornfield above the first station and by woodland below that point.

Phosphorus values do not indicate any additions from the feedlot area. They change from one station to another showing no trend of increase or decrease through the length of the stream. Values decreased through the time period of the study, approaching zero on May 10.

Nitrogen also shows a decrease in concentration through time going from a maximum value of 1.8 ppm. on March 6 to zero on May 10. As with phosphorus, there is no indication that the feedlot contributes nitrogen to the stream--the only notable increase occurs at Station Three, one-quarter mile below the feedlot.

Ammonia, on all of the dates of analysis shows additions at the site of the feedlot. Values increase at Station Two and then decrease downstream through Stations Three and Four. The concentration of ammonia decreases through time as runoff from the feedlot area decreases.

BOD_5 increases at Station Two on two of the three sampling dates indicating the presence of waste runoff. There are, however, maximum values found at Stations One and Four on May 10 which may be the result of late season ponding of the stream at Station One and the pasturing of cattle in the area below Station Three.

Bacterial analysis showed the presence of 5,000 total coliforms and <1,000 fecal coliforms per 100 ml. on March 6. Bacterial content decreased by March 27 to 410 total and 140 fecal coliforms per 100 ml. These figures also indicate that waste from the feedlot is entering the stream. In addition, the stream contains large algae growths throughout its length by late April and amorphic organic material covers the stream bed in the area of Station Two.

It appears from the values found for ammonia, BOD_5, and bacteria, that the feedlot does contribute waste runoff to the stream and causes a deterioration in water quality.

Table 15

WATER QUALITY DATA

FEEDLOT NUMBER 14

Stream Discharge (at Station Two)

March 6	3.1 ft.^{3}/sec.
March 27	0.5
April 25	0.1
May 10	0.04
May 20	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 6	3.3	1.0	7.67	2.67
March 27	0.23	0.4	0.63	0.23
April 25	0.1	0.5	0.53	0.2
May 10	0.13	0.0	0.3	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 6	1.0	1.1	1.8	1.8
March 27	0.6	0.35	0.38	0.58
April 25	0.1	0.0	0.0	0.0
May 10	0.1	0.0	0.1	0.22

Table 15--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 14

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 6	—	—	—	—
March 27	0.1	0.7	0.6	0.3
April 25	0.0	0.5	0.2	0.2
May 10	0.1	0.3	0.0	0.0

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 6	—	3.6	—	—
March 27	1.1	5.3	1.8	0.7
April 25	0.9	3.9	1.8	3.7
May 10	2.3	0.8	0.3	2.3

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 6	—	15.8	—	—
March 27	20.5	23.2	22.3	26.6
April 25	23.6	27.6	23.9	31.6
May 10	25.3	36.8	33.7	35.9

3.2.15 Water Quality at Feedlot 15

Old buildings, poorly adapted to livestock use, hamper efficient waste removal from this feedlot. Manure is removed from the yard only after it reaches a depth of a foot and is piled on the slope below the feedlot or is spread directly onto fields. Tiles installed to aid field drainage in the area between the feedlot and the stream also may carry liquid wastes from the feedlot.

The stream runs through cornfield above the feedlot and pasture below it. Station One was located 0.2 miles above the feedlot because the point of potential waste entry was not obvious. Station Two was located 300 feet downstream from the feedlot with Stations Three and Four a further 0.25 and 0.5 miles downstream.

Phosphorus concentrations are highly variable and show a maximum value at Station Two on only one date (March 6). Values on two subsequent dates show the highest values at Station One and these decrease downstream. Phosphorus concentration decreases to zero by May 10.

Nitrogen values are indicative of both field and feedlot runoff. Values at Station One, in an area of fertilized cornfield, are highest of the group on one date and second highest on the other three dates. On those latter three dates, the concentration increases at Station Two downstream from the feedlot. Values decrease rapidly below Station Two as the stream runs through sparsely used pasture. As at some other feedlot sites, there is no decrease in concentration through time.

<u>Ammonia</u> concentration is highest above the feedlot on two sample dates and decreases downstream. On March 27, there is a high value at Station One which decreases downstream past the feedlot and then increases again at Station Four.

<u>BOD_5</u> also showed high values above the feedlot which increased on two dates at Station Two. Downstream values were considerably lower on two of the three sampling dates. Concentrations on May 10 were relatively uniform along the length of the stream with the highs at Stations One and Two eliminated.

<u>Bacteria</u> levels of $<$2,000 total coliforms and 1,000 fecal coliforms on March 6, decreasing to 1,360 total coliforms and 200 fecal coliforms on March 27 are the major indicators of livestock waste presence in the stream. These values were recorded at Station Two where there was also a heavy benthic covering of the stream bed and a dense algae mat.

The high readings obtained at Station One for some of the characteristics measured are difficult to account for since there are no livestock operations above that point and some of the land is not cultivated and thus not as susceptible to erosion. The readings obtained at Station Two do indicate that runoff from the feedlot area has an adverse effect upon water quality.

Table 16

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 15

Stream Discharge (at Station Two)

March 6	20.2 $ft.^3/sec.$
March 27	3.2
April 25	1.5
May 10	0.8
May 20	0.0

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3	4
March 6	0.67	1.67	1.3	1.0
March 27	16.7	4.0	0.87	0.83
April 25	0.2	0.2	0.0	0.13
May 10	0.0	0.0	0.0	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3	4
March 6	3.0	4.0	2.0	1.8
March 27	5.0	6.0	0.84	1.2
April 25	5.1	4.8	0.21	0.14
May 10	3.7	4.2	0.18	0.2

Table 16--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 15

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3	4
March 6	—	—	—	—
March 27	0.4	0.3	3.0	0.6
April 25	0.4	0.2	0.2	0.1
May 10	0.1	0.1	0.0	0.0

BOD_5 (mg./l)

Date	Sample Stations 1	2	3	4
March 6	—	5.0	—	—
March 27	5.0	6.0	0.84	1.2
April 25	5.1	4.8	0.21	0.14
May 10	1.1	1.9	1.4	1.4

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3	4
March 6	—	10.3	—	—
March 27	27.4	29.7	26.0	24.7
April 25	38.5	37.5	26.0	24.7
May 10	38.1	38.1	36.2	34.6

3.2.16 Water Quality at Feedlot 16

This feedlot is situated on level ground adjacent to a steep slope leading to a stream of larger than average discharge. As at Feedlot 13, the depth and fast current of this stream prevented an accurate measurement of discharge on March 6. The feedlot floor, when viewed in late February, was covered with almost a foot of frozen liquid waste. This forzen waste extended out for some distance from the feedlot yard with decreased thickness.

The feedlot is cleaned only occasionally and usually contains a large amount of waste. During March, when frozen waste began to thaw, the entire area around the feedlot was flooded with liquid waste and the volatilizing ammonia created an obnoxious odour for hundreds of yards around the feedlot. Due to the level topography of the feedlot area, this waste remained at the site rather than running off. On some date between March 27 and April 25, the owner cut a channel through the bank between the feedlot and the stream allowing all of the waste liquid to drain rapidly into the stream and the effects of this runoff on the stream could not be measured. As a result, the data for this feedlot is not representative of all of the runoff that did take place during the spring.

Station One was located 100 feet upstream and Station Two was located 200 feet downstream from the feedlot. Station Three was located 0.3 miles below the feedlot and a fourth station was omitted because the runoff from a pig farm was visible below Station Three. The stream is bounded throughout by cornfield.

<u>Values for all factors measured</u> are low when compared to those found in other streams used for the study. Also, each decreases in concentration through time. None of the water quality characteristics measured showed any consistent trend of increase at Station Two.

While the values indicate very little feedlot runoff, the stream appears visually to be of very poor quality. There is a thick covering of benthic material on the stream bed throughout its length and there are many aquatic invertebrae in this material. Algae is absent from the stream surface. It is clear that the data presented in the accompanying tables do not represent the full effects of the study feedlot. Of particular note are the low bacterial counts of 930 total coliforms and 40 fecal coliforms per 100 ml. which were recorded on March 27. The release of the large volume of liquid and semi-aqueous waste from the feedlot between the two sampling dates mentioned no doubt was extremely detrimental to the quality of the stream and much higher values for all of the characteristics measured and particularly that of bacteria would have been recorded had the writer known of the waste release and taken samples at that time.

Table 17

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 16

Stream Discharge (at Station Three)

March 6	>300.0 $ft.^3/sec.$
March 27	95.0
April 25	22.5
May 10	11.0
July 20	4.2

Phosphorus (P) (ppm)

Date	Sample Stations 1	2	3
March 6	—	—	—
March 27	1.0	1.3	1.0
April 25	0.0	0.1	0.23
May 10	0.2	0.0	0.0
July 20	0.0	0.0	0.0

Nitrogen ($NO_3^- + NO_2^-$) (ppm)

Date	Sample Stations 1	2	3
March 6	—	—	—
March 27	1.9	1.0	1.1
April 25	0.54	0.66	0.44
May 10	0.32	1.9	1.0
July 20	0.19	1.1	0.7

Table 17--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 16

Ammonia (NH_4^+) (ppm)

Date	Sample Stations 1	2	3
March 6	—	—	—
March 27	0.6	0.2	0.4
April 25	0.1	0.1	0.1
May 10	0.0	0.0	0.1
July 20	0.0	0.0	0.0

BOD_5 (mg./l)

Date	Sample Stations 1	2	3
March 6	—	5.4	—
March 27	1.0	1.0	1.1
April 25	2.0	1.9	1.7
May 10	0.2	0.3	0.6
July 20	0.2	0.3	0.2

Volatile Residue as % of Total Residue

Date	Sample Stations 1	2	3
March 6	—	22.8	—
March 27	18.0	21.4	20.5
April 25	29.4	29.1	33.0
May 10	36.1	31.4	37.0
July 20	30.2	33.4	29.5

3.2.17 Water Quality at Feedlot 17

This feedlot was selected because of its location on a hill leading down to a stream of moderately large discharge. The piling of manure on the slope and the semi-aqueous flows of waste beyond the feedlot indicated that there might be some adverse effect upon stream quality. Unfortunately, the creation of a reservoir below the feedlot in mid March resulted in heavy flooding around the feedlot and thus eliminated the stream and made further study impossible. Values for March 6, the only date on which samples were collected, are included and indicate that water quality is better than the average found in the sample group.

Table 18

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 17

Date: March 6

Stream Discharge (at Station Three) 209 ft^3/sec.

	Sample Stations 1	2	3	4	
Phosphorus (P)	1.0	0.67	0.67	0.6	ppm
Nitrogen (NO_3^- + NO_2^-)	2.0	2.0	4.0	2.0	ppm
BOD_5		5.6			mg./l
% Volatile Residue		13.8			

3.3 Summary of Spring Runoff Analysis

The foregoing values indicate that all of the study streams receive runoff containing greater than normal concentrations of nutrients and bacteria during the spring runoff period, although not necessarily at the location of the feedlot. The concentrations are greatest during the initial stages of runoff and tend to decrease gradually beginning in April. In many cases, this decrease proceeds until only trace levels can be found of some of the nutrients. Concentrations of the various characteristics are highly variable from one stream to another.

Concentration profiles indicate that nutrient runoff occurs from both cultivated fields and livestock operations. Since some of the factors measured, most notably phosphorus and nitrogen (nitrate), occur in both locations, it is difficult to adequately isolate the effect of each type of runoff. Fecal coliforms, however, occur only in waste runoff and prove the detrimental effect of livestock on most of the streams studied.

According to the few water quality criteria that apply to these streams, none can be said to be beyond permissible levels of contamination for any of the characteristics measured save fecal bacteria (Ministry of the Environment, June, 1973). Since bacterial analysis of streams is not usually included as an integral component of stream analysis, the foregoing values found for fecal coliforms suggests that such analysis is necessary during spring because it may be the most reliable for the detection of livestock waste pollution.

Those feedlots which show significant inputs of livestock waste to the streams in their area (feedlots 1, 8, 10, 11, and 15) have one factor in common which sets them apart from the rest of the feedlots in the study group. Each is situated in very close proximity to the stream or has drainage tile laid close to the feedlot which facilitates the movement of liquids to the stream. Distance to a drainage channel appears to be the only observable factor operative in this group. Since there is rapid change in the state of some nutrients (e.g., ammonia) and chemical bonding occurs with others (e.g., phosphorus), it is likely that any delay in the runoff of waste products results in a great decrease in nutrient concentration before the waste reaches the stream. The number of cattle found at any site no doubt has an effect upon the amount of runoff as does the yard cleaning practices of the owner; however, these factors vary greatly among those feedlots with runoff and a much larger sample group would be necessary in order to draw conclusions on the effect of those factors.

The effect of downstream movement on nutrient concentration is obvious at those feedlots where high concentratiosn were recorded. Feedlot 1 is a particularly good example of decreasing concentrations downstream for all of the water properties measured. Within a half-mile distance downstream from the feedlot, there is an almost geometric decrease for some of the higher values recorded. This decreasing trend downstream is apparent at most of the sites used.

Data on the per cent of volatile residue contained in total residue proved to be of little value. In most cases, values were erratic with few identifiable trends through either time or distance. The measurement of volatile residue is carried out only occasionally in water quality studies because the interpretation of results cannot be made with a high degree of reliability. "In cases where the organic content of water is important it is usually best to obtain such information by means of a COD or BOD determination." (Sawyer, 1960, p. 305)

3.4 Water Quality Variation During Summer Runoff

The main question to be examined during the summer period was whether or not manure which had become dehydrated with high temperatures and low rainfall and which, in many cases, had been pulverized in the feedlot, would rapidly be taken into suspension by runoff from thunderstorms and degrade the quality of the nearby streams. Since this type of study involved much more difficult scheduling, only five feedlots from the original group of seventeen used in the spring study were selected. The feedlots selected were numbers 1, 2, 6, 11, and 15. The reasons for this selection have been discussed in Chapter II and stem from either the level of contamination found at the site during the spring or conditions at the site during summer which seemed to indicate that there was significant potential for waste runoff during and after heavy rains.

The water quality properties analyzed were orthophosphate, nitrite-nitrate nitrogen, ammonia, BOD_5, and volatile residue. Bacterial analysis was planned for, but difficulties in returning samples to the laboratory on a day of the week when they could be analyzed made it impossible. Measurement of rainfall was made with standard rain gauges which were checked and emptied periodically by both the writer and the farmers involved.

Collection dates of samples during the summer were determined by the amount of rain received and resulting stream discharge at each site. This, of course, necessitated constant monitoring through the study period of June and July. Since the rain at that time of the year is usually convectional and therefore local and short-lived, the daily reports of Atmospheric Environment Services could not be relied upon for more than a statement of general regional conditions. Therefore, it was necessary to telephone the farmers themselves in many cases in order to better predict the amount of rainfall and resulting stream discharge. Rain, however, occurred most often during the night, eliminating the farmer as an information source.

Precipitation in the study region during July and August was below normal, in some cases, extremely so. Table 2 lists the precipitation values for four weather stations within the study area. The small amount of rainfall that occurred throughout most of the study area during July is not indicated at all sites in the table, but Bradford-Springdale and Orangeville show low values representative of the situation in the study region. The owner of Feedlot 11 also reported that precipitation was only one-third of the usual amount in his area and other owners also reported below average amounts of rain. Because of the small amount of rain in July, it was necessary to continue monitoring the weather through August in the hope that some heavy rains would occur. Unfortunately, at most sites rainfall did not increase. Totals for August for the four stations within the study area do indicate more rainfall but the totals represent local occurrences beyond the region of the study farms.

The lack of rainfall comlicated the study in several ways. When the study streams were first selected, an approximation of the date of their minimum or final flow was obtained and most streams reached zero discharge well before the predicted dates. According to some farmers, wells too were below normal levels by August. Also, crops were greatly in need of moisture. Because of the high temperatures and shortage of water, grain in some areas was ripening several weeks ahead of schedule.

These conditions exaccerbated the problem of sample collection for while solid wastes had reached the point where they would easily be carried into suspension, most of the rain that did fall went to the immediate needs of the crops and rapidly infiltrated the soil to recharge the water table. Thus only very heavy and short duration thunderstorms re-established streamflow in the dry channels.

For these reasons and several others which pertain more to local site conditions, the measurement of water quality was carried out on only four different occasions and involved only three of the five feedlots.

Three tables of data represent samples which were collected in June from feedlots 11 and 15 and the fourth set was collected from Feedlot 2 during July. It should be made clear that the four sample sets presented do not represent the number of visits made to the various sites during the summer. On numerous occasions, heavy rains were predicted and the writer went to the sites in order to obtain samples of the initial runoff. However, the rain either failed to materialize in the immediate area or was not of sufficient duration or intensity to bring about streamflow.

With regard to Feedlots 1 and 6 at which no samples were collected, there were several occasions on which runoff did occur from Feedlot 1, however these were discovered after the fact. The amount of runoff was small--a fact which could be derived from the stream bed which was dry on the days following the rain and the ponding of all of the discharge in a marsh which had developed during May and June. No runoff ever occurred at Feedlot 6 as the level of water in the holding pond was very low and all runoff was contained.

In the tables which follow, the 'hour' column indicates the number of hours elapsed since the first rain on that date. It was unfortunate that the length of time spent at each site combined with the days of the week on which samples were collected prevented analysis of bacterial content--a factor found very useful during the spring period.

3.4.1 Water Quality at Feedlot 15--June 17, 1973

As indicated in Table 1, this feedlot is situated 160 yards from the stream but drainage tile is present running from the feedlot area to the stream. The stream also receives runoff from cornfield from above Station One to Station Two. Below Station Two, the stream runs through seldom used pasture.

Rainfall on this date amounted to 0.85 inches and fell over a three hour period. The stream, which had ceased to flow in late May but still contained numerous algae cover ponds, began flowing shortly after rainfall had commenced. The flow, which reached a maximum of 0.15 c.f.s. an hour after the end of the rain, carried large pieces of surface algae which were purposely excluded from the samples. At three points between Stations One and Two, field drainage could be seen running from tiles into the stream. Another of these field drains could be seen running at a point 200 feet upstream from Station One.

Phosphorus exhibits highest values at Station Two during each time period. Values below Station Two decrease as the stream runs through grassland. Phosphorus is at quite low levels throughout the period but does show an increase between hours two and four. The higher concentration was maintained through hour six.

Nitrogen also exhibits an increase in concentration at Station Two with decreases through Stations Three and Four.

Maximum concentrations were recorded during hour four at each station and decreased through hour six.

Ammonia was consistently low in concentration, showing no significant changes through time. The lowest values recorded were at Station Four, one-half mile downstream from the feedlot. Since ammonia undergoes rapid change to form both NO_3^- + NO_2^-, or is lost to the atmosphere as NH_3 gas, it would not be surprising to find low ammonia concentrations even at sites where waste is clearly entering a stream. At this time of the year, the waste remains around the feedlot long enough for the ammonia to be transformed before runoff occurs.

BOD_5 concentrations are greatest at the feedlot; however, the value recorded at Station One is higher than that at Station Three and indicates the possibility that field runoff accounts for much of the concentration. Values decrease through the downstream pasture area. Unlike either phosphorus or nitrogen, BOD_5 increases between hours four and six when runoff and discharge are decreasing.

The concentrations of phosphorus and nitrogen indicate clearly that runoff is occurring from the feedlot area and that concentrations increase and decrease with discharge under the rainfall conditions that prevailed on this date.

Table 19

WATER QUALITY DATA

FEEDLOT NUMBER 15

Date: June 17, 1973   Precipitation: 0.85 inches

Stream Discharge

Hour	
0	0.0 ft.^{3}/sec.
2	0.08
4	0.15
6	0.09

Phosphorus (P) ppm

Hour	Sample Stations 1	2	3	4
2	0.2	0.4	0.2	0.1
4	0.3	0.6	0.4	0.2
6	0.3	0.5	0.4	0.2

Nitrogen ($NO_3^- + NO_2^-$) ppm

Hour	Sample Stations 1	2	3	4
2	0.2	2.4	2.4	1.8
4	1.9	4.1	3.8	2.0
6	1.4	3.8	2.7	2.0

Table 19--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 15

Date: June 17, 1973 Precipitation: 0.85 inches

Ammonia (NH_4^+) ppm

Hour	Sample Stations 1	2	3	4
2	0.1	0.2	0.2	0.0
4	0.2	0.2	0.1	0.0
6	0.2	0.2	0.2	0.1

BOD_5 mg./l

Hour	Sample Stations 1	2	3	4
2	1.1	1.7	1.3	1.1
4	1.5	1.8	1.1	1.2
6	1.9	2.1	1.2	1.3

Volatile Residue as % of Total Residue

Hour	Sample Stations 1	2	3	4
2	29.8	36.4	36.8	32.0
4	27.2	30.1	33.7	34.3
6	22.4	32.7	34.5	28.1

3.4.2 Water Quality at Feedlot 15--June 28, 1973

Rainfall on this day also occurred as a sudden thunderstorm with the major portion of the total amount coming in the second hour. Stream discharge reached a maximum of 0.16 c.f.s. in hour four and decreased slowly after that time.

Phosphorus levels increase with discharge to hour four and then remain stable through hour six. The highest values recorded were at Stations One and Two, in the area of corn cultivation. Values decreased below Station Two, through the area of pasture. All Values, however, were very low.

Nitrogen concentrations were consistently higher at Station Two for all sample sets analyzed and decreased downstream. Concentrations increased through time on this date with maximums recorded during hour six as the stream discharge was beginning to diminish.

Ammonia was almost entirely absent. Only four samples, taken at different times and locations showed even trace amounts present.

BOD_5 concentrations show increases from Station One to Station Two and decreases then to Station Three. The increase at Station Two is small and the values indicate that field runoff is the major factor involved.

Values recorded for the various properties on this date are all very low relative to those recorded earlier in the year and are well below what criteria have been set by the Ministry of the Environment for permissible levels. At this low level there is some indication (N, BOD_5) that there is runoff from the feedlot.

Table 20

WATER QUALITY DATA

FEEDLOT NUMBER 15

Date: June 28, 1973 Precipitation: 1.1 inches

Stream Discharge

Hour	
0	0.0 $ft.^3/sec.$
2	0.05
4	0.16
6	0.12

Phosphorus (P) ppm

Hour	Sample Stations 1	2	3	4
2	0.1	0.1	0.2	0.0
4	0.3	0.3	0.1	0.0
6	0.2	0.3	0.1	0.0

Nitrogen ($NO_3^- + NO_2^-$) ppm

Hour	Sample Stations 1	2	3	4
2	0.4	1.2	1.1	0.8
4	1.2	2.8	1.9	1.0
6	2.0	3.1	2.1	1.0

Table 20--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 15

Date: June 28, 1973 Precipitation: 1.1 inches

Ammonia (NH_4^+) ppm

Hour	Sample Stations 1	2	3	4
2	0.0	0.1	0.1	0.0
4	0.0	0.0	0.0	0.1
6	0.0	0.0	0.1	0.0

BOD_5 mg./l

Hour	Sample Stations 1	2	3	4
2	1.2	1.5	0.8	0.9
4	1.4	1.7	1.1	1.2
6	1.5	1.6	0.8	1.1

Volatile Residue as % of Total Residue

Hour	Sample Stations 1	2	3	4
2	45.8	41.6	42.9	35.5
4	42.6	44.2	40.7	29.0
6	43.0	39.1	38.1	34.2

3.4.3 Water Quality at Feedlot 11--June 17, 1973

The first collection of samples at this site was made six hours after a heavy and sustained rain had begun. This occurred because the writer was working at Feedlot 15 earlier in the same day. Thus no analysis values could be obtained for water quality prior to the beginning of the rain. The figure of 0.8 c.f.s. for stream discharge is an estimate based on a measurement of 0.9 c.f.s. made several days earlier.

The discharge of the stream was relatively constant from the time of the first sample collection to last but reached a peak of 2.6 c.f.s. at hour eight.

Phosphorus concentration in the stream showed a general increase at Station Two and decrease below that point. Also, three of the four stations show a decrease in concentration from hour six to ten, indicating that the peak levels occurred during or before hour six. The area between Stations One and Two is cornfield and the increase of phosphorus at Station Two could be a combination of both field and feedlot runoff.

Nitrogen profiles show two clear trends. The first is an increase in concentration at Station Two with diminishing values downstream through Station Four. The second is a peak concentration for all stations during hour eight. It is unfortunate that the cultivated fields separate the feedlot from the stream because nitrate runoff from the feedlot area is indicated but it could come from either source.

Ammonia concentrations support the contention that runoff in the Station Two area does indeed come from the feedlot. There are increased concentrations of ammonia at Station Two for all three sample sets collected. In the downstream area, which is woodland and residential, the values diminished slightly. The maximum values recorded occurred during hour six.

BOD$_5$ concentrations show the same trends as those of ammonia. The feedlot again appears to contribute runoff to the stream causing peak values at Station Two which then decrease downstream. Maximum values were again recorded during hour six.

Volatile residue values are less erratic in this instance and show peaks at Station Two in two of the three sample sets. The significance of volatile residue in the summer, however, is even more likely to be unreliable than during the spring since algae and other debris are being carried along in the stream and may have no connection with the location at which they are accidentally included into a water sample.

Considering all properties measured, there does appear to be runoff entering the stream from the feedlot. Runoff of nutrients from fields in the area is also a strong possibility, however concentrations of all properties are quite low.

Table 21

W A T E R   Q U A L I T Y   D A T A

FEEDLOT NUMBER 11

Date: June 17, 1973   Precipitation: 1.3 inches

Stream Discharge

Hour	
0	0.8 $ft.^3/sec.$
6	2.4
8	2.6
10	2.5

Phosphorus (P) ppm

Hour	Sample Stations 1	2	3	4
6	0.8	1.2	0.8	0.6
8	1.1	1.0	0.4	0.3
10	0.6	0.8	0.2	0.2

Nitrogen (NO_3^- + NO_2^-) ppm

Hour	Sample Stations 1	2	3	4
6	3.2	3.7	2.9	3.0
8	3.8	4.4	4.3	3.8
10	3.3	3.9	4.0	3.6

Table 21--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 11

Date: June 17, 1973 Precipitation: 1.3 inches

Ammonia (NH_4^+) ppm

Hour	Sample Stations 1	2	3	4
6	0.2	0.5	0.4	0.4
8	0.2	0.3	0.2	0.2
10	0.2	0.3	0.2	0.1

BOD_5 mg./l

Hour	Sample Stations 1	2	3	4
6	2.8	3.6	3.3	2.8
8	2.2	3.1	2.9	2.7
10	2.2	2.8	2.7	3.1

Volatile Residue as % of Total Residue

Hour	Sample Stations 1	2	3	4
6	26.2	42.4	38.3	36.2
8	28.9	39.4	36.1	35.7
10	25.2	33.6	37.2	36.3

3.4.4 Water Quality at Feedlot 2--July 13, 1973

Streamflow at Feedlot 2 had stopped by mid June although water remained in the small marsh sections through July. Rain on this day fell in the form of several thundershowers over the period of two to three hours. Maximum streamflow of 0.1 c.f.s. was recorded upon the writer's arrival approximately four hours after the first shower had begun. In spite of the large amount of manure in the feedlot and below it, on the hillside leading to the stream, the location of the feedlot was not identifiable through higher levels of contamination at Station Two.

Phosphorus, nitrogen, and BOD_5 concentrations are quite similar in that all concentrations are low and the maximums are consistently found at Station Three. Also, nitrogen decreases in concentration from hour four to six.

Ammonia is at trace levels in all samples measured.

Feedlot runoff is not indicated and the quality of water in the stream is good relative to all properties measured.

Table 22

WATER QUALITY DATA

FEEDLOT NUMBER 2

Date: July 13, 1973 Precipitation: 0.8 inches

Stream Discharge

Hour	
0	0.0 ft.^{3}/sec.
4	0.1
6	0.05

Phosphorus (P) ppm

Hour	Sample Stations		
	1	2	3
4	0.1	0.1	0.5
6	0.1	0.0	0.4

Nitrogen (NO_2^- + NO_3^-) ppm

Hour	Sample Stations		
	1	2	3
4	1.1	1.8	3.4
6	0.8	0.9	2.9

Table 22--Continued

WATER QUALITY DATA

FEEDLOT NUMBER 2

Date: July 13, 1973 Precipitation: 0.8 inches

Ammonia (NH_4^+) ppm

Hour	Sample Stations 1	2	3
4	0.1	0.1	0.1
6	0.1	0.0	0.1

BOD_5. mg./l

Hour	Sample Stations 1	2	3
4	0.9	1.0	1.6
6	1.0	1.1	1.4

Volatile Residue as % of Total Residue

Hour	Sample Stations 1	2	3
4	32.4	30.1	38.2
6	28.6	22.9	27.0

3.5 Summary of Summer Runoff Analysis

In only two of the four cases studied, could the feedlot be identified as a source of runoff. Feedlot 11 and to a lesser degree Feedlot 15, both sampled on June 17, indicated through increases in most measured characteristics that livestock waste was entering the stream. In the other two cases, Feedlot 15 on June 28 and Feedlot 2 on July 13, there is no evidence that runoff from the feedlots affected the stream in any way.

At those sites where feedlot runoff can be identified, the concentrations of each of the properties measured are well within the permissible criteria set down by the Ontario Ministry of the Environment and in many instances are below the maximum levels set for 'desirable' water quality. It is clear that those feedlots employed in this part of the study did not produce serious variations in water quality under the summer runoff conditions of 1973.

Analysis of summer runoff was restricted by both a lack of rainfall during July and a shortage of days with rain during June and August. This situation was quite out of the ordinary according to the two agricultural representatives in whose counties three of the summer feedlots were located.

With only four cases of summer runoff, it is not possible to draw any general conclusions regarding the effect of summer rainfall on livestock wastes and their movement to adjacent streams. Indeed, the lack of data resulting from the unusual climatic conditions makes it impossible to predict what would happen at the study feedlots under conditions of normal summer rainfall. It may be that heavy sustained rains could bring about conditions of water quality similar to the most inferior recorded during spring.

In order to draw general conclusions on the subject much more data is required, which means a larger sample number and more storms of varying amount, intensity, and duration.

CHAPTER IV

CONCLUSIONS

The increase in beef production that is taking place today in Ontario as a result of the demands of a growing population poses certain environmental problems which require analysis. One of these problems is the potential water pollution threatened by the feedlot method of operation. Feedlots, located mainly in the north-west region of southern Ontario are sites of great accumulations of livestock waste that is difficult to dispose of.

In the United States where feedlots are much larger and concentrated in areas susceptible to heavy rains during short periods of the year, there have been numerous cases reported of severe water pollution caused by livestock waste runoff. Many studies have been carried out in an effort to develop economical methods for the treatment and disposal of wastes.

The situation in Ontario is different from that in the United States because feedlots are much smaller and the climate does not exhibit the same extremes of temperature and rainfall. Therefore, comparisons cannot be made in the area of runoff and water pollution. Studies of waste characteristics and potential pollution must be expanded to included analysis of surface waters in the feedlot areas.

This study was designed to assess the effect of feedlot runoff on water quality in nearby streams during spring runoff and following summer rains. The selection of feedlots to be used revealed that in the western Lake Ontario region there are few operations that are situated in such a way as to be sites of potential pollution. From over one hundred feedlots visited, seventeen were selected for the spring runoff study. Samples were collected from stations above, at and below each feedlot on at least four dates from March to June. The samples were analyzed for concentrations of phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, BOD_5, and volatile residue. In addition, bacterial analyses were made of at least one sample from each feedlot during the season.

Results of the analyses indicate that the over-all level of stream contamination from all sources is highest during the first stages of spring runoff and decreases with the stream discharge through March and April. At only four sites was there clear evidence that livestock waste adversely affected water quality in the stream. The factors that distinguished these four feedlots from the others in the sample were either a short distance from feedlot to stream or the presence of drainage tile between the feedlot and stream. There were high concentrations of fecal coliforms in many of the samples collected in March. While fecal coliforms originate solely in animal waste, high bacteria levels did not necessarily correspond with high levels of phosphorus, nitrogen, or BOD_5. This may be the result of differential rates of change. The concentrations of nutrients contained in all of the samples were within the 'permissible' limits set by the Ontario Ministry of the Environment.

The study of runoff occurring during summer as the result of rainfall proved very difficult due to the local nature of the rain. For this reason as well as the general shortage of rain throughout the region during July and August, samples were collected on only four occasions. On two of these occasions, there were indications of livestock waste runoff. However, the measured concentrations were so low as to be within the 'desirable' limits set by the Ministry of the Environment. The amount of contamination found in summer runoff was negligible.

Bearing in mind the limitations involved in the study--the restricted area, the limited number of feedlots, sample collection on a three week schedule, only one season of recorded values, and problems with summer rain--there are still certain general comments that can be made with regard to runoff from feedlots and the effect such runoff has upon water quality.

The recorded data indicate that in the study area at least, with feedlots of approximately 200 head, there is little actual pollution of stream. This, in spite of the many statements made regarding the potential of waste accumulations to contaminate water sources. In areas where the size of feedlots is greater there may be a greater amount of waste runoff occurring than was found in the study area; however, it is likely less than the potential indicated. Also, the situation of the feedlot with respect to the stream was found to be a large factor in determining the degree of stream contamination and therefore larger feedlots do not necessarily mean a larger volume of waste reaching the nearest stream.

It would appear, from the published literature and the results of this study that more work is required analyzing actual stream quality as opposed to the study of livestock wastes in feedlots. Also necessary for further study of feedlot runoff is the use of continuous water quality monitoring equipment which would record shock loadings of waste that would otherwise go unnoticed.

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APPENDIX I

TOTAL* BEEF CATTLE, 1951-1971

*(all calves, beef heifers, beef cows, steers)

County	1951	1956	1961	1966	1971
Brant	9,886	14,878	51,224	20,584	19,522
Bruce	77,818	113,044	125,018	150,440	174,560
Carleton (Ottawa)	24,068	59,057	34,952	141,454	43,287
Dufferin	32,770	46,997	48,960	54,408	52,083
Dundas	9,140	13,487	13,931	12,563	16,305
Durham	23,924	30,630	34,395	41,448	41,379
Elgin	25,593	30,033	38,459	39,987	39,242
Essex	8,321	9,327	12,859	9,635	7,624
Frontenac	13,298	17,198	19,382	20,273	23,316
Glengarry	8,314	9,894	13,080	10,452	14,042
Grenville	5,985	6,519	9,247	9,919	12,810
Grey	85,564	114,108	124,830	137,116	144,955
Haldimand	12,002	15,363	21,571	23,414	22,649
Halton	10,113	13,635	14,540	14,726	13,246
Hastings	18,394	23,524	27,069	30,210	34,821
Huron	91,200	119,166	135,484	153,722	153,757
Kent	27,758	33,423	42,746	49,816	44,652
Lambton	52,160	63,179	35,507	78,794	77,189

APPENDIX I--Continued

County	1951	1956	1961	1966	1971
Lanark	22,287	29,212	31,958	32,852	38,531
Leeds	12,980	15,536	20,158	18,861	24,901
Lennox and Addington	12,031	24,663	19,225	19,959	26,921
Lincoln	4,601	5,952	8,123	7,478	
Manitoulin	13,328	18,387	18,864	22,216	22,717
Middlesex	65,968	84,224	100,188	107,801	112,119
Niagara					15,966
Norfolk	6,845	8,595	11,114	14,247	12,982
Northumberland	18,731	13,187	29,902	34,458	40,840
Ontario	34,452	42,863	50,367	49,057	51,124
Oxford	27,116	39,574	48,850	58,593	66,565
Peel	15,319	22,004	25,009	26,035	25,038
Perth	53,400	69,220	81,005	93,646	92,868
Peterborough	17,406	24,814	29,658	33,295	34,710
Prescott	10,478	11,254	13,311	11,260	14,930
Prince Edward	5,773	8,051	11,231	12,130	13,963
Renfrew	34,906	47,106	48,646	44,129	58,957
Russell	8,766	9,925	12,701	10,431	10,182
Simcoe	54,389	78,366	89,414	99,317	106,352
Stormont	7,819	7,831	9,861	8,882	13,140

APPENDIX I--Continued

County	1951	1956	1961	1966	1971
Victoria	42,326	53,732	58,593	57,886	59,468
Waterloo	23,142	32,463	41,935	49,899	54,967
Welland	4,029	5,296	7,203	7,528	
Wellington	59,460	79,818	86,946	99,471	99,006
Wentworth	7,874	11,289	13,783	13,664	15,019
York	21,090	26,838	30,775	29,317	30,509
Totals for Province	1,120,824	1,503,662	1,702,074	1,961,373	1,974,284

Source: adapted from Census of Canada 1951, 1956, 1966, 1971; Statistics Canada.

APPENDIX II

County	No. of Farms Reporting Cattle on Feed--1971
Brant	282
Bruce	1,310
Dufferin	577
Dundas	138
Durham	511
Elgin	533
Frontenac	188
Glengarry	120
Grenville	146
Grey	1,657
Haldimand	438
Halton	226
Hastings	308
Huron	1,837
Kent	736
Lambton	1,127
Lanark	351
Leeds	171
Lennox & Addington	213
Manitoulin	55
Middlesex	1,313
Niagara	437
Norfolk	330
Northumberland	449

APPENDIX II--Continued

County	No. of Farms Reporting Cattle on Feed--1971
Ontario	710
Ottawa-Carleton	383
Oxford	865
Peel	301
Perth	1,433
Peterborough	354
Prescott	119
Prince Edward	195
Renfrew	398
Russel	96
Simcoe	1,235
Stormont	104
Victoria	528
Waterloo	880
Wellington	1,333
Wentworth	312
York	426
Total	23,398

Source: Census of Canada