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NUTRIENT ACCUMULATIONS FROM LIVESTOCK AND POULTRY OPERATIONS IN THE GREAT LAKES BASIN 1931 - 71

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Social Sciences Division

June 1974

UNPUBLISHED REPORT
RAPPORT NON PUBLIE

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(CUMULATIVE TOTALS)

INTRODUCTION

The growth of large algae blooms with their attendant repercussions on water quality signaled the beginning of a new phase in the study of water pollution. Unlike other forms of water pollution, eutrophication or over-enrichment of water did not result in the destruction of the lake biomass. In fact, this living matter (fish, phytoplankton, zooplankton, etc.) was more likely to increase under these enriched conditions. However, a change in the trophic state of a water-body does result in species alteration and this may be unfavourable from a recreation and fisheries standpoint. The change in water quality may also detract from the scenic beauty, and the pursuit of other water based recreational activities; i.e., swimming and boating. This is especially important at a time when Canadians are enjoying more and more leisure hours than ever before.

Although limnologists agree that eutrophication is a result of increased nutrient inputs, there is still not complete agreement on whether phosphorus (P) or nitrogen (N) is the controlling nutrient. It is not the objective of this paper to continue this debate, so both nitrogen and phosphorus will be considered.

Nitrogen and phosphorus both enter water from a variety of sources. These sources may be divided into point sources and diffuse sources. The former includes municipal and industrial waste discharges and the latter includes loadings from precipitation, groundwater flow, and surface water drainage. The very nature of these diffuse discharges makes them difficult to quantify and difficult to control.

In light of the concern expressed about the origin, extent, causes, and location of these diffuse loadings in the agreement between Canada and the United States of America on Great Lakes Water Quality, this paper will examine the magnitude and possible nutrient inputs to the Great Lakes Basin from livestock and poultry 1931 - 1971. This approach will consider both the historical nutrient accumulations in the Lower Great Lakes Basins where the situation is already critical, as well as the accumulations in the Upper Great Lakes Basins where there is still time for preventive measures to maintain the present trophic state. In addition, thirteen of the Great Lakes major tributary river basins are also considered.

In order to make this paper more meaningful in the absence of good quantitative monitoring data on the contributions from livestock and poultry operations, the following form will be followed. First the changing perspective of agriculture in the Great Lakes Basin will be discussed with special emphasis directed towards those changes in animal husbandry including the handling of wastes which may affect the nutrient loadings to the Great Lakes. Secondly, the possible environmental implications of these changes will be dealt with; in particular, the mechanism for movement of P and N from their point of discharge to the receiving body of water. In section three, statistics on the actual accumulations of P and N from livestock and poultry in each of the 17 drainage basins will be presented, along with maps indicating the concentrations of P and N per acre of improved agricultural land. Special emphasis will be placed on the contributions from intensive beef feeding operations for the period 1966 and 1971. Finally, those basins where concentrations of livestock activity are expected to increase will be identified, along with recommendations for further study of this problem.

SECTION I

AGRICULTURE, A CHANGING PERSPECTIVE

The primary purpose of the following section is to outline briefly the nature and scope of change in agriculture during the period 1931-1971 in the Great Lakes Basin. Without some appreciation of this change, the statistics on animal nutrient accumulations will not be as meaningful and the implications of the problems facing agriculture will not be as well understood.

Traditionally, agriculture's prime responsibility was the production of foodstuffs for the non-agrarian section of the population. Today, it has another commodity for sale which may have far reaching repercussions for both the future production potential of agriculture and the environmental consequences of this production. This new commodity is land. Probably the most dramatic change to occur in agriculture during the last twenty years has been the reduction of total land area in farms.*

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* At all times in this paper, agriculture statistics will be presented on the basis of Statistics Canada, Census Farm Definitions (see Appendix 1).

	1931	1941	1951	1961	1971
No. of Acres in Farms in Ontario (000's Acres)	22,841	22,388	20,880	18,579	15,963

Source: Statistics Canada Cat. No. 96-707, 1971.

The figures found above indicate a withdrawal between 1931 - 1971 of 6,877,842 acres from agriculture or 44 percent of the acreage farmed in 1971. Although there was an overall decline in acreage, the actual number of acres per farm increased.

	1931	1941	1951	1961	1971
Acres per Farm in Ontario	119	126	139	153	169

Source: Statistics Canada Cat. No. 96-707, 1971.

Some of the change found here may have been the result of a change in census farm definition (see Appendix 1).

Further evidence that this trend will continue was found in a report by ODAF (1962) [1]. It was noted that, in townships where the average crop acreage per farm was less than 50 acres, the percentage of land leaving agriculture was from five to eleven times as great as in townships where the average crop acreage was greater than 50 acres. In

1971, 11 percent of the 86,545 farms reporting area under crops were within this category. It should also be noted that during this period, the losses in improved and unimproved agricultural land are not comparable.

	1931	1941	1951	1961	1971
Improved	13,273	13,363	12,693	12,033	10,865
Unimproved	9,568	9,025	8,187	6,546	5,098
(000's of acres)					

Source: Statistics Canada, Cat. No. 96-707, 1971.

These figures indicate an 18 percent reduction in improved land as compared to a 47 percent reduction in unimproved land.

This land has been lost to agriculture for three main reasons. First, the increasingly competitive nature of agriculture has resulted in an abandonment of those areas where marginal soils predominate. These marginal soils would include C.L.I. Class 4 and lower (see Appendix 2). In the Great Lakes Basin, areas on or adjacent to the Precambrian shield most often fall into these categories. In addition to land capability, MacDougall [2] and Hesselink [3] have found that age of operator, availability of alternative employment, and demand for semi-permanent residences by city dwellers are also important considerations in farmland abandonment.

Secondly, and perhaps of greater consequence to agriculture because of its irreversible nature, is the loss of agricultural land around the rapidly expanding urban centres. Calculations made by the Centre for Resources Development, University of Guelph, [4] indicate that, if urban expansion continues in its present form, between 121,800 and 386,800 acres of land will be lost by 1991. The variability of these figures is a result of the use of three different population projections. Although this only represents a loss of between .8 percent - 2.4 percent of the total land in farms in 1971, a comparison of the loss of land in capability class 1 and 2 indicates that between 1.26 percent and 4.0 percent of this land will be lost to agriculture.

Lastly, the increased dissatisfaction of urbanites with the quality of life in today's cities, coupled with rising incomes and more leisure time, has allowed urbanites to "escape" to the country. This "escape" has resulted, in many instances, in the establishment of semi-permanent residences or low density residential areas. This growth in rural non-farm population in Ontario is reflected in the following statistics:

	1931	1941	1951	1961	1971
Farm Population*	800,960	704,420	702,778	524,490	391,713
Rural Non-Farm Population**	628,748	822,730	668,400	906,864	885,735

Sources: * Statistics Canada, Census of Agriculture.

** Statistics Canada, Census of Population.

Changes in agriculture have not been restricted to just changes in overall acreage and size of the production unit. Farm management practices have also changed. This is evident in the following table which records the rate of adoption of new technology in the form of farm machinery.

	1931	1941	1951	1961	1971
Machinery & Equipment Average Value/Farm Ontario ($)	791	844	2,970	4,774	9,396

Source: Statistics Canada, Cat. No. 96-707, 1971.

Further evidence that farmers have adopted new technology is given by the following table:

	1931	1941	1951	1961	1971
% of Total Ontario Population Living on Farms	23.3	18.6	15.3	8.4	5.1

Source: Statistics Canada Cat. No. 96-707.

Despite this reduction in labour force, production has continued to increase. Furniss [5] noted that, between 1946 - 1964, there was an annual rate of increase in productivity of 5 percent, compared to 2.6 percent in the manufacturing sector.

The Science Council of Canada [6] further reinforced this trend when they recommended that "Canada should seek to contribute to the expansion of output more through the improved application of technology to prime land than attempt to cultivate her virgin fringe areas".

The change in adoption of new technology is only one manifestation of a more profound change in farm operators themselves. Before, the average farm operator combined the skills and knowledge necessary to plant and harvest crops, breed and raise livestock, and buy and sell both. His capital outlay was relatively small, and thus, he had no need for a sophisticated knowledge of financial affairs.

	1931	1941	1951	1961	1971
Average Capital Value per Farm $ Ontario	7,273	6,675	16,996	30,837	72,819

Source: Statistics Canada Cat. No. 96-707, 1971.

The rapidity of technological change, widely fluctuating prices, rising input costs relative to gross income, and improving off-farm employment opportunities are all factors forcing changes in farm operation. The trend today is moving towards dividing the factors of production - land, labour, capital, and management - between either different people or agencies; or by enlisting the support of farmers' cooperatives, marketing boards, or computerized management systems; i.e., CANFARM [7].

Systems such as CANFARM are a direct result of the demand by farmers for the development of new technology to not only minimize labour inputs, but to maximize management and marketing capability. A farmer's willingness to adopt or incorporate these improvements in his own operation will directly affect his ability to compete in the market place. In the Report of the Federal Task Force on Agriculture, 1969 [8], it was stated that "some producers are less able to employ this technology than others and shall fall behind competitively and in incomes".

Despite the comments by many on the doom of the family farm, statistics collected in the 1971 Census of Agriculture indicate that 90 percent of the 94,722 census farms reported in Ontario were owned by private individuals. Only 298 or .3 percent were classified as incorporated businesses other than family.

AGRICULTURAL ACTIVITIES

In Ontario, between 1931-71, there has been little variance in the ratio between total cash receipts from farming operations and total cash receipts from sale of livestock and livestock products. It is important to note, however, that, during this time, receipts from livestock and livestock related products have accounted for an average of 72 percent of total cash receipts from farming operations. G. J. McDonald [9] also indicated that, in 1966, 90 percent of Ontario's improved farm land was used for the production of crops suitable for livestock. Both of these statistics clearly indicate the dominant position of livestock in Ontario's agricultural economy. Therefore, any programs aimed at regulating this industry may strongly affect Ontario agriculture and related industries.

FARM CASH RECEIPTS

FROM FARMING OPERATIONS IN ONTARIO

($000's)

	1931	1941	1951	1961	1971
Total Livestock and Livestock Products	127,181	204,310	597,619	609,141	923,573
Total Cash Receipts	171,004	274,503	784,073	874,110	1,387,619
% of Total Receipts Represented by Livestock	74%	74%	76%	70%	67%

Source: Statistics Canada, Cat. No. 21-511, 21-001.

Although the total value of livestock and livestock related products has not varied greatly in its share of the total value of agricultural products sold, the acreage of land traditionally used to support these animals is decreasing. (See Table I.)

The Lake Erie Basin experienced the greatest rate of decrease, as well as the greatest absolute decrease in acreage. This occurred despite the fact that the Lake Erie Basin experienced the smallest decline in total acreage of improved agricultural land (see Table II). The Lake Ontario and Lake Huron Basins, to a lesser extent, also reflect this trend towards a more rapid decrease in the acreage of improved pasture, relative to the decrease in total improved agricultural land.

In addition to a decrease in the number of acres of improved pasture which were used to support most livestock during the warmer part of the year, there was also a significant change in the acreage planted to one of the traditional winter livestock feeds. (See Table III.)

Both of these changes occurred despite a net increase in the total number of animals found in these basins. (See Table IV)

The apparent contradiction of a net increase in animal numbers at a time when traditional feed sources are on the decline can be explained by examining the changes in cultivation of alternative feeds. (See Table V)

To meet the increasing demands for meat and meat products, farmers have adopted the alternative feeds listed in Table V, which provide higher total digested nutrients (T.D.N.) per acre of production than traditional feeds. (See Table VI)

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* Tables I, II, III, and IV were all calculated in a manner similar to that outlined on Page 72, <u>Animal Numbers</u>.

The supply of T.D.N. is especially important for growth, lactation, reproduction, and fattening. Without feeding an excess of energy nutrients, insufficient fat will be deposited throughout the body of a beef animal in preparation for market and an insufficient surplus will be available for the production of milk in dairy animals.

In addition to encouraging a reduction in the acreage of protective meadows, the above mentioned feed crops are increasingly being grown in a monoculture situation with its attendant risks of accelerated soil erosion.

The development of new hybrids which extended the viable growing area and the changing methods of cultivation have also encouraged farmers to adopt these feed sources.

Coincident with the move away from the traditional ways of supporting livestock has been the development of the confinement method of managing livestock and the change in importance of the various livestock classes. Some of the more important changes are discussed in the next section.

TABLE I

CHANGES IN IMPROVED PASTURE (ACRES)

	1951	1971	% Change
Lake Ontario - Acreage of Improved Pasture	691,229	419,586	-39
Lake Erie "	890,793	488,193	-45
Lake Huron "	1,013,937	840,855	-17
Lake Superior "	15,191	11,045	-27

Source: Statistics Canada, Census of Agriculture.

TABLE II

CHANGES IN TOTAL IMPROVED AGRICULTURAL LAND (ACRES)

	1951	1971	DIFFERENCE	% CHANGE
Lake Ontario Basin	2,603,189	1,951,947	651,242	-25
Lake Erie Basin	3,934,167	3,833,782	100.385	- 3
Lake Huron Basin	3,455,114	3,061,130	393,984	-11
Lake Superior Basin	75,723	49,140	26,583	-35

Source: Statistics Canada, Census of Agriculture.

TABLE III

TOTAL ACREAGE REPORTED IN HAY

	1951	1971	DIFFERENCE	% CHANGE
Lake Ontario Basin	743,316	609,205	134,111	-18
Lake Erie Basin	707,849	521,862	185,987	-26
Lake Huron Basin	932,076	785,425	146,651	-16
Lake Superior Basin	45,248	25,531	19,717	-44

Source: Statistics Canada, Census of Agriculture.

TABLE IV

ANIMAL POPULATION CHANGES

1951-71

	1951	1971	DIFFERENCE	% CHANGE
1) LAKE ONTARIO BASIN				
Dairy	287,793	160,711	127,082	- 44
Beef	219,741	423,191	203,450	93
Pigs	347,143	371,379	24,236	7
Sheep	85,106	47,759	37,347	- 44
Horses	56,581	21,428	35,153	- 62
Hens & Chickens	5,525,552	9,162,517	3,636,965	66
2) LAKE ERIE BASIN				
Dairy	326,782	201,955	124,827	- 38
Beef	333,527	626,832	293,305	88
Pigs	614,144	1,091,917	477,773	78
Sheep	77,660	47,191	30,469	- 39
Horses	67,219	21,555	45,664	- 68
Hens & Chickens	8,882,076	10,997,621	2,115,545	24
3) LAKE HURON BASIN				
Dairy	273,134	185,681	87,453	- 32
Beef	479,640	888,104	408,464	85
Pigs	580,642	751,230	170,588	29
Sheep	125,805	81,921	43,884	- 35
Horses	70,737	18,323	52,414	- 74
Hens & Chickens	5,916,409	8,285,906	2,369,497	40
4) LAKE SUPERIOR BASIN				
Dairy	6,647	5,155	1,492	- 22
Beef	3,483	6,624	3,141	90
Pigs	3,868	2,403	1,465	- 38
Sheep	965	431	534	- 55
Horses	497	276	201	- 81
Hens & Chickens	125,841	127,761	1,920	2

TABLE V

TOTAL AREA PLANTED TO SELECTED LIVESTOCK FEED CROPS

(ACRES / BASIN)

	1951	1971	DIFFERENCE	% CHANGE
ENSILAGE CORN				
Lake Ontario	53,663	101,394	47,731	89
Lake Erie	115,507	230,663	115,156	100
Lake Huron	54,694	164,906	110,212	202
Lake Superior	26	91	65	250
GRAIN CORN				
Lake Ontario	7,448	110,079	102,631	1,378
Lake Erie	255,534	863,873	608,339	238
Lake Huron	23,944	237,960	214,016	894
Lake Superior	1	1	0	0
BARLEY	1951	1966		
Lake Ontario	19,196	47,278	28,082	146
Lake Erie	51,599	94,578	42,979	83
Lake Huron	93,281	100,051	6,770	7
Lake Superior	816	658	158	- 19

Source: Statistics Canada, Census of Agriculture.

TABLE VI

NUTRITIONAL VALUE OF FEEDS*

	YIELD/ACRE (lbs)	% TDN**	TOTAL TON/ACRE (lbs)
Barley	2,347	74	1,737
Corn Silage	26,000	28	7,112
Grain Corn	4,256	78	3,320
Hay	5,000	53	2,650

*TDN ratings are for cattle and may vary for **all livestock**
**on an as-fed basis

SOURCE: (1) Agri. Statistics for Ontario, 1972
OMAF, Agdex 850
(2) Average Composition of Common Feeds for
Cattle, Oct. 1970, OMAF, Agdex $\frac{410}{60}$

LIVESTOCK

The original settlers who came to the Great Lakes Basin established a subsistence level of agriculture where market forces were at a minimum; bartering being the most prevalent means of exchange. In the 1880's, the move to a cash crop economy began with the adoption of wheat [10]. Once farmers began cash cropping, they devoted fewer and fewer acres to provide for their own needs. Because of the relative risks involved in producing for fluctuating markets and because the soils and climate of the Great Lakes Basin are well suited to the production of a wide variety of agricultural products, mixed farming became the most popular form of activity.

The period after World War II marked the beginning of another change in agricultural activity. This transition from mixed to monoculture of both crops and livestock has not only affected the agricultural community, but it has also had far reaching effects on everyone living in the Great Lakes Basin.

For the purposes of this paper, only the more important changes in the management of livestock which are likely to have environmental repercussions will be discussed for this post-World War II period.

Dairy

Perhaps the most important change to occur in the dairy industry was the move to adopt specialized dairy breeds. Before this time, the industry had centred around the dual-purpose animals, which provided a dairy and a beef output. This process of specialization was hastened by the development of aritificial insemination in the late 1940's, and this was further improved in the early 1950's, when frozen semen became available. Now, farmers could, with very little capital outlay, take advantage of an even greater variety of sires for their dairy herd.

In Ontario, the dairy industry is divided into fluid and industrial milk producers. The fluid producers, who are predominantly located in the milk sheds around large urban concentrations, produce milk for processing and bottling. The high demands for quality and dependable supply have resulted in these operations generally adopting new technology to retain their competitive position. In most cases, cattle are kept indoors during their fresh period, as this minimizes labour inputs, allows for maintenance of higher standards of hygenic cleanliness, and insures a high quality product through the feeding of a specialized diet.

Industrial milk producers, whose product is primarily used for the production of cheese and butter, do not have to meet the same standards of quality and supply as fluid producers. This difference in final market demand has resulted in a strong contrast between the two production units. Many industrial milk producers are characterized by lower inputs of technology. In Canada, nearly 50 percent of non-fluids are milked by hand, and only 36 percent use artificial insemination [11]. Many of the producers are not located in milk sheds around large urban centres, but rather, are located in areas of the province characterized by lower opportunity costs for agriculture. Value and size of herds are generally lower. Furniss [12] noted that this problem of low opportunity costs will probably result in the maintenance of a dairy industry in Northern and Eastern Ontario.

Furniss also stated that almost 70 percent of all dairy herds in Ontario were less than 33 cows in size, and that, on the smaller operations, approximately 1.3 acres of improved pasture were provided for each cow, in contrast to larger operations, where only 2/3 of an acre/cow was found. These statistics reflect the practice of indoor housing and specialized feeding of dairy cows in the more important operations.

In each of the Great Lakes Basins, the number of dairy cows declined between 1951 - 1971 (Table IV). This decline has occurred despite an increase in total milk production over the same period.

<u>TOTAL MILK PRODUCTION IN ONTARIO</u>

('000 lbs.)

1951	5,050,270
1971	6,150,187

Source: Statistics Canada, Cat. No. 23-001

These statistics reflect the great improvement in per animal production. However, over this same period, per capita milk consumption has declined.

<u>MILK PRODUCTION - PER CAPITA</u>

(lbs.)

1951	1,098
1971	787

Source: Agricultural Statistics for Ontario - 1971.

This, coupled with decreasing income from the sale of dairy products, has resulted in a poorer position for dairy farmers.

FARM INCOME IN KIND

($000)

	1963	1971
Dairy Products	6,210	3,878

The development of milk substitutes -- filled milk and synthetic milk -- may tend to accelerate this decline. Although these products are not yet sold in Canada, they are marketed in the U.S. In Arizona and Hawaii, the sale of these products has taken a substantial share of the market, 10 - 20 percent respectively.

The dairy industry in the Great Lakes Basin does have an alternative available, in the form of a dairy beef industry. C. Rutherford [13] indicated that the Canadian dairy herd provides 90 percent of the total veal and 30 percent of the beef produced in Canada. There are several factors which may hasten the growth of this sector of the industry. The development of a feeder industry in Western Canada, with its attendant reduction in the number of feeder calves being shipped to the East for finishing, has created a demand for feeder calves. Dairy steers, in many cases, have a comparable weight gain to some traditional beef breeds, and therefore, may prove competitive. In addition to dairy herd improvement, artificial insemination has also made more males available for feeding.

Therefore, in areas of the Basin where there are concentrations of marginal dairy operations, the development of a dual function feeder dairy industry may result. The relative veal-feeder prices will largely determine the development of the industry. Any changes in the dairy industry will, undoubtedly, have effects on nutrient loadings to the Great Lakes. This is especially true since one dairy cow produces more than twice as much phosphorus and nitrogen as a beef animal. (See Page 73.)

Beef

A steadily increasing per capita consumption of beef (see Table VII) has provided the main stimulus for a rapidly growing beef industry in the Basin. This increased production to fulfill demand was hastened by the following factors:

- The development and constant improvement of specialized beef breeds to replace dual-purpose animals in a pattern similar to that outlined in the section on Dairy.
- The move from extensive to intensive feeding practices, which reduced the time required to bring a steer to market from at least 15-18 months to 12-15 months, but involved feeding the animals a more

concentrated ration while maintaining them in a confined environment.

- The growth of increasingly large amounts of concentrated feeds (see Table V) to provide the needed feed base to bring these animals to market in the shorter time span.

The combination of a good market potential, favourable climatic conditions, and an abundance of soils suited to the cultivation of feed crops has resulted in the Great Lakes Basin becoming the focus of the cattle feeding industry in Eastern Canada.

This intensive feeding of beef in the Basin is characterized by the following two approaches. The stocker is the result of a less intensive feeding program which relies on use of pasture as well as concentrated feeds to bring the animal to market. For this reason, the stocker requires about 15-18 months to slaughter, in comparison to the 12-15 months required for feeder beef. The greater land requirements needed to support this livestock class and its lower quality has resulted in its concentration in areas of lower priced land found in parts of the Lake Huron Basin [14] and the gradual decline in competitive position with cattle fed on intensive fattening operations.

TABLE VII

PER CAPITA DISAPPEARANCE

OF MEAT AND DAIRY PRODUCTS IN CANADA

(pounds/capita/annum)

	1957	1958	1959	1969	1970	1971
Pork	46.2	51.7	58.4	51.9	57.2	66.1
Beef	74.8	64.8	64.4	86.4	85.9	87.2
Veal	9.0	8.8	7.5	5.1	4.4	4.4
Mutton and Lamb	2.6	2.7	3.0	4.0	3.8	3.3
Chicken	13.8	15.0	15.6	28.8	30.6	29.3
Fluid Whole Milk	400.2	396.1	393.7	287.1	286.8	286.8

SOURCE: Statistics Canada, Cat. No. 32-226

TABLE VIII

CHANGE IN BEEF OPERATIONS IN THE GREAT LAKES BASIN

1966

	Total Beef	Cattle on Feed	% of Total
Lake Ontario	404,944	66,740	17%
Lake Erie	637,314	254,278	40%
Lake Huron	842,758	210,808	25%
Lake Superior	8,133	741	9%
Gr. Lakes Basin	1,893,149	532,567	28%

TABLE IX

1971

	Total Beef	Cattle on Feed	% of Total
Lake Ontario	423,191	85,656	20%
Lake Erie	626,832	309,438	49%
Lake Huron	888,104	267,425	30%
Lake Superior	6,624	365	5%
Gr. Lakes Basin	1,944,751	662,884	34%

Source: Statistics Canada, Census of Agriculture.

TABLE X

NUMBER OF CATTLE ON FEED/FARM IN ONTARIO

Ontario	Total Cattle on Feed	# Farms Reporting	$\bar{x}$ No. of Animals/Farm
1966	566,380	27,924	20
1971	698,580	24,166	29

Source: Statistics Canada, Census of Agriculture.

TABLE XI

PROPORTION OF TOTAL ONTARIO BEEF IN GREAT LAKES BASIN

Year	Total Beef Cattle Ontario	Beef Cattle Great Lakes Basin	% of Total
1931	1,396,467	1,081,115	77%
1941	1,483,639	999,327	67%
1951	1,543,759	1,036,391	67%
1961	2,123,282	1,766,640	83%
1971	2,326,704	1,944,751	84%

Source: Statistics Canada, Census of Agriculture.

Tables VIII and IX provide an assessment of the change in beef operations in the Great Lakes Basin between 1966 and 1971. Unfortunately, Statistics Canada did not collect data previous to 1966 for the "cattle on feed" class.

For similar comparative tables for river basins, see Table XVI.

During this same period, the density of cattle on feed per farm has also increased (see Table X). It should be noted that the number of beef animals/farm only represents averages which do not adequately provide information on the variation in size of feedlots from one part of the province to another.

Not only has the Great Lakes Basin become the major focus of intensive beef feeding operations in Eastern Canada, but it also accounts for most of the beef raising activity in the province of Ontario (see Table XI).

The feedlot industry is largely dependent on a supply of feeder calves from Western Canada where, in 1968, 83% of all beef cows were located. [15] This has resulted because the major requirement of a viable cow-calf operation is the availability of large acreages of relatively cheap land. Inputs of feed and labour must be kept low to maximize the narrow profit margin found in the sale of feeder calves. In the Great Lakes Basin, the Lake Huron Basin alone provides the necessary land base for cow-calf operations.

The swing towards the development of a Western feeder industry centred in Alberta has resulted in decreased shipments of feeder calves to the Basin. [16] As long as there is an abundance of surplus non-quota feed grains at lower prices than in Ontario, Western farmers will move to convert this surplus to a profit through beef feeding rather than ship feeder calves to the Great Lakes Basin. If this situation continues, an expanding cow-calf operation in the Lake Huron Basin may result.

Pigs

A relatively stable demand for pork (see Table VII) has resulted in a slower growth rate in the hog industry when compared with that of beef. Despite this slower relative growth rate, there were still significant advances in the Lake Erie and Lake Huron Basins. Only the Lake Superior Basin experienced a decline in hog production (see Table IV). The growth of hog production in the Lake Erie and Lake Huron Basins is strongly linked to the increased growth of concentrated feeds in these Basins (see Table V).

The Task Force has indicated that any marked improvement in the rate of growth in the hog industry will depend on the competitive position of Canadian hogs in the American market. In addition, a growing demand for hogs in the new Japanese market may provide a stimulus for increased production.

Level of technology and relative prices of feeds seem to be the most important factors affecting the competitive position of the hog industry. This will encourage hog farmers to remain land based in order to be self-sufficient in feeds. Reeds and Maas [17] have suggested that fully automated hog fattening units are compatible with part-time farming, thus reducing some of the risks for hog producers.

Hogs have traditionally been kept in confined conditions and this has made them suitable for the adoption of improved technology for feeding and waste handling.

Hens and Chickens

Prior to 1950, the poultry industry was dominated by dual purpose cockerels. In 1949, the loss of British egg contracts caused a sharp reduction in the demand for eggs, as well as stimulating a move towards developing specific broiler stock. [18] This, in turn, resulted in reduced prices for spent layers which led to the breeding of smaller, more efficient layers. In 1955, average annual egg production was 180 eggs/hen. In 1961, this production had climbed to 208 eggs/hen.

In addition, increased levels of mechanization, better nutrition, improved disease control and increased demands for broiler meat (Table VII) and eventually for eggs all stimulated the move towards highly concentrated poultry operations. These operations are generally characterized by high demands for capital investment in buildings and equipment and low requirements for land. A number of factors have led to this situation. D. Paarlberg [19] has noted that 25 years ago, the poultry industry exhibited the greatest gaps between the nutritional, genetic, and sanitary knowledge available and the management practices in use at that time. The steadily increasing demand for eggs and poultry meat resulted in the rapid adaption of the most advanced techniques. The need for specialized diets for maximum production resulted in farmers substituting feed grown on their own farms with that purchased from feed producers. This lack of a land base for poultry enterprizes may result in manure disposal problems, especially if other farmers in the area do not require additional manure.

Not only has this sector moved quickly to adopt new technology, while abandoning the traditional land base used to support its activities, but it has also experienced the highest levels of vertical integration between the factors of production.

In Ontario, a few feed companies own most of the hatcheries and poultry processing plants. The growers are usually separated from this fully integrated approach, but they are often under contract to feed producers.

All of the Great Lakes Basins showed an increase in the numbers of hens and chickens between 1951 - 1971 (see Table IV); however, the Lake Erie Basin has the largest number of chickens, while the Lake Ontario Basin has enjoyed the most rapid growth. This increase of 66 percent over the 20 year period is indicative of the important position poultry will play in future agricultural activities in the Basin.

Sheep

In comparison to poultry, sheep farming in the Basin has been noted for its lack of adaptation and improvement in the face of a very competitive market situation. The higher potential of much of the Basins' farmland for other more profitable forms of farming has also tended to discourage any widespread rearing of sheep. Only in those areas where marginal, low priced land is available in quantity, do farmers tend to adopt sheep.

Increasing competition from lower priced sources of mutton of high uniform quality imported from New Zealand and Australia has further reduced the viability of the Basins' sheep farming. Sheep farmers in the Basin must begin to produce a product of uniform quality, while assuring a dependable supply, if they are to effectively compete with imports. Statistics in Table IV indicate that this is not the case since numbers of sheep are rapidly declining in all Basins.

Most sheep operations in the Basin keep animals in unconfined conditions where the dangers of concentrated manure accumulations are avoided, however, this situation may change.

Studies being undertaken at the University of Guelph have indicated that intensive breeding and fattening of sheep may be economical, especially for industrial milk producers and cow-calf operations. [20]

Horses

A decline in numbers of horses occurred throughout the Basin, and can be related to the increasing levels of mechanization found on the modern farm. For the most part, horses are kept only for riding and show purposes. Although their numbers experienced rapid decreases in all drainage Basins between 1951 - 1971, the patterns of concentration have changed. Instead of finding two or three horses on every farm, as would often be the case previous to 1951, large numbers of horses may be found on a single farm where they are used for recreational purposes. This change in management may present more water quality problems even though the actual number of horses has decreased.

ANIMAL WASTES

Changes in livestock and poultry management outlined in the previous section have, for the first time, had repercussions which extend beyond purely economic considerations to impinge on environmental ones. Perhaps the most important reason for this development has been the change in management of farm animal wastes.

In the past, the wastes from livestock and poultry were distributed in a relatively even fashion over pasture land by animals bred and raised in relatively unconfined conditions. During winter months, these animals were forced into confinement when feed sources were restricted, but the accumulated wastes were important to the farm as a source of fertilizer for fields planted to crops.

Today's farmer, faced with an ever increasing cost price squeeze (see REASONS FOR CHANGE), where economic concerns have supplanted biologic ones, has found that, in many cases, manure has turned from an asset to a liability. In an unpublished study of farmers in the Rideau River Basin, researchers noted that only the smaller operations relied on animal manure to fertilize crops, while larger farming units had adopted commercial fertilizers. Statistics collected in the census of Agriculture further substantiate this statement. In 1971, 62,447 farms in

Ontario reported purchases of commercial fertilizers totalling $54,355,340; 30,965 or 50 percent of these farms had a value of agricultural products sold exceeding $10,000. These same farms, while only accounting for 50% of the total number of purchases, did account for $43,099,770 or 79 percent of the total value of commercial fertilizers purchased.

In 1961, Ontario farms in the "greater than $10,000 value of products sold" class accounted for only 38 percent of the total number of farms reporting the use of commercial fertilizers, however, the same 38 percent spread fertilizers on 71 percent of the total land fertilized.

The reasons for manure ceasing to be an "economic good" in some instances are many. Today's high crop yields require heavy applications of fertilizer. These applications must be applied evenly and inexpensively, with a high expectation of providing all of the crop with the same amount of nutrients. Commercial fertilizers easily meet these requirements. They have a proven nutrient content and can be obtained in a variety of formulas tailored to suit the needs of each particular crop and soil type. Application has been facilitated by a product with a given consistency which can be easily applied from the many spreaders available to do this job. Animal manure is unable to provide a source of consistent crop nutrients. The ratio of Nitrogen and Phosphorus may be affected by the kind of animal (i.e., Dairy, Beef, etc. - see Page 73). These values, which exist only at the point of excretion if the animals are all fed similar rations, may be further altered by the addition of bedding material and by improper storage. Liquid manure may lose some nutrients through oxidation and solid manure, if left uncovered, may have soluble nutrients leached during precipitation. To further complicate matters, the application rates of both solid and liquid manure may vary widely, depending on the equipment used. Spence [21] has noted that, in some field trials where application rates were measured, the following results occurred:

	High Rate	Low Rate
Solid Manure	20.1 tons/acre	3.6 tons/acre
	35.5 tons/acre	6.4 tons/acre
Liquid Manure	17.7 tons/acre	8.4 tons/acre

To offset some of these disadvantages, farmers may obtain an analysis of manure at the University of Guelph. This analysis could benefit the farmer in several ways. The application rates for manure could be adjusted to avoid application at a rate excessively above the optimum and manure deficient in certain nutrients could be combined with a commercial fertilizer to provide an improved balance of nutrients. Table XII gives some indication of the value of manure when compared with commercial fertilizers. [22]

Although manure in many cases compares favourably with applications of commercial fertilizer, this advantage may be quickly lost if manure is not applied during the optimum spring planting period. Application during this period provides the maximum benefit for plants while avoiding the possibility of water pollution from spreading manure on frozen or saturated soils. The costs of optimizing the spreading of manure on a once-a-year basis have been shown by both Spence [23] and Jensen [24] to be prohibitive.

Spence has calculated that the value of manure produced by one beef animal is $23 - $35/ton. Jensen has noted that to store this quantity of manure in a dry lot system would cost $24 - $30/12 month period. If spreading is done twice a year, this cost disadvantage is reduced, but the value of half the manure is not optimized since it was not applied at the correct time.

The existence of this narrow cost advantage for utilizing manure twice/year and the availability of more free time during the winter months has resulted in many

TABLE XII

SUMMARY OF THE VALUE OF MANURE IN FIELD TRIALS ON GRAIN CORN

Treatments (1)	I	II	III	IV
Manure Type				
Poultry	$3.40/ton			
Hog		$0.97/ton		$3.67 - $4.67 per 1000 gals.
Dairy			$0.33 - $0.90 per ton	
Beef	$2.66/ton (2)	$1.00 (3) - $1.50 (2) per ton	$0.94/ton (3)	

(1) I. Solid manure versus a check plot with no manure or commercial fertilizer.

II. Solid manure versus commercial fertilizer.

III. Solid manure plus a balancing amount of commercial fertilizer versus Commercial fertilizer.

IV. Liquid manure plus a balancing amount of commercial fertilizer versus commercial fertilizer.

(2) Average of 4 years of study.

(3) Average of 11 years of study.

NOTE: In most cases manure was applied preplant. In some cases manure was analysed and applied according to a soil test, in other cases a set amount of unanalysed manure was applied. Manure value is based on the extra yield of corn at $1.00 per bu. in treatment I and on the value of commercial fertilizer replaced in other treatments. There are problems when the two treatments don't give a similar yield.

Source: Spencer, V. D. Livestock Manure Disposal on Agricultural Lands.

farmers spreading manure during this period without regard for the loss of nutrients during the spring melt period.

Often farmers who do store their manure during the winter months do so improperly, with the result that nutrients are leached from the pile to ground or surface water. The proper design of manure storage facilities is essential if problems resulting from the loss of nutrients are to be avoided.

Another development which will affect the handling of manure in the Great Lakes Basins has been the steady retraction of the land base traditionally used to support livestock and poultry operations. This trend has still not reached the point where remedial measures cannot be taken, but without effective legislation (requiring minimum amounts of land for manure spreading), problems will develop. The poultry industry, with its dependence on specialized feeds purchased off the farm, is a good example of what may develop in other sectors.

In the Basin, land has become one of the most expensive factors of production and this has limited expansion in the size of livestock farms relative to the increased numbers of animals they support. The result has been a growing inability to remain self-sufficient in the production of feed grains (see Table XIII) and disposal of manure in concentrations exceeding crop requirements.

This lack of self-sufficiency is especially evident in the case of larger farming enterprizes with sales exceeding $10,000.00. (See Table XIII.)

This trend has been evident in the U.S. for a number of years, with the result that many intensive feeding operations have had to treat their wastes due to an insufficient land base. This increased cost for waste treatment has again contributed to a narrowing profit margin for intensive feeding operations.

H. Henry [25] has suggested that the Ontario Government sponsor a manure transportation policy to help alleviate the problems of high density animal wastes. Since the value of manure is so low, transportation becomes the key cost in any plan to sell this product to other farmers.

A policy like this is certainly preferable to the alternative of farmers applying excessive amounts of manure to the land with certain undesirable environmental consequences.

In most of the literature, there is a preoccupation with the changes which have occurred in the beef industry and the attendant environmental repercussions of these changes. It should be noted that the same market forces which have caused the development of the beef feedlot have also been responsible for the move to intensive feeding of almost all other livestock. This is especially important when one considers that one dairy cow produces twice as much phosphorus as a beef feeder, and most dairy animals are maintained in confined conditions during their fresh period. In the previous discussion on livestock and poultry management, it was evident that all livestock classes are moving in this direction or have the potential to do so. Therefore, any consideration of environmental degradation from agricultural sources must necessarily consider all classes of livestock and poultry.

REASONS FOR CHANGE

The previous sections have dealt with the nature of change in agriculture in the Great Lakes Basin. This section will outline briefly some of the more important reasons for this change which has affected agriculture from a social, economic, and environmental perspective.

Probably the most important factors which have affected this metamorphosis in the family farm are the economic factors operating in the market place. These economic forces have used the rapidly changing technology of the 20th Century as the vehicle for this change.

Unlike most other sectors of the economy, agriculture is faced with a relatively inelastic demand for its products. As the incomes of Canadians increase, the tendency is for consumption of non-farm products to increase in comparison to consumption of farm products. Since there is a finite capacity for per capita consumption of foodstuffs, most of the increased consumption is generated by a growing population and the establishment of new export markets. The most important change that increasing incomes have had on the demand for agricultural products is to generate an increasing demand for higher quality products with their attendant improved processing and packaging. Most of these changes are more likely to benefit the processor of agriculture products.

This relative inelasticity has forced farmers to produce more per unit of input. The Ontario Farm Machinery Investigation Committee [26] reported that, prior to 1941, one agricultural worker fed 10 persons; in 1963 that same worker fed 26 persons.

Farmers have accomplished this expanded production in times of high land values and assessment by automating production to minimize costly land and labour inputs. This investment in technology has resulted in a dramatic increase in the capital value of farms.

TABLE XIII

ONTARIO AGRICULTURAL FEED SALES

Ontario	Total Feed Purchases	Feed Purchased by Farms with total value of agriculture products sold exceeding $10,000	% of total
1971	$211,182,960	$180,083,700	85%
1961	147,154,030	--	--
1951	84,125,000	--	--

-- Indicates statistics unavailable.

Source: Statistics Canada, Census of Agriculture.

TOTAL CAPITAL VALUE OF FARMS

($,000)

	1951	1961	1966	% Increase
Lake Ontario	597,832	836,311	1,083,869	81%
Lake Erie	918,976	1,512,807	2,058,390	124%
Lake Huron	636,743	870,086	1,146,243	80%
Lake Superior	13,392	18,052	18,709	40%

Source: Statistics Canada, Census of Agriculture.

Until recently, the agriculture sector had adapted to the steadily narrowing cost-price squeeze (see below); however, this adaptation to an increasingly undesirable competitive situation was not made without costs, and many of these costs were not fully apparent until just recently. Much of this awareness has come as a result of the travel and settlement of urban dwellers in the rural setting. This group, with its growing awareness of environmental problems, has been quick to demand improvements in environmental quality. In many instances, this demand for improvements in environmental quality has been directly related to the problem of eutrophication. The farm, with its high potential for nutrient enrichment of water, has become an important target for criticism. The question remains, will farmers be able to absorb the cost of purchasing additional land or pollution control equipment and will society be willing to pay more for agriculture products to finance these changes.

COST PRICE RELATIONSHIPS IN ONTARIO AGRICULTURE

Ont.	No. of Census Farms	Cash Receipts $,000	Net Income $,000	% Net Income Represents of Cash Receipts	Net Income/ Farm
1971	94,722	1,387,619	338,209	24	$3,570
1961	121,333	872,530	308,792	35	2,540
1951	149,920	784,073	448,139	57	2,990

Source: Agriculture Statistics for Ontario 1972.

SECTION II

ENVIRONMENTAL IMPLICATIONS

This report has concentrated on describing those changes in agriculture with special emphasis on animal husbandry that have a potential for increasing the nutrient input to the Great Lakes. Since agriculture is a major user of both water and land, such changes as: a reduction in agriculture's traditional land base both in pasture and total improved land; increased numbers of livestock and poultry; move to intensive feeding of livestock and poultry; monoculture of specialized feed crops; developing reliance on purchased feeds; dominance of livestock in total farm income; growing use of commercial fertilizers; increasing costs of handling manure and the uncertain economic position of farmers are certain to have environmental repercussions. Many years ago, farmers discovered empirically the value of manure for fertilizing crops. Technological advances and the influence of economic factors are causing an abandonment of this traditional approach. How this change in approach may affect water quality in the Great Lakes Basin is a subject that must be investigated.

Acting in combination with the above factors, the climate of the Great Lakes Basin, characterized by a cold winter season followed by a period of rapid spring runoff, has resulted in a danger of rapid nutrient enrichment of water from both point and diffuse sources of animal wastes.

Although animal wastes may cause other problems (i.e., bacteriological [27]), this paper will limit itself to an examination of the fate of Phosphorus and Nitrogen in manure.

PHOSPHORUS

Phosphorus in manure most often moves to a receiving body of water in four ways.

1) Infiltration through the soil profile to groundwater.

2) Infiltration through the soil profile with artificial interception by sub-surface drains.

3) Overland flow in solution with surface runoff.

4) Overland flow by attachment to dislodged sediment particles.

Infiltration to Groundwater

Phosphorus is generally one of the least mobile of the plant nutrients found in manure. Once the negatively charged phosphate ion comes in contact with the positive ions in the upper soil horizons, it readily forms insoluble compounds. In acid soils, the cations of Al and Fe fix the phosphate anion, and, in basic soils, the Ca cation completes the fixation of phosphorus. The resulting precipitates are largely unavailable to plants and, because of their insoluble nature, will accumulate in the upper soil horizons. A minimum of phosphorus fixation occurs in neutral soils pH 6-7. [28] The phosphate ion may also be absorbed by the clay colloids and the soil organic matter. All of these mechanisms act to limit the movement of phosphorus in the soil column. A. J. Metson [29] provides well documented evidence of this lack of movement of P to groundwater. L. R. Weber and J. W. Ketcheson [30] have indicated that poultry manure applied over a three year period to natural soil core lysimeters at Guelph gave the following results:

TREATMENTS

	A	B	C	D
Phosphorus Added, kg/ha	50	408	1240	1590
Phosphorus in Percolates, kg/ha	0.35	0.65	0.38	0.35
Phosphorus Concentration, mg/l	0.029	0.057	0.033	0.034

M. H. Miller [31] presents further evidence of the immobility of phosphorus in the soil column. In test plots, 300 lbs./acre of fertilizer P were applied over a seven year period, with little increase in the concentration of P below 12" depth.

Recently, settlement geographers and archaeologists have used the characteristic immobility of phosphorus to their advantage in detecting ancient settlement sites. Since most of these sites are characterized by an accumulation of human and animal wastes, a simple soil chemical test modified by Gundlach [32] has allowed researchers to detect the locations of ancient settlements where no detectable surface remains are visible.

There are, however, some exceptions to this general rule. G. J. Kolenbander [33] has reported that the water soluble phosphorus contained in organic compounds of dairy slurry may percolate well into soil profile if application is followed by rainfall. This occurs when the phosphorus does not have sufficient time to mineralize. Both A. J. Metson [34] and G. J. Kolenbander [35] have reported instances of deeper phosphate percolation through sandy soils, which could result in eventual contamination of groundwater. In the Great Lakes Basin, the Lake Erie Basin has the greatest concentration of sandy soils. These predominate in the region of the Norfolk sand plain.

The very shallow soils adjacent to or on the Precambrian shield may also present some problems from phosphate leaching, however, the acid nature and poor permeability of some of these soils may offset the disadvantages offered by their thin profiles. Soils of this nature are found in parts of the Lake Ontario, Lake Huron, and Lake Superior drainage basins. The shallow soils overlying the Ordovician limestone of the Eastern Lake Ontario Basin may also present problems, especially since the fractured structure of the limestone bedrock facilitates the movement of percolates to groundwater.

E. F. Bolton [36] has reported that the application of fertilizer phosphorus on a Brookston clay "resulted in a small but consistent increase in the P concentration of the drainage water". The average concentrations of P in the drainage water were as follows:

PHOSPHORUS CONCENTRATION
IN WATER EFFLUENT
FROM TILE DRAINS
(ppm)

MANAGEMENT	CROP	NO FERTILIZER	FERTILIZER
(1) Rotation:			
	Corn	0.20	0.22
	Oats and Alfalfa	0.20	0.19
	Alfalfa 1st Year	0.18	0.21
	Alfalfa 2nd Year	0.17	0.27
(2) Continuous:			
	Corn	0.17	0.19
	Bluegrass Sod	0.17	0.19
	Mean	0.18	0.21

SOURCE: E. F. Bolton, J. W. Aylesworth and F. R. Hore, Nutrient Losses Through Tile Drains Under Three Cropping Systems and Two Fertility Levels on a Brookston Clay Soil.

Runoff and Erosion

Although the opportunities for phosphorus to reach surface water sources through soil infiltration are limited, the mechanism of surface runoff and soil erosion present a far greater hazard.

Surface runoff presents a problem when animal manure is applied at a time or place where the phosphate ion does not have an opportunity to establish contact with the soil. This situation could occur with the application of manure to frozen or saturated soils, application on bare, compacted, steeply sloping soils or application just prior to a period of heavy intense precipitation.

Before runoff can occur, precipitation must exceed the requirements for evaporation, infiltration, and surface retention. Once this situation occurs, the phosphate ion may move in solution in the overland flow. Weber and Ketcheson [37] have noted that "the greater the degree of incorporation, the lower the loss of nutrients in runoff water".

In the Great Lakes Basin, the danger from runoff is greatest during the spring and summer. In the spring, when the winter's accumulated snow undergoes melt and is unable to infiltrate the frozen and saturated soil, tributaries to the Great Lakes record their highest flows. In the summer months, storms of short duration, high intensity, and larger rain drop size are more likely to destroy the surface porosity of a soil through the action of rain drop impact and thus increase the danger of runoff. U. Sporns [38] has reported that the Great Lakes Basin and the Lake Erie Basin, in particular, have a higher probability of experiencing the more hazardous frequent intense precipitation than the remainder of Ontario.

Once the phosphate ion has been 'fixed' by the soil, the opportunities for its removal in solution are minimal. At this point, the most important mechanism for transport of phosphorus is through the detachment and movement of soil particles. The rate of erosion is generally a function of the following factors: -- climate, length and degree of slope, soil type, vegetative cover, and land management. Since the organic matter and fine clay particles which attract the P ions are concentrated in the uppermost soil layers, the P ion is very susceptible to displacement by erosion.

In the Great Lakes Basin, there is very little information on the losses from erosion. E. D. Ongley [39] has analysed some data on sediment discharges from Canadian Basins to Lake Ontario, but this data lacks any consideration of extreme meteorological events which have profound inlfuences on the rates of erosion.

J. D. Greer [40] has reported that, in studies of soil erosion under excessive rate rainfall, which accounted for 37 percent of total rainfall in the study area, between

73 percent and 80 percent of the total soil loss occurred then.

The high potential of most soils for fixing phosphorus has minimized the danger of phosphorus movement through the process of infiltration and surface runoff. As a result, soil erosion is probably the most important mechanism for transport of phosphorus to surface waters. The widespread adoption by farmers of commercial fertilizers and the tendency towards monoculture of row crops has accelerated the potential losses due to soil erosion.

Most studies evaluating the benefits of manure when compared to commercial fertilizers have only considered their respective nutrient values. The importance of the organic fraction of manure has often been overlooked. This deletion is especially important in terms of erosion control. The organic fraction of a soil directly determines the structure and permeability of that soil by influencing the formation of soil aggregates. Unlike the mineral fraction, organic material is destroyed by biologic activity and must, therefore, be constantly replenished if good soil structure is to be maintained.

A study completed in the U.S. provides evidence of the value manure has in maintaining soil structure and thus reducing erosion losses. Weidner [41] has reported that, despite the larger applications of manure and fertilizer to their study watersheds, there was a a marked decrease in the nutrient losses when compared to other watersheds operating under prevailing practice.

		PO_4 LOSS (lbs./acre)
Improved Practice	Corn	8.4
Prevailing Practice	Corn	27.7
Improved Practice	Wheat	1.1
Prevailing Practice	Wheat	3.6

Improved Practice - Contour tillage 180 lbs. of 5-20-20 fertilizer/acre and 180 lbs./acre wheat. 6 tons/yr./acre of manure.

Prevailing Practice - Straight row tillage 50 lb. of 5-20-20 fertilizer/acre corn and 100 lbs. on wheat. 4 tons/yr./acre of manure.

SOURCE: R. B. Weidner, A. G. Christianson, S. R. Weibel and G. G. Robeck. Rural Runoff as a Factor in Stream Pollution.

Although other studies are more concerned with sediment yields under varying soil organic conditions resulting from crop residue incorporation, the information does provide ample proof of the value organic material offers in preventing phosphorus loss through soil erosion.

W. H. Wiechmeier and J. V. Mannering [42] have indicated that, in their studies, runoff has ranged from 3 to 36 percent of total precipitation on the same soil type. This wide variation has been attributed to the amount of decomposed or partially decomposed organic matter in the soil. Soils with higher organic matter contents experienced less runoff. In their studies, organic matter referred to both crop residues and manure. They also found that, although there were wide variations in the texture and mineral content of the soils studied (sands - 4 to 64 percent; silt - 24 to 75 percent; clay - 9 to 41 percent), these differences were not as significant in affecting infiltration as was organic matter content and management.

While not all of the eroded soil reaches surface waters, A. P. Barnett [43] states that, of an estimated 50 million tons of soil eroded annually in the Potomac Basin, only 2.5 million tons are discharged at the estuary; the importance of this potential source of phosphorus should not be overlooked.

Farmers who optimize livestock and poultry manure will not only provide valuable nutrients for crops, but will also provide an important input of organic matter to insure long-term soil productivity. In addition, an improved soil structure and proper incorporation of manure with the soil will minimize the input of nutrients to surface waters.

NITROGEN

The nitrogen component of animal manure follows a much more complex cycle than does phosphorus. The various forms of nitrogen may reach surface water in the following ways:

(1) leaching of nitrogen to groundwater;

(2) movement of nitrogen in solution in surface runoff;

(3) movement of nitrogen in suspended form on eroded soil particles.

Leaching

When manure is applied to the land or when it is stockpiled in unprotected areas, the nitrogenous constituents will move into the soil profile where they may be adsorbed to the clay and humus fractions. Unlike the adsorption of the phosphate ion, which results in a very stable union, the ammonium ion (NH_4^+) is in a readily exchangeable form. There is some exception to this when the ammonium ion is adsorbed by one of the clay minerals, vermiculite, illite, and montmorillonite. These clay minerals all have a high affinity for NH_4^+ and may restrict its movement back into solution. Once the relatively immobile ammonium ion moves into solution, however, it will rapidly undergo nitrification to form the highly mobile nitrate ion.

NITRIFICATION

$$2NH_3 + 3O_2 \xrightarrow[\text{nitrosococcus bacteria}]{\text{nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+ + \text{Energy}$$

$$2NO_2^- + O_2 \xrightarrow{\text{nitrobacter}} 2NO_3^- + \text{Energy}$$

SOURCE: Role of Soils and Sediment in Water Pollution Control.

As outlined by the two reactions above, nitrification is a two step process requiring the presence of autotrophic bacteria to complete the conversion. The Nitrite (NO_2^-) form seldom exists except in poorly drained soils where it may be toxic to plants.

J. de Vries [44] has indicated that this process of nitrification is severely inhibited under conditions of low pH. Therefore, where acid soils exist in the basin, losses of nitrate nitrogen through leaching will be limited.

If anaerobic conditions develop in a soil, denitrification will occur. This usually happens in the lower soil horizons of poorly drained soils. In this case, the nitrate will be converted by micro organisms to gaseous forms which will be lost to the atmosphere. Once the nitrate ion reaches groundwater, it is beyond microbiological influences and is, therefore, protected from assimilation by organisms.

The amount of nitrate nitrogen leached is a function of the size of the zone of aeration, rate of leaching, concentration in the soil and rate of uptake by plants.

The following examples present some data on the movement of nitrogen through the soil profile. In this example, the rate of uptake under different crops is probably the most important factor limiting Nitrogen loss.

NITROGEN CONCENTRATION
IN WATER EFFLUENT
FROM TILE DRAINS
(ppm)

MANAGEMENT	CROP	NO FERTILIZER	FERTILIZER	% DIFFERENCE
(1) Rotation:				
	Corn	8.5	14.0	+ 65%
	Oats and Alfalfa	6.4	8.5	+ 33%
	Alfalfa 1st year	6.3	5.8	- 8%
	Alfalfa 2nd year	9.3	10.1	+ 9%
(2) Continuous:				
	Corn	4.4	8.9	+ 102%
	Bluegrass Sod	3.5	1.1	- 69%
	Mean	6.4	8.1	+ 27%

SOURCE: E. F. Bolton, J. W. Aylesworth and F. R. Hore, Nutrient Losses Through Tile Drains Under Three Cropping Systems and Two Fertility Levels on a Brookston Clay Soil.

In this example, the rate of uptake under different crops is probably the most important factor limiting nitrogen loss.

M. H. Miller [45] outlined an experiment in which an excessive amount of nitrogen as urea was applied to a corn crop. The urea form was quickly converted to nitrate nitrogen which accumulated in the soil. At the onset of fall rains, this nitrate accumulation disappeared. Groundwater monitoring disclosed that concentrations of nitrate nitrogen at a level of 66 ppm were found. This is far in excess of the 10 ppm level allowed in water for human consumption.

It was previously noted that the addition of the organic component of manure improved soil structure and reduced erosion. This addition of organic material also improves the water holding capacity of soils, and thus, reduces losses of nitrogen through leaching. Good soil structure also promotes plant growth and, therefore, increases the demand for nitrogen and reduces the amount of water available for leaching by increasing the rate of evapotranspiration.

Runoff in Soluble Form

The NO_3^- ion is extremely water soluble and, as a result, there is considerable opportunity for manure applied to frozen or saturated surfaces to contribute nitrogen in this form to surface water. If nitrogen is still in the NH_3^+ or NH_4^+ form, it will exert an oxygen demand on surface water, as well as contributing more nutrients to aggravate the problem of over-enrichment. This oxygen demand will occur when the NH_3^+ form is converted to NO_3^- in the aquatic environment.

Runoff in Suspended Form

Unlike phosphorus, there is not as significant a build-up of nitrogen in the upper soil horizon. This reduces to some extent the danger of nitrogen loss through soil erosion. Research completed by Weidner [46] has shown, however, that this may still be significant.

		TOTAL N (lb./acre)
Improved Practice	Corn	88
Prevailing Practice	Corn	237
Improved Practice	Wheat	11
Prevailing Practice	Wheat	31

Improved Practice - Contour tillage 180 lbs. of 5-20-20 fertilizer/acre and 180 lbs./acre wheat. 6 tons/yr./acre of manure.

Prevailing Practice - Straight row tillage 50 lb. of 5-20-20 fertilizer/acre corn and 100 lbs. on wheat. 4 tons/yr./acre of manure.

SOURCE: R. B. Weidner, A. G. Christianson, S. R. Weibel and G. G. Robeck. Rural Runoff as a Factor in Stream Pollution.

There is also a danger from animal manure washed directly into water sources or deposited there by animals not properly managed. This route would, of course, be the most direct and would cause the most marked impact on water quality.

In the recently published "Agricultural Code of Practice for Ontario" [47], land requirements for spreading manure are outlined. Nitrogen's high mobility within the soil profile has resulted in its designation as the limiting nutrient for spreading of manure.

The nitrogen component of manure requires careful management in order to minimize losses. This management component includes a consideration of the level of application, the timing of application, and the means by which manure is stored between applications. Applications to the soil at a time when plants cannot maximize the use of this nutrient or in amounts excessive to their needs only invites problems from leaching and surface runoff. Improper storage of manure can result in a significant portion of the available nitrogen being lost before application to the soil.

SECTION III

PATTERNS OF NUTRIENT ACCUMULATIONS IN THE GREAT LAKES BASINS AND THEIR MAJOR TRIBUTARIES

Data on the actual accumulations of P and N from livestock and poultry has been collected for the Census years 1931 - 1971. This data is presented on a drainage basin basis (see Graphs 1 - 17). No attempt has been made to quantify the portion of the accumulated nutrients reaching surface waters. This is a problem for field investigation where the many variables discussed in the foregoing sections on the mobility of Phosphorus and Nitrogen can be considered. However, the information is so presented that anyone wishing to apply their own pollution coefficients may do so with little difficulty.

Some authors have attempted to correlate the pollution potential of animal wastes with that of human wastes to provide some measure of the pollution impact from this source. This approach has one very important weakness in that, generally, animal wastes are disposed of in a diffuse manner in a soil medium, and human wastes are disposed of in a concentrated manner in a water medium. This difference in disposal results in very different environmental impacts.

For the purposes of this paper, the concentrations of P and N from livestock and poultry per acre of improved agricultural land have been developed for each major drainage basin.

This information, which has been presented both in tabular and cartographic format (see Tables XIV, XV; Maps 1 - 8) provides an indication as to which drainage basins are moving most rapidly towards a situation where concentrations of animal nutrients are approaching the acceptable limit. The limit, in this case, was established by the Agricultural Code of Practice for Ontario at between 170 - 340 lbs. of nitrogen per acre, depending on soil type. This is a maximum application rate which, if exceeded, could result in leaching of nitrates to groundwater. In order to maximize the benefits from manure, a farmer would be recommended to apply smaller quantities/acre. Due to data limitations, the approach taken by this paper must assume an even application of manure over all improved agricultural land in the basin.

The relative importance of the agricultural input to the total nutrient loading may vary between basins because the nutrient budget of any watershed depends on the nature of all the activities within that basin. For instance, different concentrations of urban and industrial activity will strongly affect the relative importance of the agricultural portion of that basin's total nutrient budget.

Livestock have been separated into the following groups:

Dairy

Beef

Cattle on Feed

Pigs

Sheep

Horses

Hens and Chickens

This breakdown will provide an assessment of the relative importance of each to the total nutrient accumulation in each basin.

In order to manage the nutrients coming from livestock manure, we must first identify the geographic co-ordinates and the volume of nutrients in the waste. Drainage Basins were chosen as the means for data aggregation over the generally accepted presentation of information by political sub-division for a number of important reasons.

Most of the concern in studying nutrient losses from agriculture has been to assess their impact on the water resource. The water resource is ultimately affected by the activities which occur within each watershed. In the case of agriculture, where few artificial diversions of animal nutrients occur from one watershed to another, only those activities occurring within a drainage basin are likely to affect the water resources of that area. Data collected on the basis of political units (township, county, etc.) must necessarily overlap several watersheds and, thus, the fate of nutrients within that unit cannot be fully understood. For example, if statistics on nutrients were presented for the county of Dufferin, it would not be clear whether these nutrients were likely to affect the Lake Huron, Lake Erie, or Lake Ontario drainage basins, since each of these drain part of this county.

The Drainage Basin as a region is often irrelevant in social and economic terms; however, in a consideration of water pollution, its value is apparent. If improvements in water quality are to be achieved, there must be an awareness of the differences which exist between basins. The Tennessee Valley Authority (T.V.A.) is perhaps the most well known example of the basin approach to planning. The Okanagan Basin Study, the St. John River Basin Study, and the design of Ontario's Conservation Authorities all reflect an appreciation of this approach.

DRAINAGE BASINS

Data was compiled on the Canadian portion of the Great Lakes Basin. This basin was further sub-divided into four major lake basins and thirteen major river basins.

1) Lake Ontario
   - (a) Moira River
   - (b) Trent River

2) Lake Erie
   - (a) Grand River
   - (b) Thames River

3) Lake Huron
   - (a) French River
   - (b) Maitland River
   - (c) Mississagi River
   - (d) Muskoka River
   - (e) Saugeen River
   - (f) Serpent River
   - (g) Severn River
   - (h) Spanish River

4) Lake Superior
   - (a) Kaministikwia River

(See Maps 1 - 8 for location of these basins.)

All of the drainage basins were determined by following the height of land on a reference set of topographic maps, at a scale of 1:250,000. This height of land, or 'divide', is the natural physical boundary between watersheds. Major river basins were selected on the basis of having a measured annual mean discharge exceeding 1000 cubic feet per second (cfs). [48] It should be noted that there may be some rivers in Northern Ontario with discharges exceeding this limit which have not yet been measured.

ANIMAL NUTRIENT ACCUMULATIONS

(a) Animal Numbers

To determine the number of livestock and poultry in each basin, it was assumed that their numbers were evenly distributed on the land designated as agricultural in the Canada Land Inventory. The previously designated drainage basin boundaries were then superimposed on a set of Canada Land Inventory Land Use maps and an estimate of the proportion of each township's total agricultural land found within the basin was made. The resulting township coefficients [49] were then used to calculate the numbers of livestock and poultry found within each basin using Statistics Canada, Census of Agriculture as a statistical base for the census years 1931 - 1971. The resultant populations (see Tables XVII - XXII) were then factored by the corresponding nutrient co-efficient to arrive at a figure representing the total accumulation of nutrients from that source.

(b) Nutrient Co-efficients

The following is a list of the phosphorus and nitrogen co-efficients used to determine the nutrient contribution from livestock and poultry.

	(lbs./year)	
	Phosphorus (P_2O_5)	Nitrogen
Dairy [1]	80	170
Beef [2]	30.47	71.64
Cattle on Feed [1]	32.5	88
Pigs [2]	12	23.6
Sheep [3]	10.95	38
Horses [3]	32.85	150
Hens and Chickens [2]	0.45	1.04

SOURCE: (1) T. H. Lane - Background material for the Agricultural Code of Practice for Ontario.

(2) See Appendix (3) for further description.

(3) S. A. Black, Pollution Problems Associated with Poultry and Animal Wastes in the Ontario Great Lakes Basin. Ontario Water Resources Comm.

There are many different estimates of the nutrient values of animal manures. Such variables as nutrient content of feeds, possible addition of bedding or floor litter to the manure, changes in temperature and humidity, age of animal may all affect the final measured nutrient content of manure. Wherever possible, the estimates made by T. H. Lane, University of Guelph, were used since they reflect prevailing conditions in Ontario agriculture.

In Tables XVII - XXII, statistics on the actual number of livestock and poultry are listed, so that other nutrient loadings may be developed on the basis of different co-efficients.

AGRICULTURAL CAPABILITY

To provide further information on the relative hazards of nutrient runoff from each basin, a tabulation of the agricultural capability of the soils for each basin was completed (see Appendix 2). This capability classification, developed under the Canada Land Inventory, provides data on the seven major soil capability classes and additional information on the limitations of these classes. Class 1 is assumed to have no limitations for agriculture. The limitation considered in the following basin analysis will be Topography.

> Topography - This sub-class is made up of soils where topography is a limitation. Both the percent of slope and the pattern or frequency of slopes in different directions are important factors in increasing the cost of farming over that of smooth land, in decreasing the uniformity of growth and maturity of crops, and increasing the hazard of water erosion. [50]

For the purposes of the paper, it was assumed that only classes 1 - 3 would undergo active cultivation and manure spreading and, therefore, be susceptible to nutrient runoff.

BASIN ANALYSIS OF NUTRIENTS FROM LIVESTOCK AND POULTRY

LOWER GREAT LAKES

Lake Ontario Basin

The Lake Ontario Basin comprises an area of approximately 10,975 square miles, of which the Trent and Moira River drainage basins account for about 50 percent. The remainder is drained by a series of smaller tributaries. The presence of the Niagara Cuesta in the western limits of the basin limits the effective drainage area to the scarp face and the narrow glacial Lake Iroquois lake plain below. The soils of this plain are either underlain by or consist of exposed lacustrine clay deposits which are relatively impermeable, encouraging rapid surface runoff.

To the north of Lake Ontario, the Interlobate or Oak Ridges Moraine once again restricts drainage to a narrow belt between the south slopes of the moraine and the Lake Ontario shoreline. This moraine extends from the escarpment in the west to the Trent River in the east. The moraine itself is characterized by a virtual lack of streams due to the very permeable nature of the depositional materials.

East of the Trent and Moira Basins, soils are shallow with only a few inches of unconsolidated material over the bedrock. This situation has limited the agricultural potential of this area. The physiography of the Trent and Moira Basins will be described later.

During the period 1951 - 1971, there has been a 44 percent decrease in the number of dairy cows in the basin while, at the same time, there has been a 93 percent increase in the number of beef animals (Table IV). Although the number of beef animals exceeds that of dairy, the contribution of total phosphorus and nitrogen from beef was less than that from dairy (see Graph 1). In addition, the move to intensive feeding of beef animals in the Lake Ontario Basin was not as marked as that of the Lake Erie and Lake Huron Basins. In the Lake Ontario Basin, only 20 percent of total beef were reported on feed in 1971, compared to 49 percent and 30 percent for Lake Erie and Lake

Huron Basins respectively. Only 8 percent of the total P_2O_5 from livestock and poultry came from cattle on feed, compared to 18 percent and 15 percent from Lake Erie and Lake Huron Basins respectively (Table XV). Thus, any nutrient pollution problems are most likely to result from dairy operations followed by beef.

While the contribution from hens and chickens was small in comparison to the total (only 12 percent), the total number and growth rate for this sector was greater than for any of the other Great Lakes Basins (Table IV). This may be an important consideration in light of the fact that few poultry operations have a land base suitable for manure disposal.

The concentration of nitrogen and phosphorus/acre of improved agricultural land was 41.47 lbs. of N/acre and 18.21 lbs. of P/acre in 1971. This represented a 20 percent increase in concentration between 1951 - 1971 (Table XIV) (Maps 1 - 4), when there was only a slight increase in the total nutrients available. If this trend continues, the hazard from nutrient pollution in this basin will undoubtedly increase.

On the 2,913,364 acres of land with an agricultural capability rating of 1, 2, and 3 in the Lake Ontario Basin, 8 percent were classified as having a topographic limitation

(Table XXIII) and, therefore, more susceptible to soil erosion and transport of nutrients. This does not include the relatively impervious clays on the glacial Lake Iroquois Lake Plain which promote rapid runoff even though slopes are not great.

- Moira River Basin

The Moira River drains an area of about 1,020 square miles and two distinct physiographic regions. In the north, the river drains the rock knob uplands of the Canadian shield where there are a number of lakes which act as reservoirs, providing continuous summer flow. The two largest lakes in the system, Moira Lake and Stocco Lake, occur in the contact zone between the Precambrian rocks of the Canadian shield and the Paleozoic limestones of the southern portion of the basin. Both of these lakes are eutrophic [51], but the source of nutrients is entirely natural since there is almost no agriculture practised in the upper reaches of this basin. Only the southern 1/3 of the basin supports agriculture, and this is limited due to the shallow nature of the soils. Over the period 1931 - 1971, there has been a significant decrease in the agricultural activity in this basin.

Dairy farming has always been the most important pursuit, followed by beef farming. Approximately 50 percent of the phosphorus from livestock and poultry comes from the dairy sector (Graph 5). Although the total phosphorus accumulation only amounted to 766 short tons in 1971 (Table XV), the concentration of nutrients per acre of improved agricultural land was comparable to the Lake Ontario Basin in 1971 (Table XIV). However, unlike the Lake Ontario Basin, which experienced an increase in nutrient concentration of about 20 percent between 1951 and 1971, the Moira Basin realized a decrease of 2 percent.

There were only 119,639 acres of land classified as having a capability of 1, 2 and 3. Eight percent of this was listed as having topographic limitations. This, coupled with the shallow soils, will probably increase the danger of nutrient runoff in this basin. It should be noted that agriculture is on the decline in this basin, and that volumes of nutrients are small, so that concern over nutrient runoff may not be of much importance.

- Trent River Basin

The Trent River, with a drainage basin area of 4,900 square miles, is the largest tributary to the Lower Great Lakes. It has experienced a maximum daily discharge of 18,000 cubic feet per second (cfs.), and a minimum daily discharge of 375 cfs. Like most of the tributaries to the Lower Great Lakes, the Trent River records its highest flows in March and April, during the period of spring melt. The river drains through a chain of lakes (Kawarthas) which occupy portions of pre-glacial valleys. The drainage of these valleys to the south is blocked by the Interlobate moraine, giving rise to low lying swampy areas at the southern extremities of many of these lakes. The basin drains one of the most extensive drumlin fields in southern Ontario where, if agriculture is not properly practised, considerable runoff and erosion may occur. The presence of this drumlin field probably accounts for the Trent River Basin having the highest percent of Class 1, 2 and 3 land affected by topographic limitations (19 percent) (see Table XXIII). This will undoubtedly contribute to problems of nutrient runoff.

Despite the large size of the basin, the land available for agriculture is considerably smaller in proportion to other tributaries to the Lower Great Lakes. This is largely the result of the significant portion of the Canadian Shield included in the drainage area.

The Trent River Basin once again reflects the importance of dairy and beef to the total agriculture nutrient budget (Graph 6). Numbers of beef have increased between 1931 - 1971 by 61 percent, while numbers of dairy cattle have decreased by 37 percent. All other classes have decreased (Tables XVII - XXII). In 1971, beef animals contributed the largest portion of total nutrients, but only 8 percent of the total came from "cattle on feed". The cattle on feed sector, while still small, showed the most rapid increase for any of the basins - 103 percent between 1966 - 1971 (Table XVI).

While the total accumulation was not great in 1971 - 5,264 short tons (S.T.) $P_2 O_5$ - and 12,027 S.T. of Nitrogen, the density/acre of improved agricultural land was comparable to other basins (Table XIV).

The nutrient runoff to the Trent River, while probably small in relation to other basins, has a greater potential for affecting the nutrient enrichment of receiving waters. This has resulted because of the location of the Kawartha Lakes, which act as a series of nutrient catchments. Any change in the nutrient status of these lakes could have important repercussions on the recreation and tourism activities centred there.

Lake Erie Basin

The Lake Erie Basin drains an area of some 8,689 square miles, and, like Lake Ontario, approximately 50 percent of this area is drained by two of its major tributaries; in this case, the Grand River and Thames River. The Thames River drains indirectly to Lake Erie through Lake St. Clair and the Detroit River. The remainder of the basin is drained by a series of small, deeply incised tributaries - Kettle Cr., Catfish Cr., Big Otter Cr., and Big Cr. The western portion of the basin is dominated by extensive areas of lacustrine clay plains. These plains are characterized by very low relief and poor drainage. In many areas, farmers are forced to install tile drainage systems to provide satisfactory conditions for crop growth. This portion of the basin should experience few problems from surface runoff of nutrients. Further east, the basin is dominated by the Bothwell and Norfold sand plains. In some cases, these plains are underlain by relatively impermeable clay soils which restrict drainage, but for the most part, drainage is facilitated by the deep sandy soils. This situation will also tend to limit runoff of phosphorus, but may result in problems of nitrate leaching. The physiography of the Thames and Grand Basins will be discussed later.

The nutrient budget for this basin is dominated by the contribution from beef animals. but there is a very substantial contribution from the other sectors. In 1971, beef animals accounted for about 35 percent of the total P_2O_5, dairy - 30 percent, pigs - 20 percent, and hens and chickens - 10 percent (Graph 2).

This more diversified nutrient budget will require careful management of all sectors in the Lake Erie Basin in order to avoid problems of nutrient runoff. This basin is also second only to the Lake Huron Basin in the total amount of accumulated nutrients. In 1971, there were 27,266 short tons of P_2O_5 deposited in the Lake Erie Basin, compared to the 28,078 S.T. of P_2O_5 in the Lake Huron Basin (Table XV). More important than the total volume of nutrients is the fact that most of the nutrients in the Lake Erie Basin come from animals where confinement feeding is practised. Forty-nine percent of the total beef were classified as cattle on feed (Table XVI), and these animals contributed 18 percent of the total P_2O_5 in the basin. This, combined with the important contributions from dairy, pigs, and hens and chickens, presents a greater potential for problems. This move to confinement feeding of animals is further reflected in the changes in acreage of improved pasture. The Lake Erie Basin experienced the greatest decline in this area - 45 percent between 1951 - 1971 (Table I). At the same time, the total acreage in row crops reported was greatest for the Lake Erie Basin (Table V). This has important implications, since the hazard of erosion and, indirectly, nutrient runoff is increased under these cropping practices.

The topographic limitation of 9 percent of the total Class 1, 2, and 3 land is one of the lowest (Table XXIII). This factor should have the effect of reducing some of the hazard of nutrient runoff. In 1971, the density of $P_2 O_5$ and N per acre of improved agricultural land was also the lowest of all of the Great Lakes Basins (Table XIV, Maps 1 - 4). These figures could be misleading, for, unlike other basins, there are large areas where specialty farming is practised, which has no relationship to livestock farming; i.e., truck crop farming in Essex county, tobacco farming in Norfolk county. Large areas devoted to uses such as these, where manure spreading is not practised, will undoubtedly introduce some error into the nutrient density calculations.

- <u>Grand River Basin</u>

The Grand River Basin, with a drainage area of 2,579 square miles, may be divided into two parts:-- the upper portion above Brantford which drains rapidly through extensive till plains with numerous tributaries and the lower portion below Brantford, which moves slowly across a clay plain with a much reduced gradient -- only two feet per mile, compared to 8.5 feet per mile above Brantford.

In the Upper Grand, the Stratford and Dundalk till plains provide soils of poor drainage, but with high livestock densities. Many of these soils have required artificial drainage as a prerequisite for successful farming. Although most of the terrain is generally even, those areas of more sloping soils are susceptible to erosion. Like the Trent River, the Grand drains an extensive drumlin field; in this case, it is around Guelph. The presence of this drumlin field is probably responsible for the Grand River having the second highest percent of Class 1, 2, and 3 agricultural land, with a topographic limitation (13 percent) (Table XXIII). Only very careful management will reduce the danger of runoff in this area, which also has one of the highest livestock densities in the basin.

The Lower Grand River drains through the Haldimand Lake Plain, which is an area characterized by very little variation in relief. The soils of this clay plain are better drained than in other areas of the Lake Erie Basin. This should have the effect of reducing surface runoff, thus preventing nutrient pollution.

Not only does the Grand River exhibit the greatest accumulation of nutrients from livestock and poultry of any of the Great Lakes tributaries, but it also has one of the highest nutrient densities/acre of improved agricultural land. This density also increased by 34 percent between 1951 - 1971 (Table XIV).

Once again, the importance of dairy, beef, and pigs, as sources of nutrients, should be underlined. Unlike many of the other basins, the number of dairy animals has experienced only a very small decline between 1931 - 1971 (Table XVII), and, therefore, will remain an important consideration in any future management of animal nutrient runoff. The number of pigs has increased by 208 percent between 1931 - 1971, indicating that this class will also be an important source of nutrients (Table XIX). In addition, 43 percent of the total beef herd was classified as cattle on feed, clearly illustrating the trend towards intensive feeding operations in this basin.

All of the above factors, combined with the higher than average susceptibility of these soils to erosion and runoff makes the Grand River Basin one of the highest risk areas in the Great Lakes Basin.

- Thames River Basin

Like the Grand River, the Thames, which drains an area of 2,210 square miles, may be sub-divided into an upper and lower basin. The Upper Thames drains that part of the basin extending above London. Below London, in the lower basin, the river drains an area of sand and clay lake plains with very little relief. The gradient of the river through this area is only about one foot per mile. The lower basin is also very narrow compared to the fan shape of the upper basin, and much of the agricultural land must undergo artificial drainage to improve productivity.

The upper basin drains an area of extensive till plains and moraines. The steeper gradient of the Upper Thames, about 10 feet per mile, combined with the glacial tills of low permeability encourages rapid runoff and drainage in this area. This rapid runoff often results in flooding of agricultural land in the lower reaches of the river. This condition could result in considerable nutrient pollution problems during the spring runoff period in the Lower Thames. With only 9 percent of the Class 1, 2, and 3 agricultural land classified as having a topographic limitation, the Thames Basin should only experience average problems of runoff. Unlike the dairy sector in the Grand River Basin, dairy farming has been of decreasing importance to the total nutrient budget of this basin. Pigs have experienced the greatest growth in this basin, both in absolute numbers and in rate of increase (Table XIX). This basin also reflects, to the greatest extent, the move to intensive feeding of beef. In 1971, 52 percent of the total beef herd was classified as cattle on feed, and these animals contributed 17 percent of the total accumulation of P_2O_5. This sector has also experienced a greater than average increase in total numbers - 31 percent between 1966 and 1971 (Table XVI). The lower density of P_2O_5 and N/acre of improved agricultural land, the slower rate of increase in the density of nutrients and the lower topographic limitation of the soils will probably result in fewer problems in the Thames River than in the Grand River. Most of the problems which do result are more likely to be in the Upper Thames.

UPPER GREAT LAKES

Many of the tributaries to the Upper Great Lakes, especially Lake Superior and the Georgian Bay North Channel portion of Lake Huron, are characterized by having relatively small nutrient accumulations. This is largely a result of the more severe climatic, soil, and market limitations of this area, which have acted in combination to restrict the development of agriculture. The small input of nutrients which may be expected from agricultural sources in this area may appear insignificant in terms of the total nutrient budget of these essentially oligotrophic lakes, but they may have considerable impact on the trophic level of the outlet bays of the tributaries to the Upper Great Lakes. Patalas [52] has presented interesting data on possible impacts that nutrients from municipal sources may have on these bays. Part of the problem has developed because the water in the bays, although directly connected to the Great Lakes, often does not circulate with the lake water. This results in very slow flushing rates which encourages a trend towards eutrophication. These bays are also very important from the standpoint of water quality since they are often a source of potable water, and they provide an area for the pursuit of recreational activities. Assuming that Patalas' approach is valid, it can be seen that Thunder Bay has exceeded twice the permissible loading and the north channel is just approaching the permissible loading. Therefore, any additional inputs from agriculture may have important implications for the trophic state of these waters.

Lake Huron Basin

The Lake Huron Basin covers an area of some 33,400 square miles - including Manitoulin Island. Approximately two-thirds of this area is composed of rocks of the Precambrian Canadian Shield, overlain in small pockets by soils suitable for agriculture. As one might expect, the most important areas for agriculture are in the area south of the Precambrian shield. This lower section of the basin is divided into an eastern and western portion by the Niagara Cuesta. The Maitland River and Saugeen River are the two most important tributaries in the western portion, and the Severn dominates in the east where it drains into Georgian Bay.

The southern portion of the basin drains across the Huron slope which is an area of clay soils often overlain by shallow sand deposits. Considerable erosion occurs at the point of abrupt change in elevation at the lakeward border of this slope.

The very shallow soils of the Bruce Peninsula are largely a result of the scouring action of the glaciers during the Pleistocene glaciation. As a result, most of these soils are used for pasture or have reverted to forest. Further east and south of the Bruce lies an area of mixed sand and clay plains which support a variety of agricultural practices from potato to livestock farming. Chapman and Putnam [53] have noted that the clay areas tend towards dairy herds because of their greater pasture potential and the sand areas specialize more in fattening feeders because of their greater corn growing potential.

The nutrient budget of the basin is dominated by the input from beef animals (Graph 3). In 1971, there were more beef animals in this basin than in any other, but there were fewer cattle on feed in this basin than in Lake Erie. Unlike the Lake Erie Basin, the concentration of nutrients/acre of improved agricultural land is higher, but as noted earlier, this may just be a result of different crop farming practices. The Lake Huron Basin also has twice as many acres of improved pasture which results in the nutrients, from beef animals in particular, being more evenly distributed over a wider area. The existence of these extensive areas of land, which are best suited for pasture, has resulted in the development of an important beef-cow-calf industry. This industry, because of its less intensive approach to land use, presents fewer risks from the viewpoint of nutrient runoff.

- <u>Maitland River Basin</u>

The Maitland River, which drains an area of 1,015 square miles, may also be divided into an upper and lower portion. The headwaters drain an area of till plain characterized by a low permeability, thus promoting rapid runoff, and the lower section of the river is deeply entrenched in a clay plain. In the upper reaches, the river drains part of the Teeswater drumlin field, which is an area of high livestock densities. The existence of this drumlin field is probably responsible for the higher than average topographic limitation of soils in Classes 1, 2, and 3 (11%) (Table XXIII).

Beef animals, once again, provide the dominant source of nutrients, although, this is the only basin in Southern Ontario to report an increase of 16 percent in the number of dairy cows between 1931 - 1971 (Table XVII). The number of beef animals has increased by 142 percent for the same period, and this represents the most rapid growth rate in the entire Great Lakes Basin. The growth rate in pig farming has also been rapid for this basin, being exceeded only by the Thames River and Grand River Basins.

In 1971, the density of nutrients/acre of improved agricultural land was the highest for any of the tributary basins to the Great Lakes, and it also demonstrated the fastest growth, having increased by 41.6 percent between 1951 - 1971 (Table XIV). Despite its lower total accumulation of nutrients, there is a definite danger of significant nutrient pollution from agriculture in the Maitland Basin.

- Saugeen River Basin

The Saugeen River drains an area of 1,561 square miles on the dip slope of the Niagara escarpment. The soils in the upper reaches of the river are very porous and shallow, a condition which encourages rapid infiltration and minimal soil erosion. In the lower reaches of the valley, Putnam [54] has reported extensive areas of erosion, even on pasture lands. Within the basin, there is an area of clay plain which varies between good and imperfect drainage - most of the farming activity is centred on the better drained soils.

The Saugeen Basin accounted for a similar accumulation of total nutrients from livestock and poultry as did the Maitland; however, the density of nutrients/acre of improved land is not as great. The soils in the basin also have fewer topographic restraints than those of the Maitland River Basin. The basin does, however, exhibit a strong trend towards the increased production of livestock and poultry, with a very definite emphasis on the intensive feeding of beef animals. At present, this basin presents fewer problems, from the viewpoint of nutrient runoff from agriculture, than does the Maitland River Basin.

- <u>Severn River Basin</u>

The Severn River drains an area of 1,982 square miles, most of which is composed of the paleozoic sediments characteristic in Southern Ontario. Lake Simcoe, the largest fresh water lake in Southern Ontario, provides a reservoir for this drainage system. The presence of this lake also increases the risk of nutrients in this watershed, causing eutrophication problems. Because this lake is an important source of water for recreation and potable supplies, the maintenance of the present trophic state is highly desirable.

The soils to the south-east of Lake Simcoe provide the focus for livestock farming in the basin. Here, the sand and till plains provide soils of variable drainage for livestock rearing. To the north of this area, soils gradually become shallower until limestone bedrock becomes visible near the contact with the shield. On the shield itself, there are only a few small pockets of land suitable for extensive livestock farming.

Although the total accumulated nutrients in the basin accounted for one of the lowest totals in Southern Ontario, the density per acre of improved agricultural land was one of the highest. The basin also reflects the general trend towards a dominance of total nutrient inputs by beef animals. In 1971, only 27 percent of the total beef were classified as cattle on feed, but this represented a substantial increase of 81 percent over the 1966 figure.

Only 3 percent of the Class 1, 2, and 3 soils in the basin have a topographic limitation, and this fact, combined with the generally low level of farming activity, should result in limited inputs to Lake Simcoe, and eventually, Georgian Bay, despite the high concentrations/acre of improved agricultural land.

- Shield Portion of Lake Huron Basin

The remaining major tributaries to Lake Huron all drain areas of the Precambrian shield. The soils suited to agriculture in this area are generally thin, and often scattered in small discontinuous patches. Normally, the lakes and rivers of this region have relatively low fertility levels and, therefore, any significant inputs of nutrients may have important consequences. This is especially important since all the tributaries studied have many lake catchments on their courses which have high recreational potential. This fact, combined with possible problems of changing trophic levels of the bays at the mouths of the rivers makes some analysis of the loss of nutrients from agriculture necessary.

Without exception, all of these basins exhibit decreasing levels of nutrients derived from livestock and poultry. This is in strong contrast to the tributaries draining Southern Ontario, with the exception of the Moira River, which all indicate rising levels of nutrients from this source.

Since the physiography of the basins is, in most cases, quite similar, and the total inputs are quite small, no further analysis of the inputs from this source will be examined, except for the maps (1 - 8), tables (XIV - XXII), and graphs (1 - 17), which present comparable information for all of the major tributaries to the Great Lakes Basin.

Lake Superior Basin

The Lake Superior Basin, with a drainage area of 34,525 square miles (including the Ogoki diversion) has the largest basin area in Ontario of any of the Great Lakes. At the same time, it has the least amount of land devoted to agriculture. Perhaps the most dramatic difference between the Lake Superior Basin and the other Great Lakes Basins is the fact that, in 1971, 71 percent of the improved agricultural land in the basin was concentrated in the basin of one tributary - the Kaministikwia.

- Kaministikwia River Basin

Only the lower portion of the 2,800 square miles of the Kaministikwia River Basin has soils suited to agriculture. Here, there are deposits of fine textured clays in an area dominated by Precambrian rocks. The short growing season, with high frost hazards, has reduced the use of these soils to pasture and forage crop production, and as a result, most of the farms in the basin report livestock. Dairying is the predominant specialization, and will probably remain in a strong position, due to the presence of the captive market of Thunder Bay.

Between 1931 and 1971, the number of dairy cows grew at a greater rate in this basin than in any other. Only the Maitland and the Kaministikwia River Basins reported any increase during this period (Table XVII).

Unlike the other tributary basins, which drain extensive areas of the Precambrian shield, the number of beef in the Kaministikwia has increased by 54 percent between 1931 - 1971 (Table XVIII), rather than experiencing a decrease. At the same time, the number of cattle on feed has decreased. It is unlikely that the feeding of beef will ever gain importance here because of the lack of markets and the low winter temperatures, which would require insulated and heated barns.

The low winter temperatures, which necessitate keeping animals in confinement conditions, may lead to some problems of nutrient runoff from manure piles. The total nutrient accumulation is not large, but the concentration per acre of improved agricultural land is slightly higher than that found in the Lake Erie Basin.

Although there is no information available on the number of acres classified with topographic limitation, the actual physiography of the area is generally flat to slightly rolling. These conditions should tend to minimize overland flow and soil erosion.

SUMMARY

The preceding analysis has shown that there exists a variety of physiographic conditions and agricultural activities in the Great Lakes Basins, which can affect the degree of nutrient runoff. These variable conditions will undoubtedly result in some basins receiving relatively larger inputs of nutrients from livestock and poultry, whether from point or diffuse sources. While all basins report significantly lower applications of nutrients than is required by the Ontario Code of Practice, this could be misleading. In order to calculate this density per acre of improved agricultural land, it was necessary to assume that all farmers would apply manure to all of the improved land in the basin. This situation is highly unlikely, for a number of reasons. First, not all farmers in the basin have livestock or poultry and, therefore, their land would be unavailable for spreading of manure. Second, many farmers prefer to use inorganic fertilizers in place of, or in combination with, manure, thus increasing the concentration per acre. Third, many farmers, through necessity or poor management, do not take the time to insure an even application over the available land.

The management aspect is probably the most important factor affecting the rate and amount of nutrient runoff from agriculture. A good manager can easily circumvent the problems of physiography by using sensible soil conservation practices. He can also optimize the value of his manure by applying it, less excessively than suggested by the Code of Practice, to his improved agricultural land. The provision of adequate storage facilities and the timing of manure application to minimize runoff and maximize use by crops are also ways in which a farmer can benefit from manure and reduce its environmental impact. One irresponsible farmer can do more damage than a far larger number of farmers using good management techniques.

However, for the purposes of this paper, we must assume equal management capability, and thus, the larger concentrated feeding operations, combined with less desirable physiographic conditions, are assumed to have a higher potential for causing problems. For example, if a comparison is made between ten operations, each with 100 cattle on feed, and one operation with 1,000 cattle on feed, it is apparent that the 1,000 cattle farm is easier to control from a management viewpoint, but its potential for exceeding the natural assimilative capacity of the stream is far greater than for the ten separate operations spaced out along the stream.

Through analyzing the aforementioned information, the basins have been listed below in order of their relative potential for nutrient runoff.

Lake Basins:
(1) Lake Erie
(2) Lake Huron
(3) Lake Ontario
(4) Lake Superior

Tributary Basins:

(1) Grand River
(2) Thames River
(3) Maitland River
(4) Trent River
(5) Saugeen River
(6) Severn River
(7) Moira River
(8) French River
(9) Kaministikwia River
(10) Muskoka River
(11) Spanish River
(12) Mississagi River
(13) Serpent River

SECTION IV

FUTURE AREAS OF CONCERN

If we assume that the trend towards intensive feeding of all forms of livestock and poultry will continue, and previously presented evidence appears to substantiate this, then we can expect the greatest increases in nutrient runoff in those basins with soils best suited to the growth of feed crops. Without an adequate supply of home-grown feed, a farmer's competitive position in the livestock sector would be seriously damaged. In order to meet the intense competition offered by American farmers and those in the west, a farmer must be as self-sufficient as possible in feed for his livestock.

D. W. Hoffman [55] has developed a series of performance indices for a number of feed crops on the basis of yields on each of the soil capability classes, designated under the Canada Land Inventory system of Soil Classification for Agriculture.

PERFORMANCE INDICES

Class	Grain Corn	Barley	Oats
1	1.00	1.00	1.00
2	.77	.83	.81
3	.59	.64	.69
4	.43	.47	.57

This was further refined to a common performance indice applicable to all field crops.

Class	Index
1	1.00
2	.80
3	.64
4	.49

Therefore, assuming similar inputs of labour and capital to the production of a crop on soils in each of the four capability classes, the output will always be in the same ratio. This situation will ideally result in soils in Class 1, 2, and 3 being the most intensively farmed.

If we assume that land will be used for its highest possible use, then the geographic distribution of soil capability, as presented in Table XXV, should provide a good basis for predictions of future agricultural activity in the basin.

The basins are arranged (in Table XXIV) in descending order of importance from the basin with the highest potential for supporting intensive livestock operations to the lowest. In addition, the ratings for each basin's potential for nutrient runoff are provided to give a clearer understanding of the future areas of concern in the Great Lakes Basin.

Although many of the tributaries to the Upper Great Lakes do not have high percentages of land in Class 1, 2, and 3, there are areas ideally suited to the development of cow-calf operations. Presently, more than half of the calves fed on Ontario feedlots come from Western Canada; however, the trend towards feeding these calves in the west is steadily becoming more popular, resulting in declining shipments to Ontario. Ontario feedlot operators are also dissatisfied with the poor handling of many of these shipments, in which as many as 1/3 of the calves have died or contracted diseases as a result of poor shipping practices.

Hill and Brown [56] have reported that, in the districts of Manitoulin and Algoma, the cost of producing 100 pounds of total digestible nutrients from hay is $1.50,

TABLE XXIV

POTENTIAL FOR GROWTH AND NUTRIENT RUN-OFF FOR THE GREAT LAKES BASINS AND MAJOR TRIBUTARIES*

	Basin	% of Total Land in Class 1, 2 & 3	Potential for Nutrient Run-Off
Great Lakes	(1) Lake Erie	87%	(1)
	(2) Lake Ontario	45%	(3)
	(3) Lake Huron	39%	(2)
Tributaries	(1) Thames River	96%	(2)
	(2) Maitland River	90%	(3)
	(3) Grand River	85%	(1)
	(4) Saugeen River	69%	(5)
	(5) Severn River	35%	(6)
	(6) Trent River	23%	(4)
	(7) Moira River	18%	(7)
	(8) French River	1%	(8)
	(9) Muskoka River	.4%	(10)

* For a complete breakdown of area in all classes for each Basin see Table XXV

compared to $2.50 in Southern Ontario. This is largely a result of lower labour costs, lower machine costs, and lower land and building costs. These lower land costs are also an important consideration in the establishment of a cow-calf operation.

Manitoulin Island, which was not tabulated separately in previous calculations, had the following distribution of soil types:--

CLASS:	1	2	3	4	5	7	0
ACRES:	0	72,651	49,365	89,694	29,809	116,749	30,439

According to D. R. Cressman [57], this distribution would give Manitoulin Island the capability to support 152,000 cattle and, in 1971, there were only 25,398 cattle reported.

This potential for producing relatively cheap feed, the large unused carrying capacity of the Island's soils, and an increasing demand for good quality feeder calves close to feeding areas in the Lower Great Lakes Basins could result in this area becoming an important base for the development of cow-calf operations. The extensive feeding approach of this type of operation should help to minimize nutrient runoff, but consideration should be given to environmental management if an industry of this type develops in the Upper Lakes Basin.

Although there remains a sufficiently large land base in the Great Lakes Basin for the disposal of today's wastes from livestock and poultry, the demands of the market place are resulting in a steady decline in the available acreage and a rapid increase in the volume of animal nutrients. It is inevitable that, if this trend towards a steadily decreasing land base continues, society will have to absorb the costs of artificial pollution control on farms.

Jensen [58] has indicated that, in our present beef feedlots, manure handling may be one of the major economic and labour inputs and, therefore, any changes in the costs of manure handling will have an important impact on this sector.

Studies by M. M. Sorboe [59] and F. R. Abraham [60] have clearly illustrated the very tenuous nature of both feedlot and cow-calf operations in the light of present economic conditions. In fact, Abraham noted that most cow-calf operators in Manitoulin would be better off investing their farm capital at 8 percent, rather than continuing in operation. M. M. Sorboe studied returns to feedlot operations on 21 lots of cattle. Operators failed to 'break even' on eleven of these, or more than 50 percent of the sales.

Not only would the agricultural sector be adversely affected if the costs of waste handling were increased, but the supporting infrastructure; i.e., farm machinery, fertilizer, feed producers, food processing, transportation, insurance, finance, etc. would also be severely affected. The Research Council of Canada has estimated that 42 percent of Canada's economy is directly or indirectly related to agriculture.

Society's growing demands for improved environmental quality will have to recognize the problems facing agriculture and the probable costs, both direct and indirect, of ensuring that the contribution from this sector is minimized.

TABLE XIV

DENSITY OF NITROGEN & PHOSPHORUS/ACRE

OF IMPROVED AGRICULTURAL LAND**

(lbs)

Basin	1951 N	1951 P_2O_5	1971 N	1971 P_2O_5	% change in Nutrient Concentration* 1951 - 1971
L. Ontario	34.70	15.04	41.47	18.21	20.29
L. Erie	29.54	12.89	31.68	14.22	8.78
L. Huron	33.59	14.41	41.39	18.24	24.90
L. Superior	24.59	10.56	32.51	14.52	34.85
L. Ontario					
Moira R.	42.56	18.72	41.35	18.32	-2.49
*Trent R.	35.81	15.37	40.95	17.92	15.47
L. Erie					
*Grand R.	35.88	15.65	47.68	21.43	34.91
Thames R.	32.79	14.48	38.36	17.54	19.06
L. Huron					
French R.	30.23	12.95	28.32	12.61	-4.47
Maitland R.	36.87	16.20	51.68	23.17	41.60
Mississagi R.	23.63	9.91	20.53	8.88	-11.76
Muskoka R.	34.13	14.33	43.13	18.47	27.63
Saugeen R.	32.46	13.87	44.29	19.53	38.63
Serpent R.	27.43	11.21	18.58	7.78	-31.43
Severn R.	36.21	15.62	50.04	21.86	39.07
Spanish R.	19.99	8.53	16.72	7.19	-16.03
L. Superior					
Kaministikwia R.	23.14	9.86	36.00	16.29	60.39

*Due to rounding of earlier calculations, it was necessary to average the change for both nitrogen and phosphorus to arrive at a uniform increase for both.

**These estimates assume an even application of all manure to the total improved agricultural land in the respective basins.

TABLE XV

TOTAL PHOSPHORUS (P_2O_5) CONTRIBUTION FROM LIVESTOCK, POULTRY, AND CATTLE ON FEED 1966 - 71 (tons/yr)

BASIN	1966 TOTAL P_2O_5 LIVESTOCK - POULTRY	1966 P_2O_5 CATTLE ON FEED	1966 % OF TOTAL FROM CATTLE ON FEED	1971 TOTAL P_2O_5 LIVESTOCK - POULTRY	1971 P_2O_5 CATTLE ON FEED	1971 % OF TOTAL FROM CATTLE ON FEED
L. Ontario	17,668	1,085	6	17,779	1,392	8
L. Erie	27,556	4,132	15	27,266	5,028	18
L. Huron	27,460	3,426	12	28,078	4,346	15
L. Superior	394	12	3	357	6	2
Great Lakes Basin	73,078	8,655	12	73,480	10,772	15
L. Ontario						
Moira R.	832	28	3	766	26	3
Trent R.	5,273	315	6	5,264	441	8
L. Erie						
Grand R.	10,815	1,503	14	10,960	1,711	16
Thames R.	8,450	1,218	14	9,346	1,597	17
L. Huron						
French R.	652	22	3	503	12	2
Maitland R.	4,876	596	12	5,353	832	16
Mississagi R.	51	2	4	35	1	3
Muskoka R.	141	5	4	123	7	6
Saugeen R.	5,269	680	13	5,424	764	14
Serpent R.	6.33	.3	5	3.3	.1	3
Severn R.	2,830	236	8	3,222	427	13
Spanish R.	142	9	6	80	2	3
L. Superior						
Kaministikwia R.	278	7	3	285	4	1

TABLE XVI

CATTLE ON FEED AS A PROPORTION OF TOTAL BEEF ANIMALS

BASIN	1966 TOTAL BEEF	1966 CATTLE ON FEED	1966 % CATTLE ON FEED	1971 TOTAL BEEF	1971 CATTLE ON FEED	1971 % CATTLE ON FEED	CATTLE ON FEED % CHANGE 1966 - 1971
L. Ontario	404,944	66,740	16	423,191	85,656	20	28
L. Erie	637,314	254,278	40	626,832	309,438	49	22
L. Huron	842,758	210,808	25	888,104	267,425	30	27
L. Superior	8,133	741	9	6,624	365	6	-51
Great Lakes Basin	1,893,149	532,567	28	1,944,751	662,884	34	24
L. Ontario							
Moira R.	20,549	1,740	8	22,083	1,628	7	- 6
Trent R.	156,149	13,398	9	164,618	27,146	16	103
L. Erie							
Grand R.	238,214	92,484	39	243,631	105,320	43	14
Thames R.	193,795	74,950	39	190,345	98,273	52	31
L. Huron							
French R.	14,435	1,368	9	12,316	762	6	-44
Maitland R.	133,504	36,697	27	137,878	51,188	37	39
Mississagi R.	2,201	95	4	1,212	37	3	-61
Muskoka R.	3,138	318	10	1,582	454	29	43
Saugeen R.	168,607	41,826	25	183,345	47,015	26	12
Serpent R.	250	20	8	137	6	4	-70
Severn R.	76,007	14,537	19	96,941	26,269	27	81
Spanish R.	4,191	566	14	2,864	96	3	-83
L. Superior							
Kaministikwia R.	5,693	441	8	5,059	275	5	-38

TABLE XVII

NUMBER OF DAIRY PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	256,679	321,543	287,793	220,538	205,362	185,910	160,711	-37
L. Erie	283,896	362,118	326,782	257,392	284,178	242,799	201,955	-29
L. Huron	258,487	325,508	273,134	248,913	241,459	215,947	185,681	-28
L. Superior	5,030	7,963	6,647	7,048	6,416	5,748	5,155	3
Great Lakes Basin	804,092	1,017,132	894,356	733,891	737,415	650,404	553,502	-31
L. Ontario								
Moira R.	17,277	21,259	16,616	11,976	11,188	10,084	8,279	-52
Trent R.	72,798	89,505	75,882	57,591	54,328	49,127	45,785	-37
L. Erie								
Grand R.	86,284	108,891	110,562	92,259	97,240	93,248	81,117	- 6
Thames R.	86,865	115,536	102,154	81,738	86,830	81,814	67,941	-22
L. Huron								
French R.	12,709	18,343	13,265	12,328	11,995	9,750	7,209	-43
Maitland R.	33,639	42,253	39,479	36,794	40,854	40,971	39,111	16
Mississagi R.	997	1,086	593	513	346	333	215	-78
Muskoka R.	5,843	6,124	3,454	2,953	2,434	1,847	751	-87
Saugeen R.	38,792	46,533	41,315	41,782	43,374	40,349	34,783	-11
Serpent R.	117	117	69	64	49	41	18	-85
Severn R.	30,423	39,142	36,015	31,276	25,932	23,428	24,642	-19
Spanish R.	5,245	6,797	3,977	2,627	1,925	1,324	690	-87
L. Superior								
Kaministikwia R.	3,544	5,544	4,725	4,985	4,619	4,295	4,207	19

TABLE XVIII

NUMBER OF BEEF PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	276,911	219,372	219,741	351,910	395,168	404,944	423,191	53
L. Erie	342,585	326,503	333,527	494,811	593,875	637,314	626,832	83
L. Huron	456,965	449,074	479,640	698,298	770,793	842,758	888,104	94
L. Superior	4,654	4,378	3,483	6,337	6,804	8,133	6,624	42
Great Lakes Basin	1,081,115	999,327	1,036,391	1,551,356	1,766,640	1,893,149	1,944,751	80
L. Ontario								
Moira R.	19,490	12,552	10,874	17,507	19,194	20,549	22,083	13
Trent R.	101,841	82,272	89,435	134,130	150,881	156,149	164,618	61
L. Erie								
Grand R.	108,417	110,217	114,905	181,669	214,246	238,214	243,631	125
Thames R.	106,191	98,389	100,179	150,494	180,749	193,795	190,345	79
L. Huron								
French R.	17,617	14,309	9,460	18,047	15,341	14,435	12,316	-30
Maitland R.	56,888	60,903	71,983	102,811	116,770	133,504	137,878	142
Mississagi R.	1,633	930	1,223	1,661	1,831	2,201	1,212	-26
Muskoka R.	7,381	4,538	2,987	4,426	3,879	3,138	1,582	-79
Saugeen R.	78,643	85,695	94,283	130,765	145,383	168,607	183,345	133
Serpent R.	215	122	131	181	173	250	137	-36
Severn R.	45,801	41,392	48,508	68,904	78,032	76,007	96,941	112
Spanish R.	6,547	4,472	2,797	5,005	3,846	4,191	2,864	-56
L. Superior								
Kaministikwia R.	3,291	2,990	2,387	4,436	4,883	5,693	5,059	54

TABLE XIX

NUMBER OF PIGS PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	279,130	381,297	347,143	286,090	300,192	303,683	371,379	33
L. Erie	454,050	697,710	614,144	598,197	722,052	881,969	1,091,917	140
L. Huron	390,706	545,293	580,642	517,933	538,980	629,215	751,230	97
L. Superior	3,156	4,324	3,868	1,645	1,584	1,599	2,403	-24
Great Lakes Basin	1,127,042	1,628,624	1,545,797	1,403,865	1,562,808	1,816,466	2,216,929	96
L. Ontario								
Moira R.	17,212	21,076	23,481	18,094	15,301	13,560	9,753	-43
Trent R.	87,994	106,828	103,759	88,352	87,363	85,090	78,874	-10
L. Erie								
Grand R.	147,753	207,470	242,563	235,437	285,219	375,497	454,615	208
Thames R.	128,953	196,642	186,946	178,721	221,875	258,227	490,376	280
L. Huron								
French R.	9,930	10,933	8,308	5,610	3,397	2,531	2,350	-76
Maitland R.	64,878	86,208	109,583	101,417	99,517	123,186	168,613	160
Mississagi R.	541	446	540	316	187	102	112	-79
Muskoka R.	2,243	2,189	1,878	1,368	795	871	199	-91
Saugeen R.	70,555	94,321	114,807	109,294	116,165	126,961	146,507	108
Serpent R.	76	68	43	32	20	24	7	-91
Severn R.	50,085	75,407	71,618	58,596	68,529	74,496	72,078	44
Spanish R.	5,094	5,242	2,716	1,956	1,744	2,066	375	-93
L. Superior								
Kaministikwia R.	2,117	2,731	827	790	720	722	2,183	3

TABLE XX

NUMBER OF SHEEP PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	216,611	138,900	85,106	95,625	76,926	60,611	47,759	-78
L. Erie	210,790	113,363	77,660	76,017	72,084	58,776	47,191	-78
L. Huron	394,721	245,389	125,805	137,462	120,117	94,475	81,921	-79
L. Superior	988	2,484	965	922	698	470	431	-56
Great Lakes Basin	823,110	500,136	289,536	310,026	269,825	214,332	177,302	78
L. Ontario								
Moira R.	11,988	6,542	2,946	4,570	3,330	1,876	1,324	-89
Trent R.	80,512	62,477	31,732	35,791	28,761	19,905	14,239	-82
L. Erie								
Grand R.	75,536	46,219	31,469	29,207	27,980	24,186	18,757	-75
Thames R.	43,832	25,918	15,202	16,112	15,777	11,984	9,774	-78
L. Huron								
French R.	16,302	8,784	2,275	2,802	1,427	1,613	1,063	-93
Maitland R.	24,849	12,415	5,351	6,124	8,855	4,867	6,932	-72
Mississagi R.	1,498	496	273	416	283	136	94	-94
Muskoka R.	6,960	2,733	677	1,218	990	894	357	-95
Saugeen R.	65,647	46,237	22,456	24,074	18,390	14,063	13,168	-80
Serpent R.	185	66	42	52	33	24	17	-91
Severn R.	49,494	33,352	16,961	19,028	17,248	14,827	11,562	-77
Spanish R.	4,362	1,172	282	310	316	200	135	-97
L. Superior								
Kaministikwia R.	752	1,947	804	761	629	394	308	-59

TABLE XXI

NUMBER OF HORSES PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	130,824	121,958	56,581	30,356	19,428	17,997	21,428	-84
L. Erie	169,816	168,767	67,219	30,960	23,778	21,217	21,555	-87
L. Huron	158,627	143,757	70,737	35,643	20,532	16,424	18,323	-88
L. Superior	2,893	2,308	1,497	862	306	297	276	-90
Great Lakes Basin	462,160	436,790	196,034	97,821	64,044	55,935	61,582	-87
L. Ontario								
Moira R.	6,188	5,528	2,935	1,623	1,010	673	514	-92
Trent R.	39,397	35,353	17,127	10,234	6,191	4,391	4,708	-88
L. Erie								
Grand R.	52,932	56,756	23,886	12,310	9,796	8,535	8,742	-83
Thames R.	46,065	41,592	16,824	6,665	4,852	4,340	4,988	-89
L. Huron								
French R.	4,857	4,765	3,137	1,802	843	532	321	-93
Maitland R.	19,572	17,712	8,338	3,504	2,162	2,009	2,027	-90
Mississagi R.	440	381	214	126	75	52	33	-93
Muskoka R.	2,819	2,009	1,130	702	380	272	170	-94
Saugeen R.	25,858	24,362	12,713	6,367	3,723	2,717	3,071	-88
Serpent R.	58	48	26	15	7	7	6	-90
Severn R.	19,128	17,136	8,169	4,252	2,454	2,463	3,433	-82
Spanish R.	2,502	2,199	1,112	562	234	158	141	-94
L. Superior								
Kaministikwia R.	1,994	1,563	994	541	160	198	216	-89

TABLE XXII

NUMBER OF HENS/CHICKENS PER BASIN

BASIN	1931 Number of Animals	1941 Number of Animals	1951 Number of Animals	1956 Number of Animals	1961 Number of Animals	1966 Number of Animals	1971 Number of Animals	% Change Between 1931-71
L. Ontario	5,575,883	5,094,186	5,525,552	5,086,080	5,879,778	7,170,520	9,162,517	64
L. Erie	7,485,551	7,942,079	8,882,076	9,909,506	9,756,227	9,659,388	10,997,621	47
L. Huron	5,336,326	5,134,418	5,916,409	6,773,630	6,857,787	6,313,484	8,285,906	55
L. Superior	195,816	152,030	125,841	156,770	127,723	99,159	127,761	-35
Great Lakes Basin	18,593,576	18,322,713	20,449,878	21,925,986	22,621,515	23,242,551	28,573,805	54
L. Ontario								
Moira R.	201,464	140,381	119,717	105,805	76,192	60,067	107,472	47
Trent R.	1,636,298	1,266,821	1,275,594	1,265,464	1,187,279	1,052,734	1,316,327	-20
L. Erie								
Grand R.	1,863,235	2,346,786	3,088,183	3,913,859	3,965,001	4,136,973	4,576,266	146
Thames R.	2,042,174	2,077,088	2,598,993	2,529,807	2,470,950	2,395,469	2,890,708	42
L. Huron								
French R.	103,332	115,113	105,453	85,795	68,126	41,033	9,166	-11
Maitland R.	1,014,569	822,921	1,283,057	1,623,981	1,743,166	1,797,482	2,691,352	165
Mississagi R.	9,163	7,080	5,414	7,163	5,851	10,334	27,681	202
Muskoka R.	73,964	53,116	42,899	48,922	38,587	21,151	279,057	277
Saugeen R.	735,154	808,986	944,196	1,197,508	1,056,262	899,942	1,059,026	44
Serpent R.	1,134	870	719	632	676	2,248	1,134	-
Severn R.	542,622	597,982	700,455	802,703	1,041,418	740,156	921,186	70
Spanish R.	70,071	70,321	62,942	48,778	42,052	38,973	14,115	-80
L. Superior								
Kaministikwia R.	114,911	88,590	69,683	85,971	65,555	57,968	94,644	-18

TABLE XXIII

TOPOGRAPHIC LIMITATION(1)

Basin	Total Capability Class 1,2,3 (Acres)	Area of Class 1,2,3 Soils with Topographic Limitation	% of Total Class 1,2,3
Lake Ontario (2)	2,913,364	245,669	8%
Lake Erie	5,679,239	382,641	7%
Lake Huron (2)	3,823,538	351,200	9%
Lake Superior (2)	-	-	-
Lake Ontario			
Moira River	119,639	9,115	8%
Trent River (2)	600,335	116,900	19%
Lake Erie			
Grand River	1,408,857	189,081	13%
Thames River	1,362,328	116,886	9%
Lake Huron			
Maitland River	583,970	64,089	11%
Mississagi River (2)	-	-	-
Muskoka River	-	-	-
Saugeen River	688,245	57,645	8%
Serpent River (2)	-	-	-
Severn River	450,144	24,222	5%
Spanish River (2)	-	-	-
Muskoka River	-	-	-
Lake Superior			
Kaministikwia (2)	-	-	-

(1) See Appendix - for further details on the C.L.I. soil capability for agriculture classification system.

(2) Some basins and sections of others which drain areas of the Canadian Shield were not included in the computer data base at the time of tabulation. This may result in a small error in the calculated area of Class 1, 2, and 3 soil types for these basins.

TABLE XXV

LAND CAPABILITY FOR AGRICULTURE *(1)

(Acres)

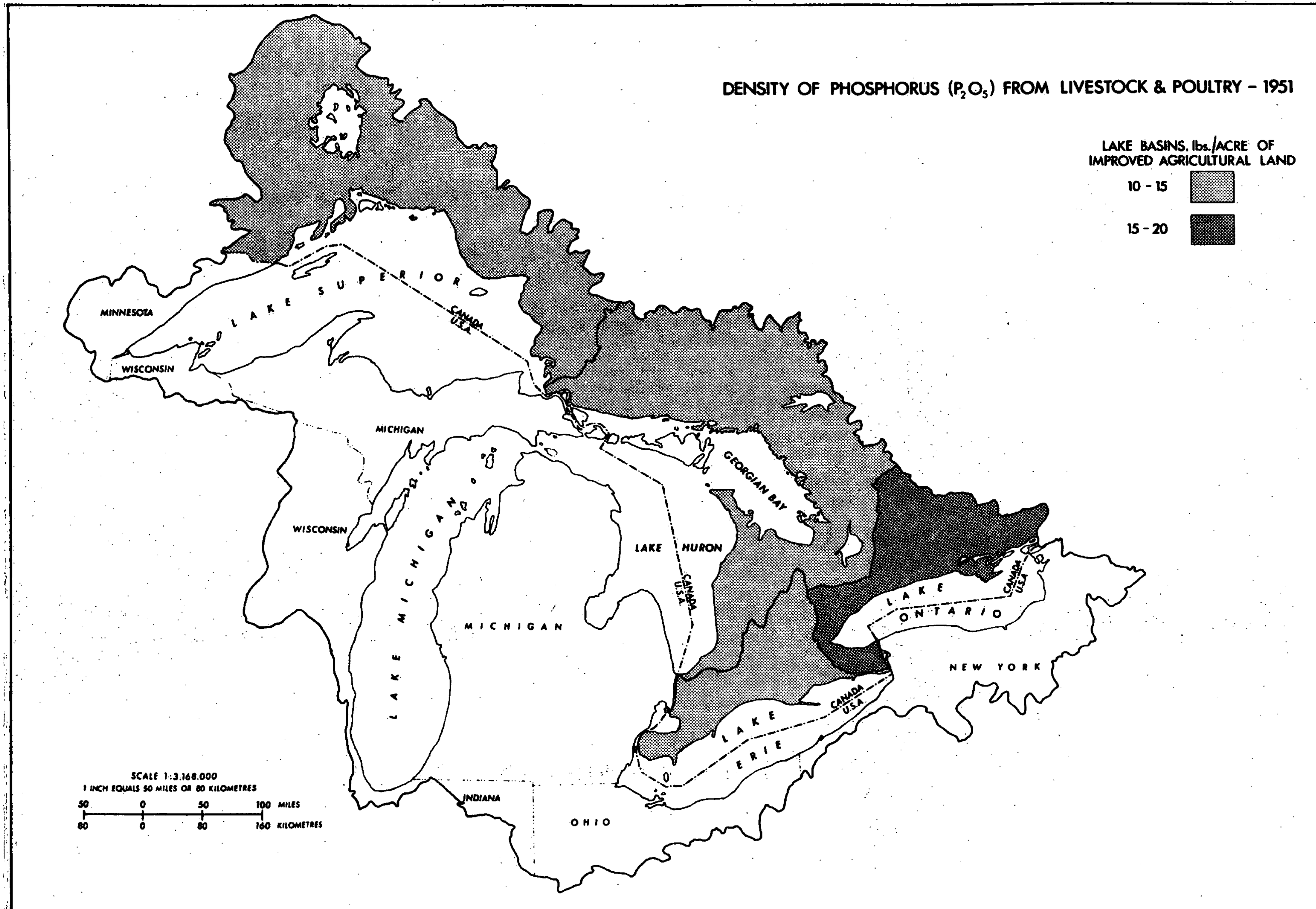
Basin	Class 1	Class 2	Class 3	Class 1, 2, 3 Total	% of Total Represented by Class 1,2,3 Soils	Class 4	Class 5	Class 6	Class 7	Class 0	Total All Classes
Lake Ontario	1,384,599	838,385	690,380	2,913,364	45%	441,922	159,952	798,423	1,868,756	318,039	6,500,456
Lake Erie	1,710,160	2,327,275	820,902	4,858,337	87%	219,907	209,516	77,366	62,668	133,406	5,561,200
Lake Huron (2)	1,973,736	1,016,534	833,268	3,823,538	39%	493,914	527,860	479,572	3,846,280	514,752	9,685,916
Lake Superior (2)	-	-	-	-	-	-	-	-	-	-	-
Lake Ontario											
Moira River	43,582	15,549	60,508	119,639	18%	11,652	5,228	100,624	381,663	31,825	650,631
Trent River	350,994	70,063	179,278	600,335	23%	242,996	33,207	335,312	1,261,171	152,349	2,625,370
Lake Erie											
Grand River	727,413	403,061	278,383	1,408,857	85%	57,587	73,878	21,908	222	88,440	1,650,892
Thames River	598,638	581,046	182,644	1,362,328	96%	10,419	20,062	-	-	21,382	1,413,921
Lake Huron											
French River (2)	-	-	2,836	2,836	1%	-	42,879	3,103	439,512	9,895	498,225
Maitland River	425,725	89,227	69,018	583,970	90%	11,667	5,851	14,290	-	33,697	649,475
Mississagi River (2)	-	-	-	-	-	-	-	-	-	-	-
Muskoka River	-	-	4,705	4,705	.4%	38,215	25,068	14,216	1,031,304	13,358	1,126,866
Saugeen River	449,420	97,978	140,847	688,245	69%	32,818	127,982	30,779	2,877	116,579	999,280
Serpent River (2)	-	-	-	-	-	-	-	-	-	-	-
Severn River	223,177	138,149	78,818	440,144	35%	123,370	23,841	146,228	426,684	108,287	1,268,554
Spanish River (2)	-	-	-	-	-	-	-	-	-	-	-
Lake Superior											
Kaministikwia (2)	-	-	-	-	-	-	-	-	-	-	-

*(1) See Appendix - for further details on the C.L.I. soil capability

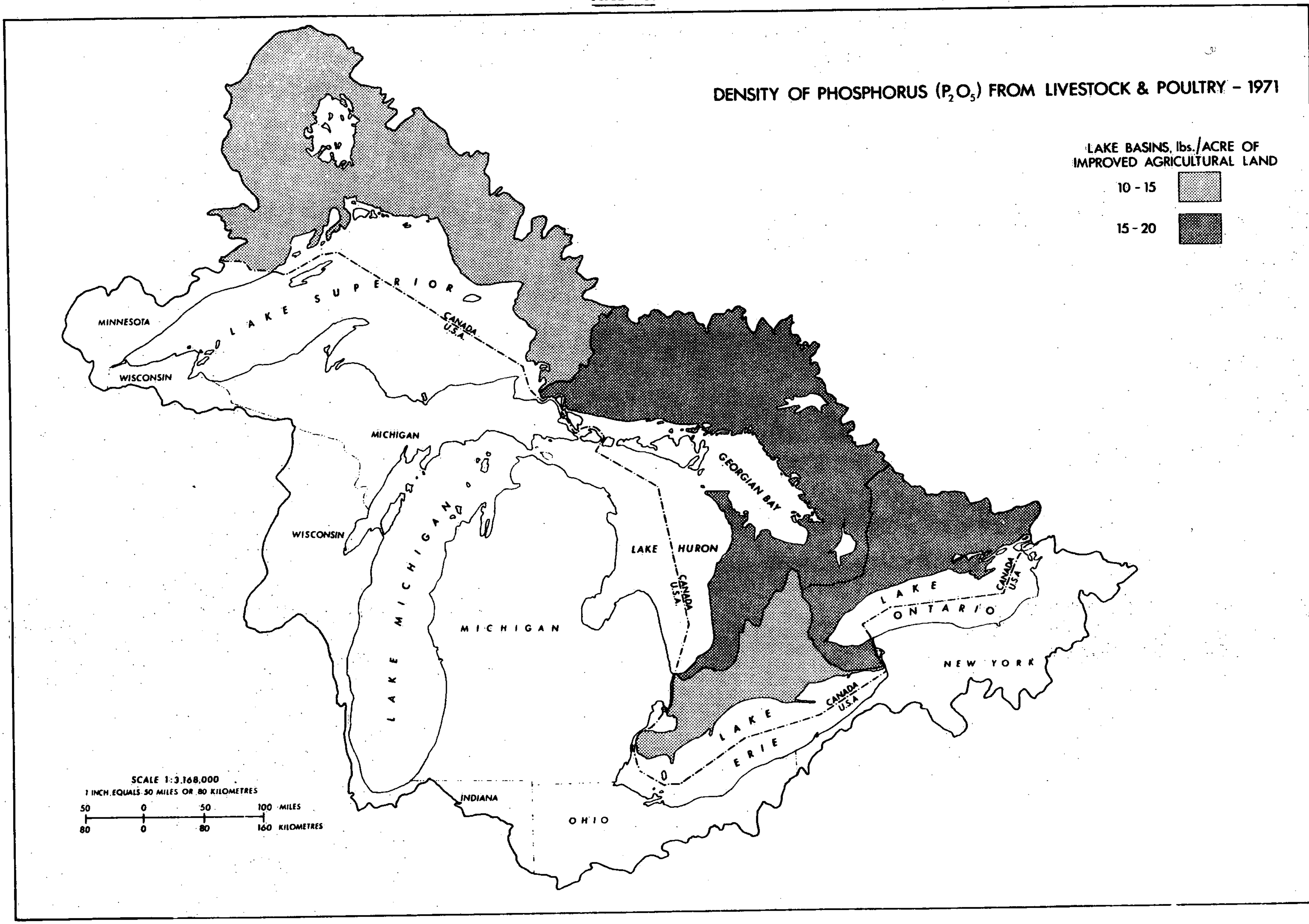
(2) Some Basins and sections of others which drain areas of the Canadian Shield were not included in the computer data base at the time of tabulation. This may result in a significant error in the calculation of the area of soil classes 6, 7.

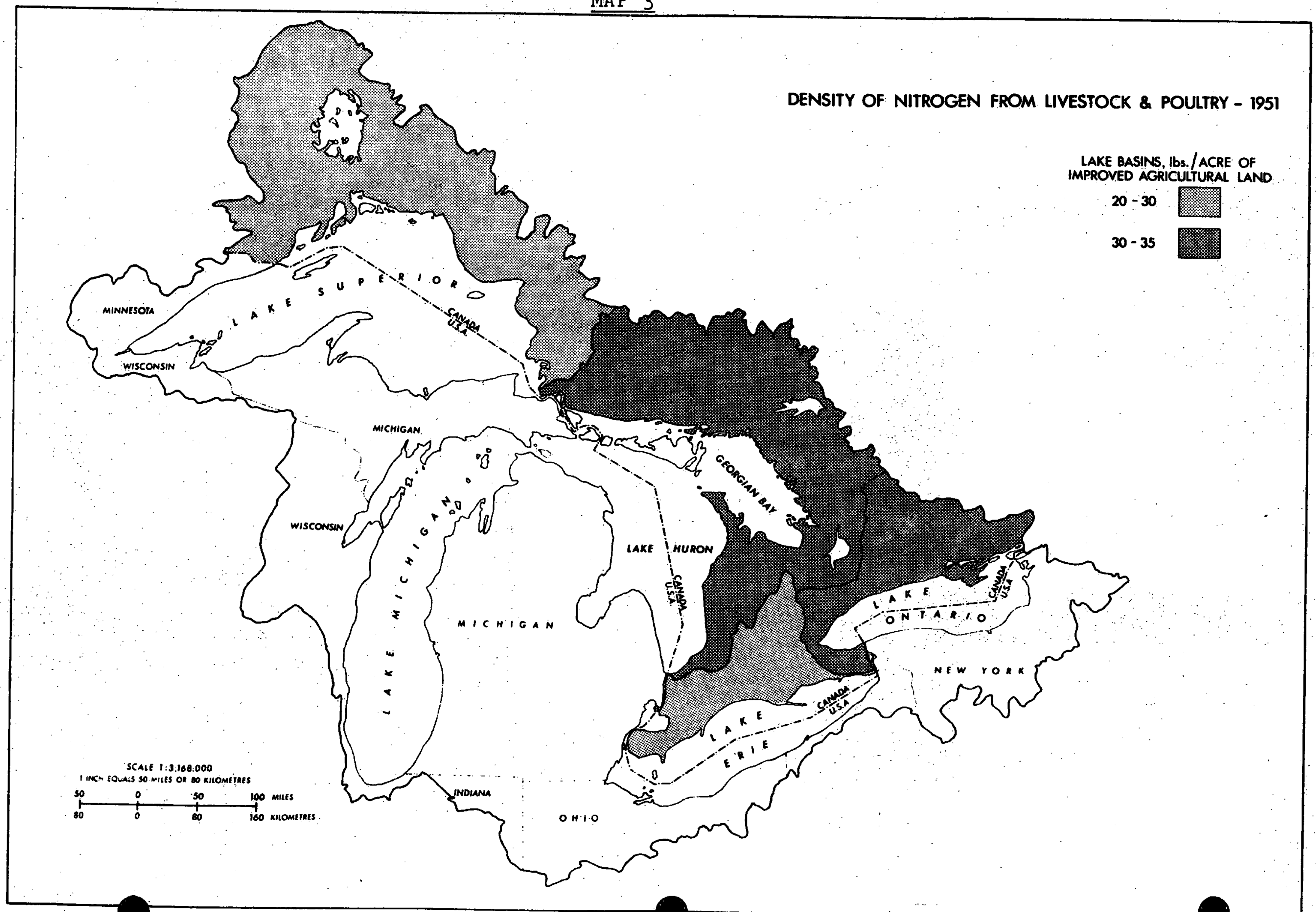
Source: Special Tabulation by Lands Directorate, Environment Canada.

MAP 1

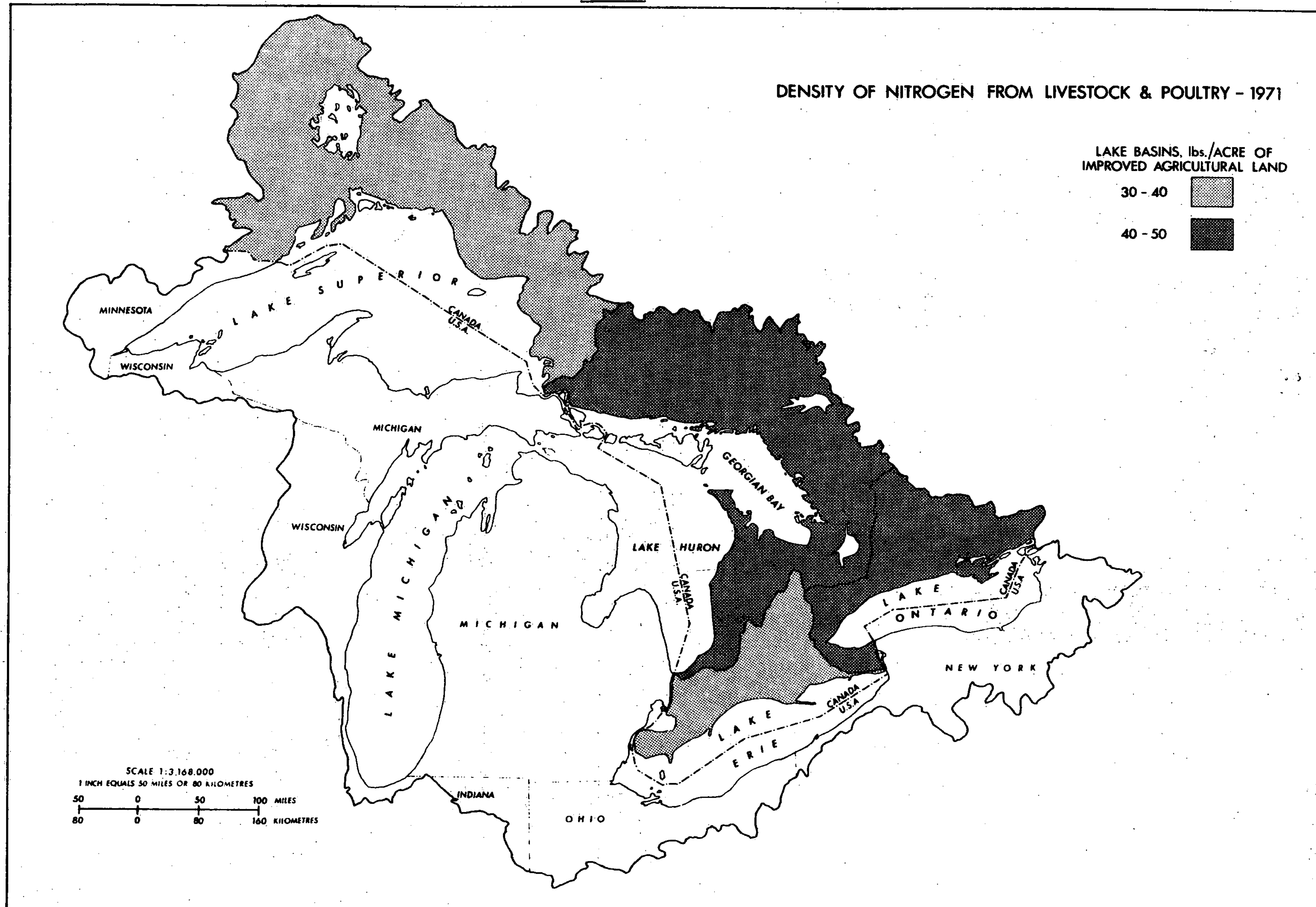

DENSITY OF PHOSPHORUS (P_2O_5) FROM LIVESTOCK & POULTRY - 1951
LAKE BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
10 - 15
15 - 20
MINNESOTA
WISCONSIN
LAKE SUPERIOR
CANADA
U.S.A.
MICHIGAN
GEORGIAN BAY
WISCONSIN
LAKE MICHIGAN
LAKE HURON
MICHIGAN
LAKE ONTARIO
NEW YORK
LAKE ERIE
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

MAP 2

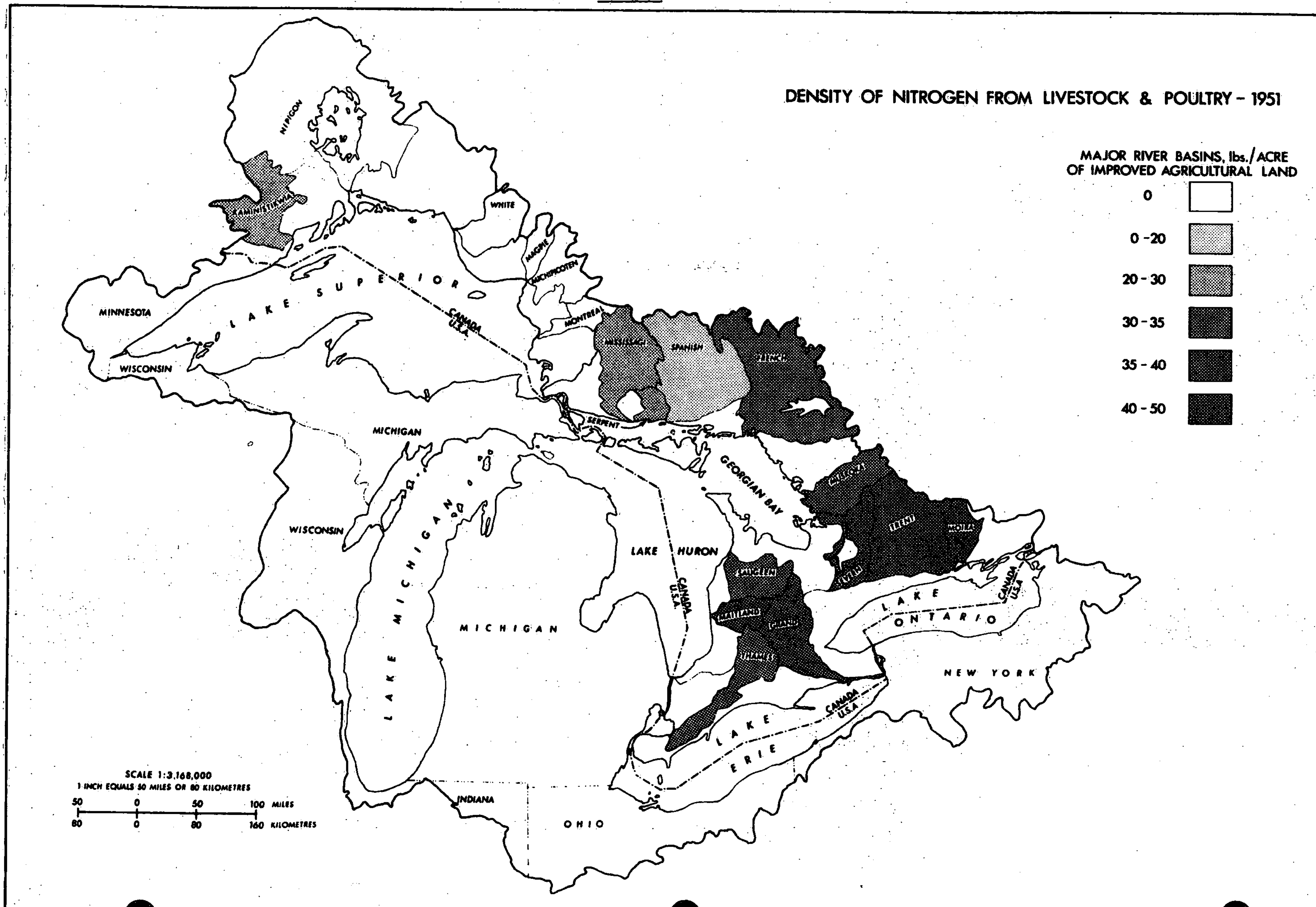

DENSITY OF PHOSPHORUS (P_2O_5) FROM LIVESTOCK & POULTRY - 1971
LAKE BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
10 - 15
15 - 20
LAKE SUPERIOR
CANADA
U.S.A.
MINNESOTA
WISCONSIN
MICHIGAN
GEORGIAN BAY
LAKE HURON
WISCONSIN
LAKE MICHIGAN
MICHIGAN
LAKE ONTARIO
NEW YORK
LAKE ERIE
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES


DENSITY OF NITROGEN FROM LIVESTOCK & POULTRY - 1951
LAKE BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
20 - 30
30 - 35
MINNESOTA
WISCONSIN
LAKE SUPERIOR
CANADA
U.S.A.
MICHIGAN
WISCONSIN
LAKE MICHIGAN
MICHIGAN
GEORGIAN BAY
LAKE HURON
LAKE ONTARIO
NEW YORK
LAKE ERIE
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

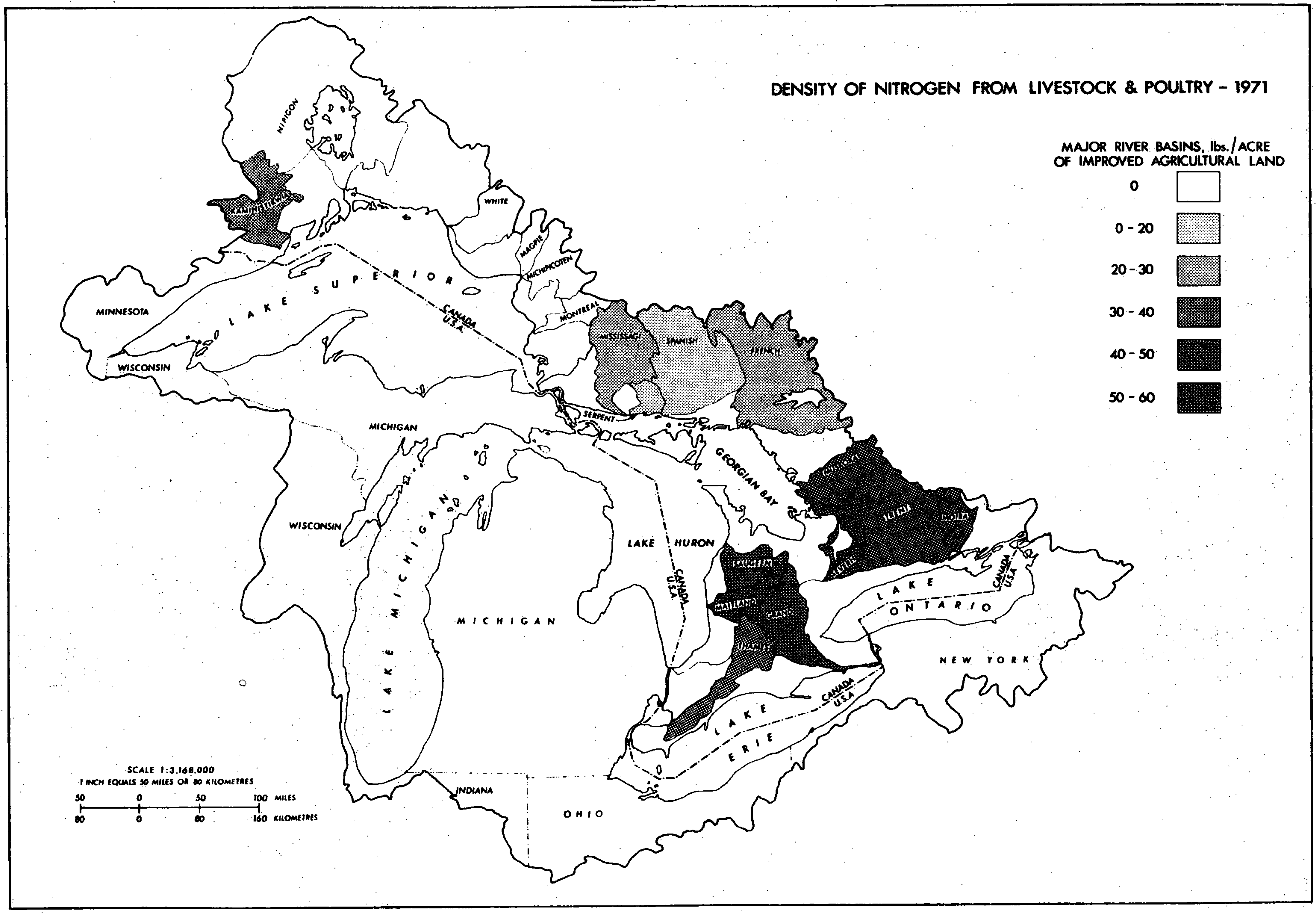
MAP 4


DENSITY OF NITROGEN FROM LIVESTOCK & POULTRY - 1971
LAKE BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
30 - 40
40 - 50
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
CANADA
U.S.A.
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
NEW YORK
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

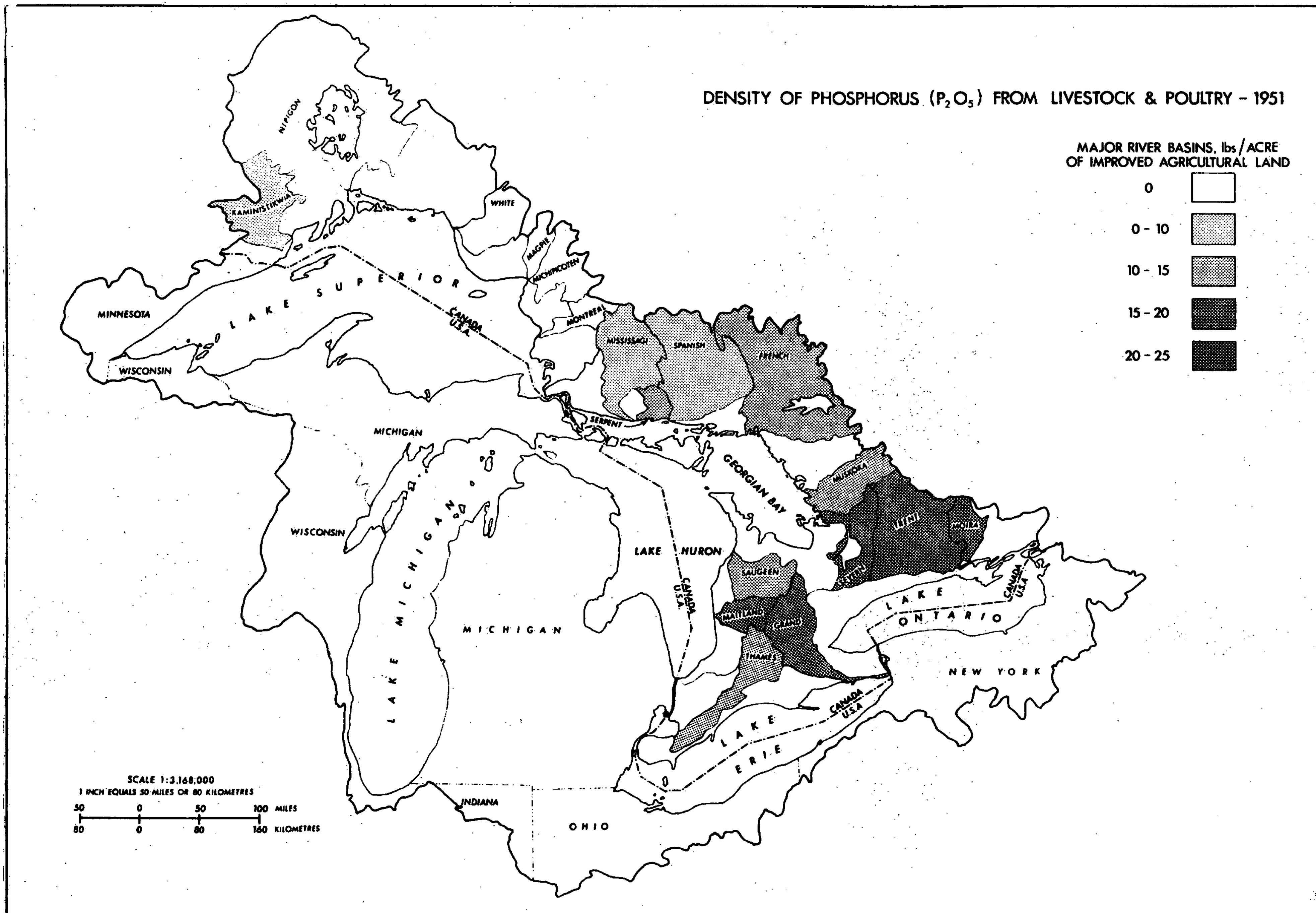
MAP 5


DENSITY OF NITROGEN FROM LIVESTOCK & POULTRY - 1951
MAJOR RIVER BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
0
0 - 20
20 - 30
30 - 35
35 - 40
40 - 50
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES
NIPIGON
KAMINISTIKWIA
WHITE
MAGPIE
MICHIPICOTEN
MONTREAL
MISSISSAGI
SPANISH
FRENCH
SERPENT
LAKE SUPERIOR
CANADA
U.S.A.
MINNESOTA
WISCONSIN
MICHIGAN
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
SAUGEEN
MAITLAND
GRAND
THAMES
TRENT
MOIRA
LAKE ONTARIO
NEW YORK
LAKE ERIE
INDIANA
OHIO

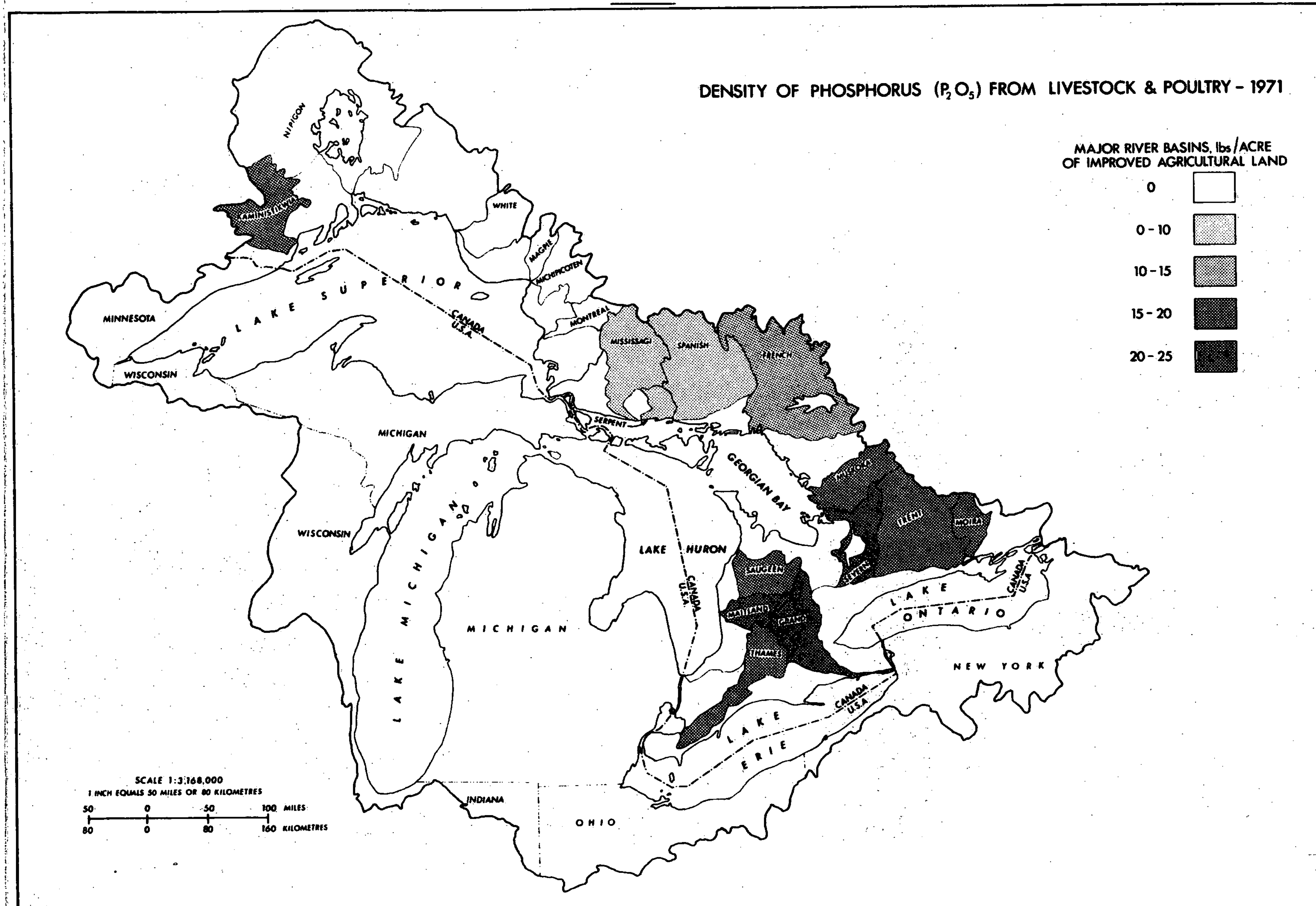
MAP 6


DENSITY OF NITROGEN FROM LIVESTOCK & POULTRY - 1971
MAJOR RIVER BASINS, lbs./ACRE OF IMPROVED AGRICULTURAL LAND
0
0 - 20
20 - 30
30 - 40
40 - 50
50 - 60
NIPIGON
KAMINISTIKWIA
WHITE
MAGPIE
MICHIPICOTEN
MONTREAL
MISSISSAGI
SPANISH
FRENCH
SERPENT
LAKE SUPERIOR
CANADA
U.S.A.
MINNESOTA
WISCONSIN
MICHIGAN
WISCONSIN
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
MICHIGAN
TRENT
MOIRA
SAUGEEN
MAITLAND
GRAND
THAMES
LAKE ONTARIO
NEW YORK
LAKE ERIE
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

MAP 7

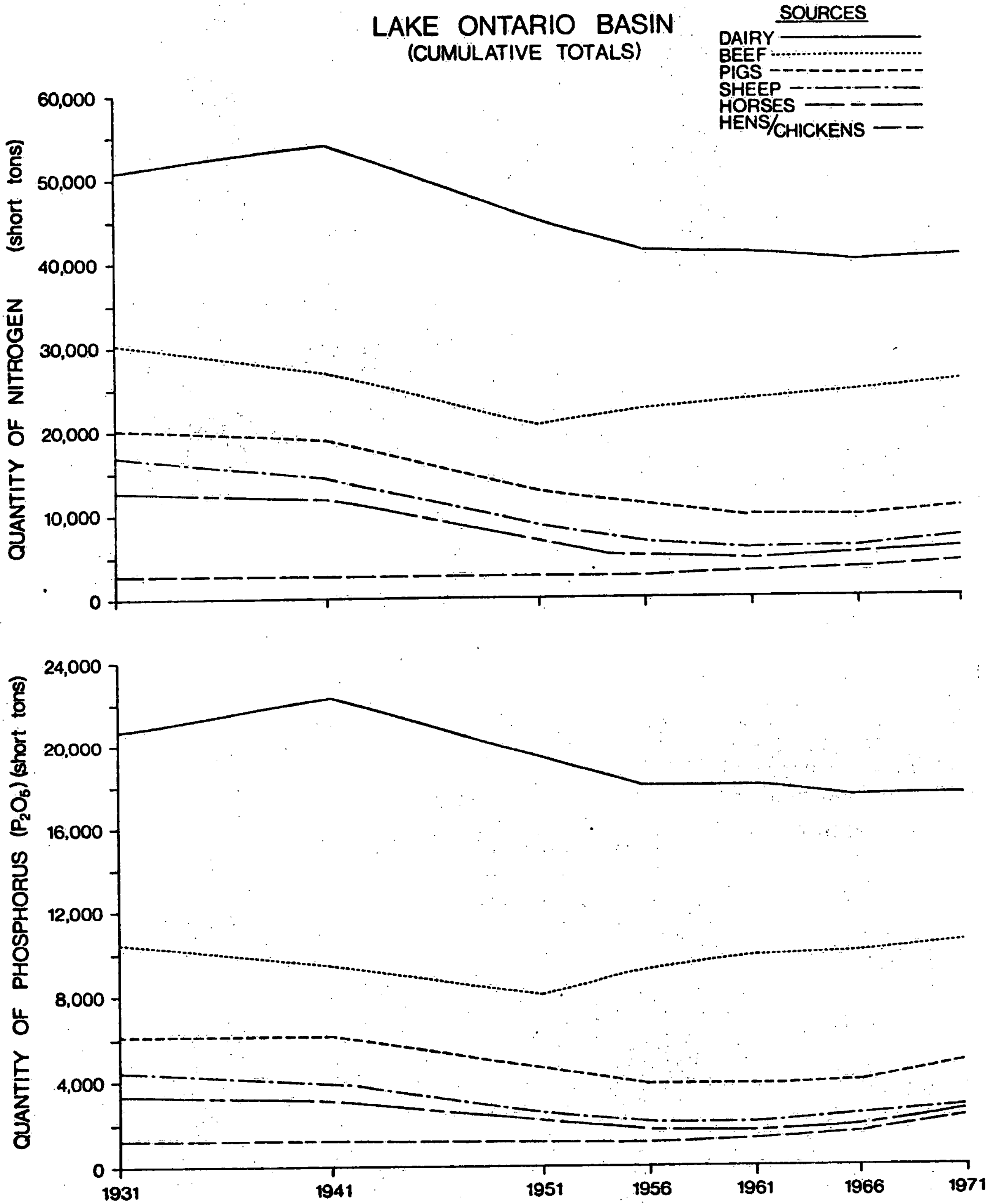

DENSITY OF PHOSPHORUS (P_2O_5) FROM LIVESTOCK & POULTRY - 1951
MAJOR RIVER BASINS, lbs/ACRE OF IMPROVED AGRICULTURAL LAND
0
0 - 10
10 - 15
15 - 20
20 - 25
NIPIGON
KAMINISTIKWIA
WHITE
MAGPIE
MICHIPICOTEN
MONTREAL
MISSISSAGI
SPANISH
FRENCH
SERPENT
MUSKOKA
TRENT
MOIRA
SAUGEEN
MAITLAND
GRAND
THAMES
MINNESOTA
WISCONSIN
MICHIGAN
LAKE SUPERIOR
CANADA U.S.A.
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
NEW YORK
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

MAP 8

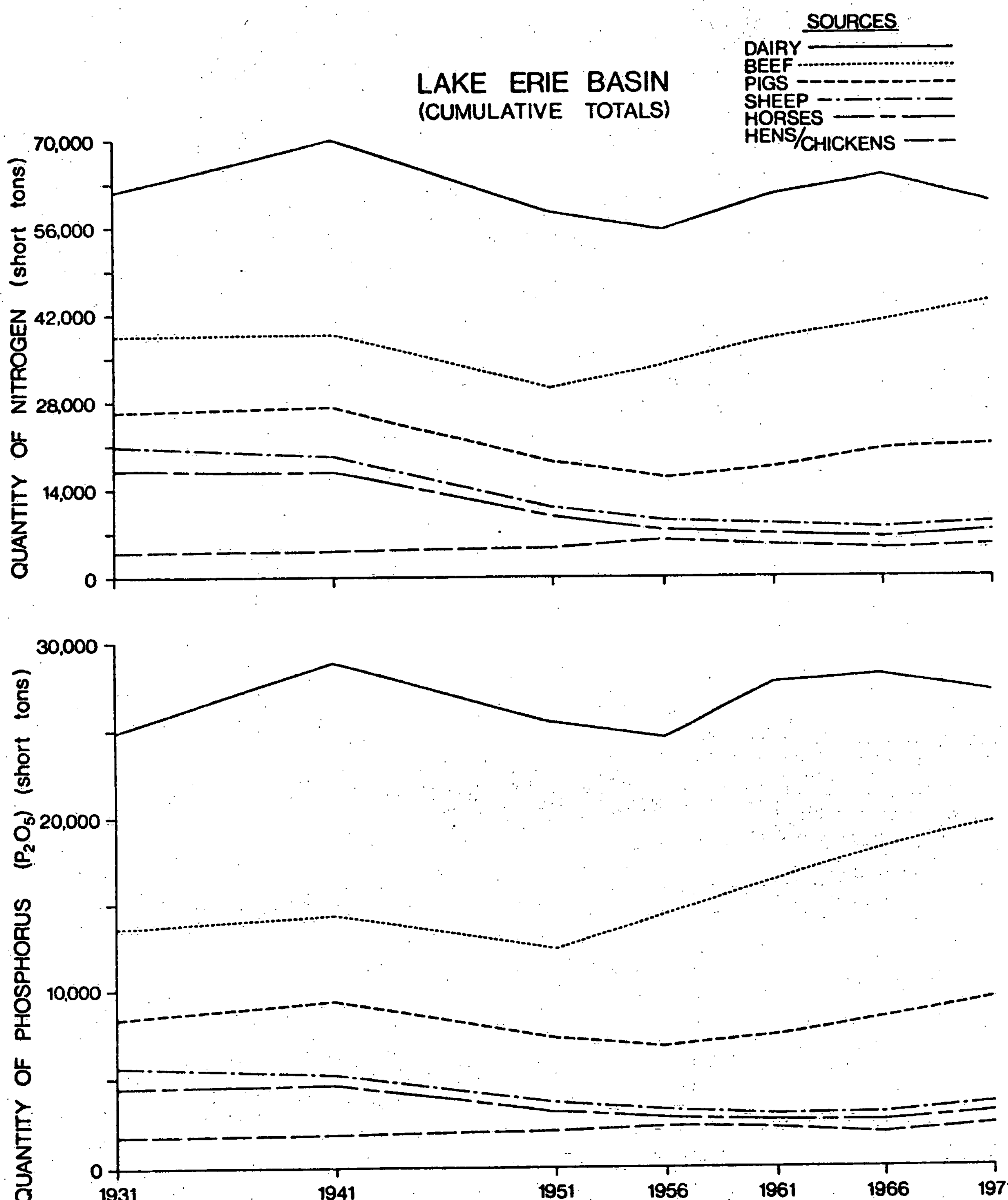


DENSITY OF PHOSPHORUS (P_2O_5) FROM LIVESTOCK & POULTRY - 1971
MAJOR RIVER BASINS, lbs/ACRE OF IMPROVED AGRICULTURAL LAND
0
0 - 10
10 - 15
15 - 20
20 - 25
NIPIGON
KAMINISTIKWIA
WHITE
MAGPIE
MICHIPICOTEN
MONTREAL
MISSISSAGI
SPANISH
FRENCH
SERPENT
MUSKOKA
TRENT
MOIRA
SEVERN
SAUGEEN
MAITLAND
GRAND
THAMES
LAKE SUPERIOR
CANADA
U.S.A.
MINNESOTA
WISCONSIN
MICHIGAN
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
NEW YORK
INDIANA
OHIO
SCALE 1:3,168,000
1 INCH EQUALS 50 MILES OR 80 KILOMETRES
50 0 50 100 MILES
80 0 80 160 KILOMETRES

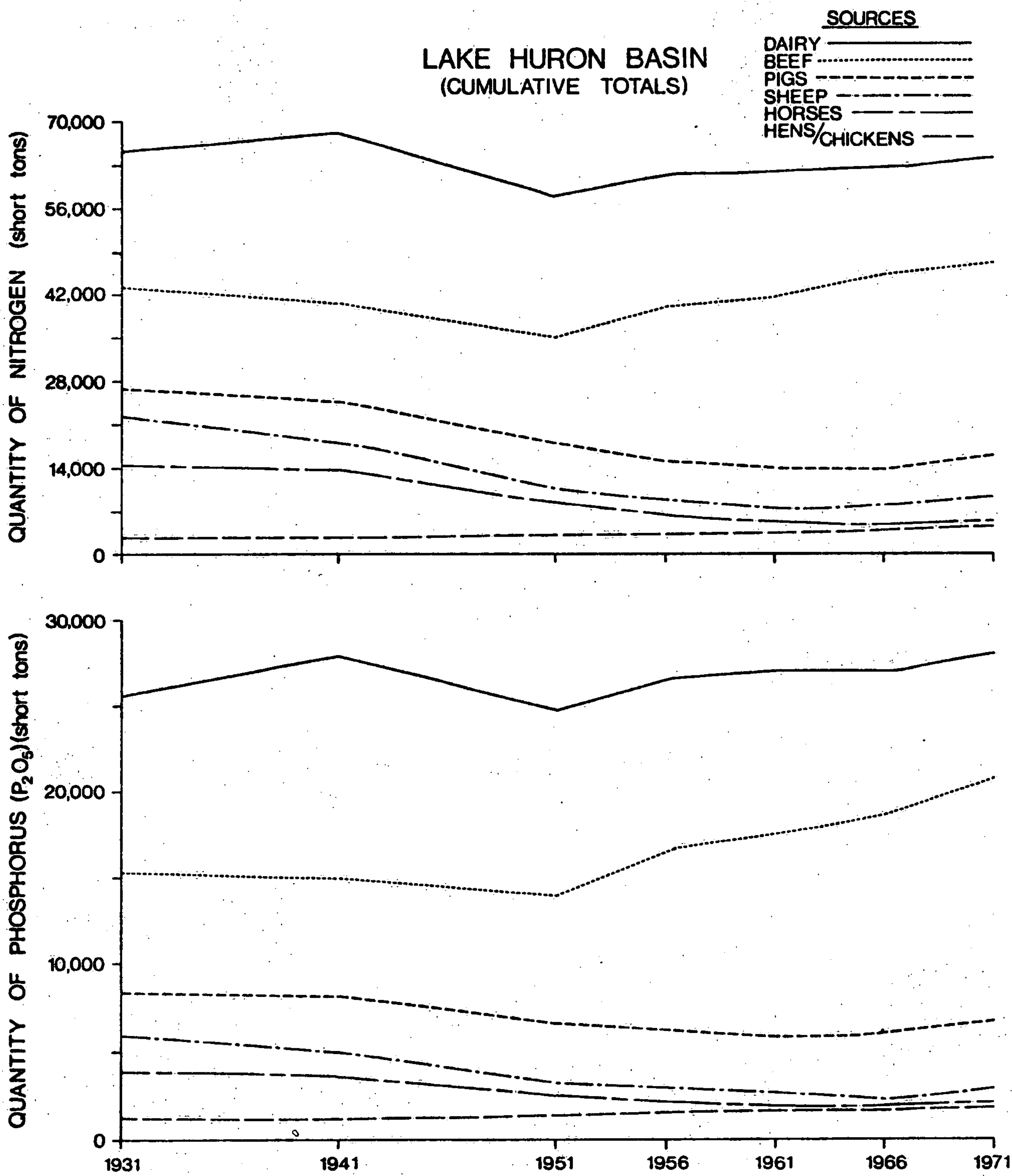
GRAPH 1


LAKE ONTARIO BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
60,000
50,000
40,000
30,000
20,000
10,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
24,000
20,000
16,000
12,000
8,000
4,000
0
1931
1941
1951
1956
1961
1966
1971

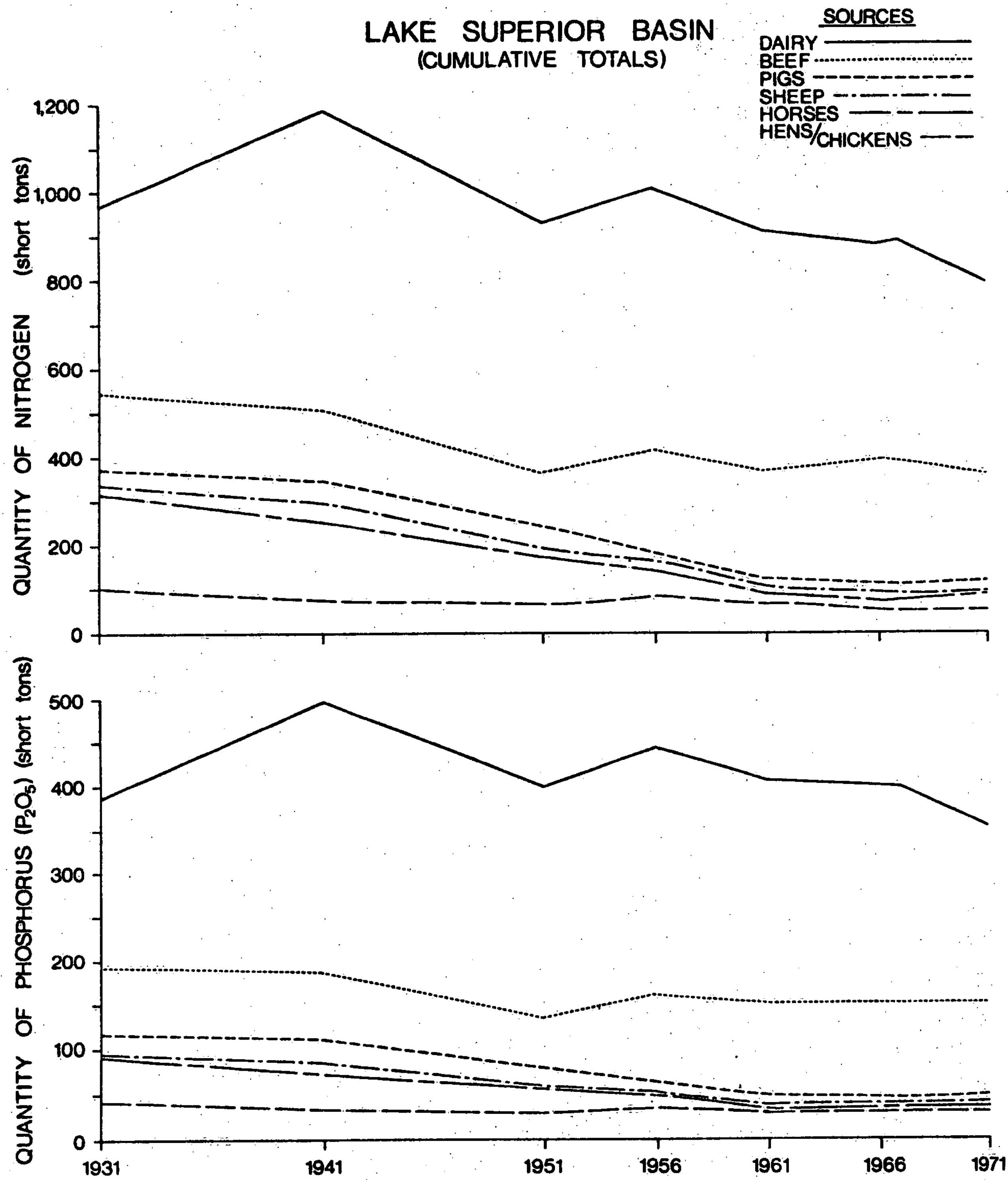
GRAPH 2


LAKE ERIE BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
70,000
56,000
42,000
28,000
14,000
0
30,000
20,000
10,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
1931
1941
1951
1956
1961
1966
1971

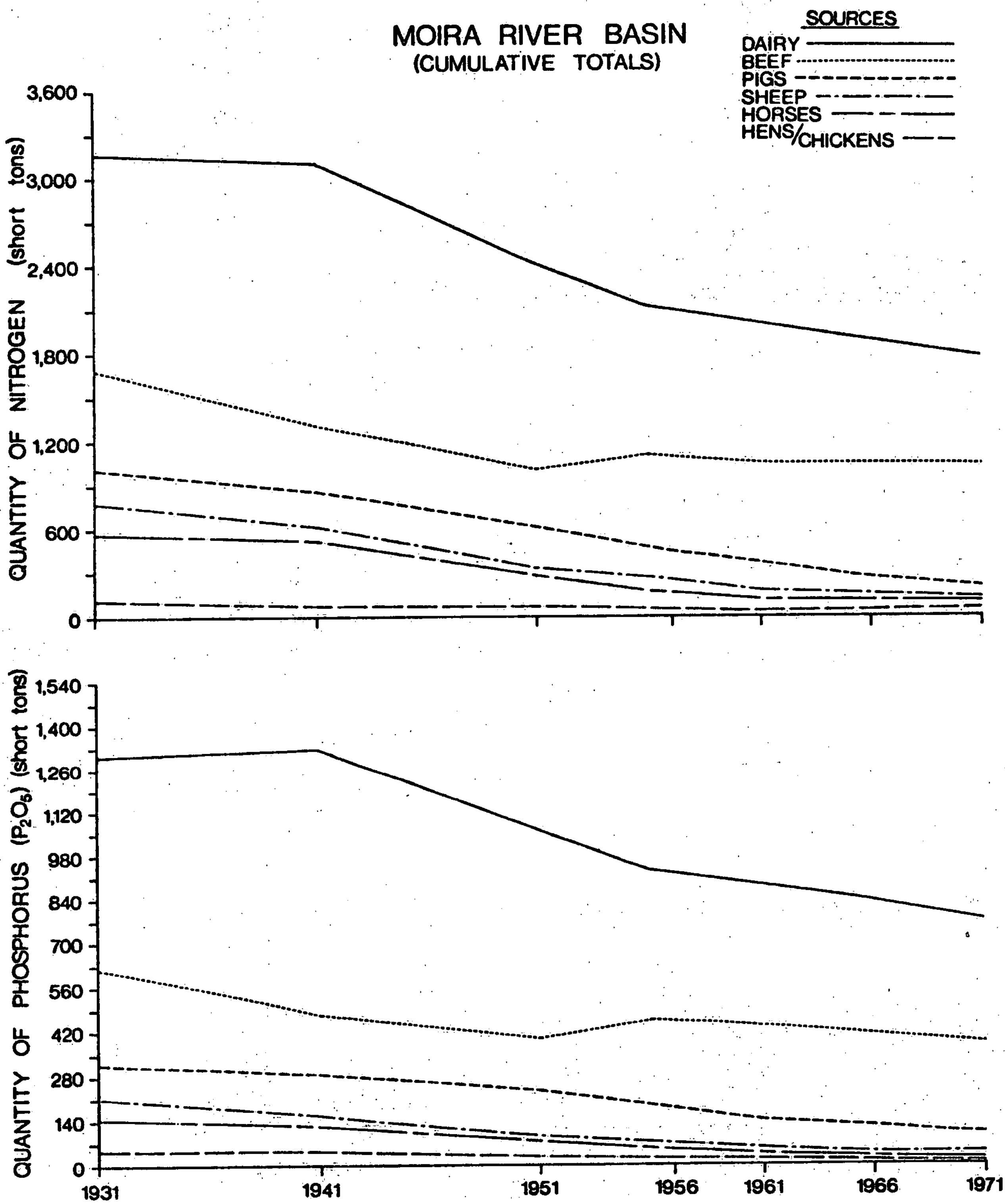
GRAPH 3


LAKE HURON BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
70,000
56,000
42,000
28,000
14,000
0
QUANTITY OF PHOSPHORUS (P_2O_5)(short tons)
30,000
20,000
10,000
0
1931
1941
1951
1956
1961
1966
1971

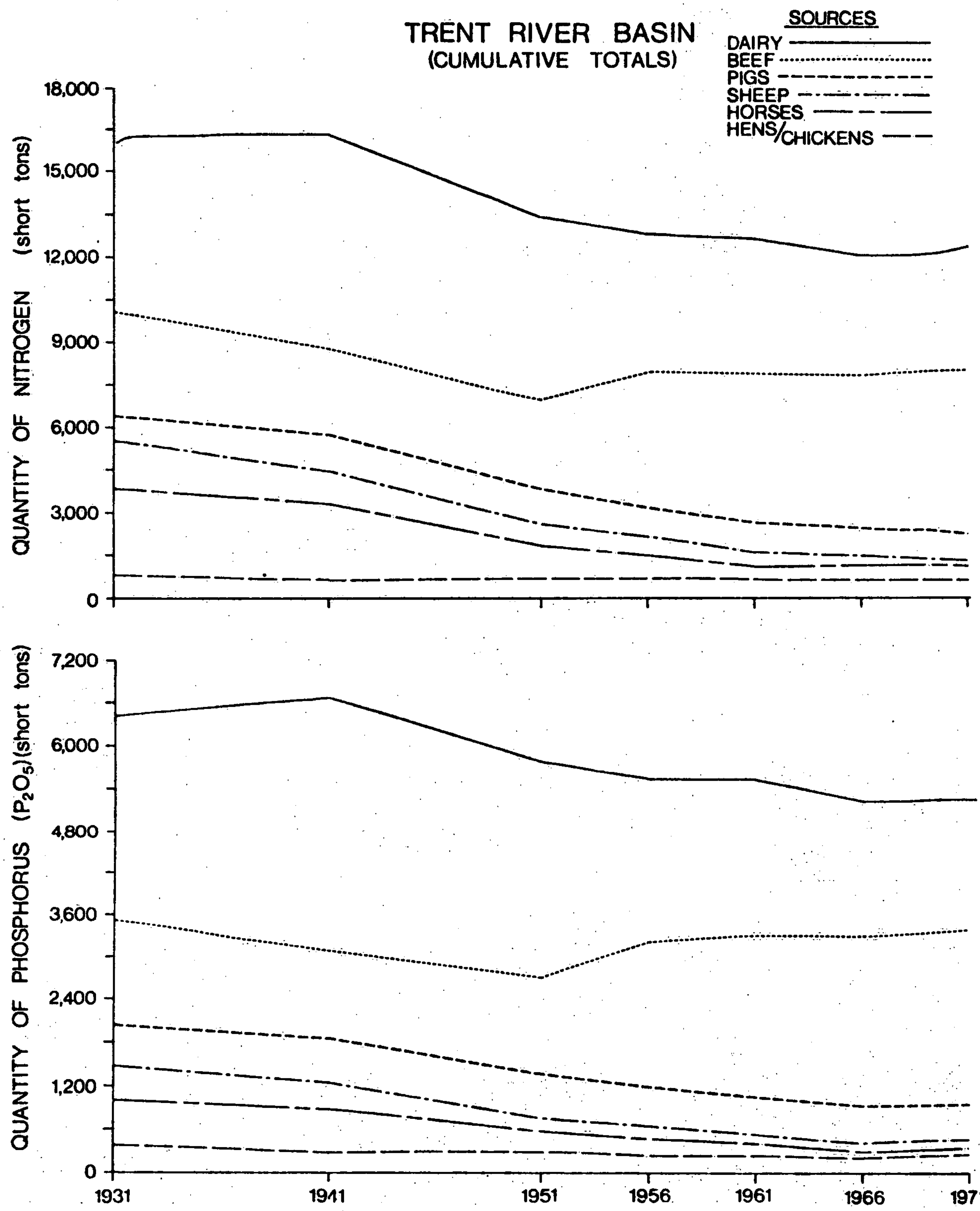
GRAPH 4


LAKE SUPERIOR BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
1,200
1,000
800
600
400
200
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
500
400
300
200
100
0
1931
1941
1951
1956
1961
1966
1971

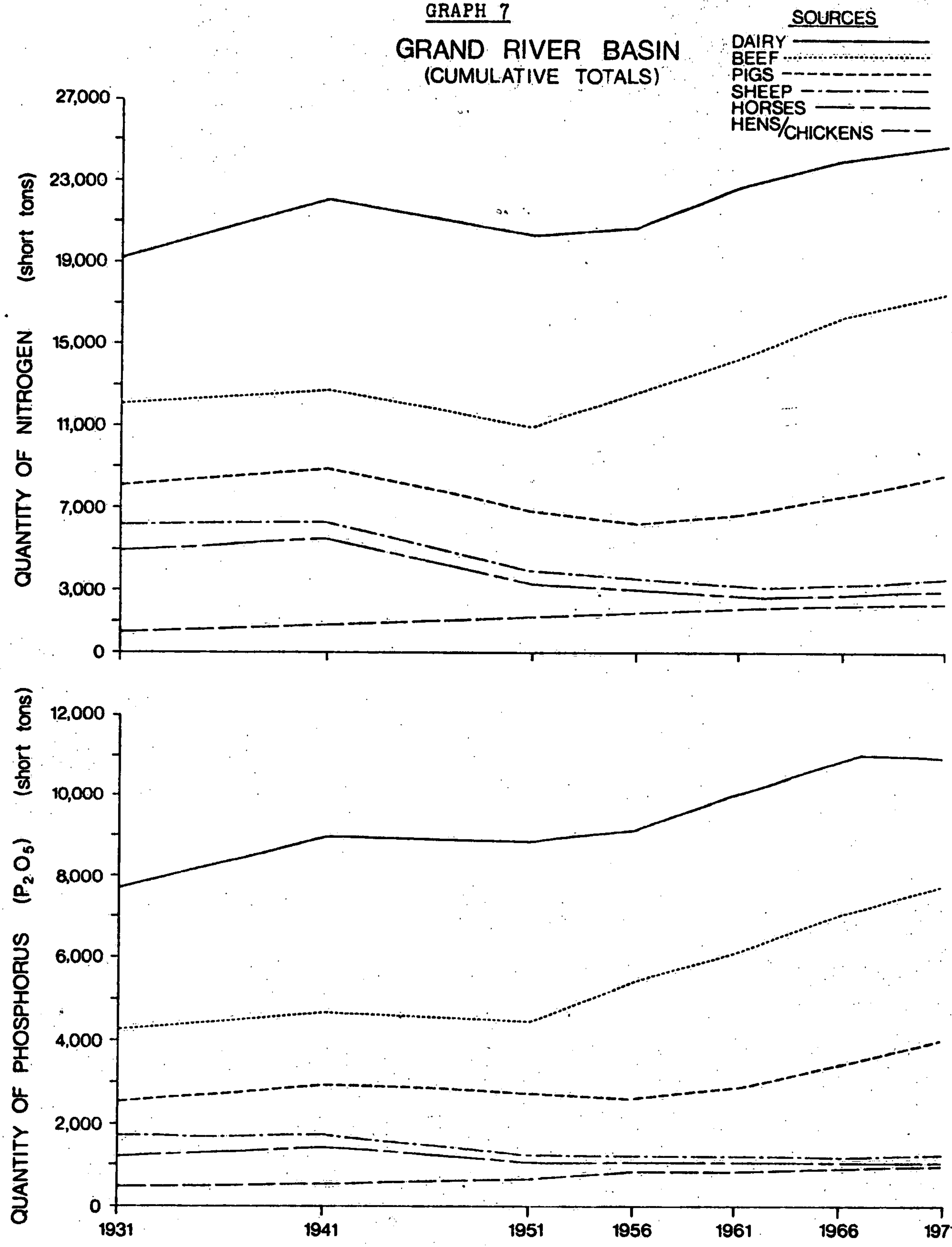
GRAPH 5


MOIRA RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
3,600
3,000
2,400
1,800
1,200
600
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
1,540
1,400
1,260
1,120
980
840
700
560
420
280
140
0
1931
1941
1951
1956
1961
1966
1971

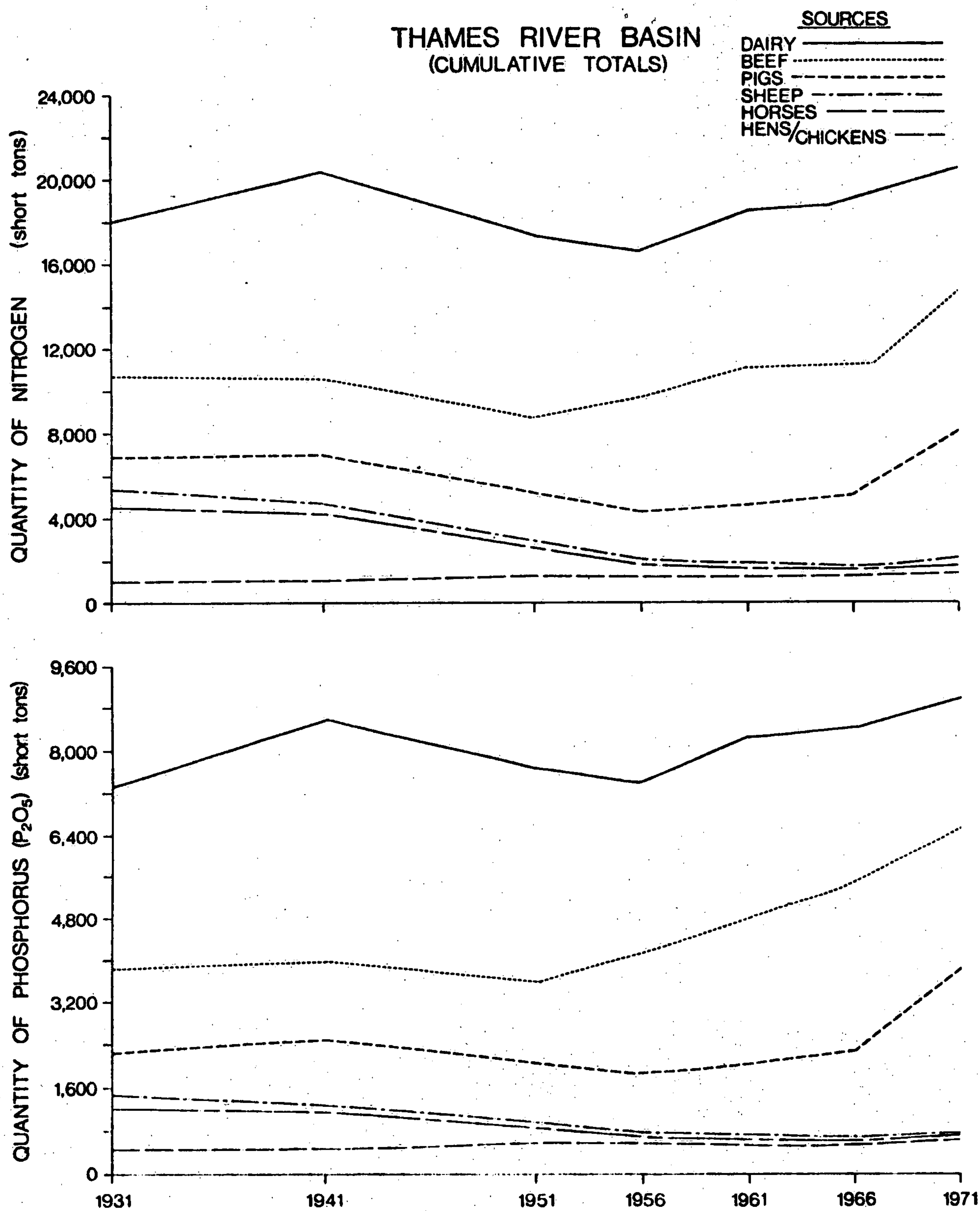
GRAPH 6


TRENT RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
18,000
15,000
12,000
9,000
6,000
3,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
7,200
6,000
4,800
3,600
2,400
1,200
0
1931
1941
1951
1956
1961
1966
1971

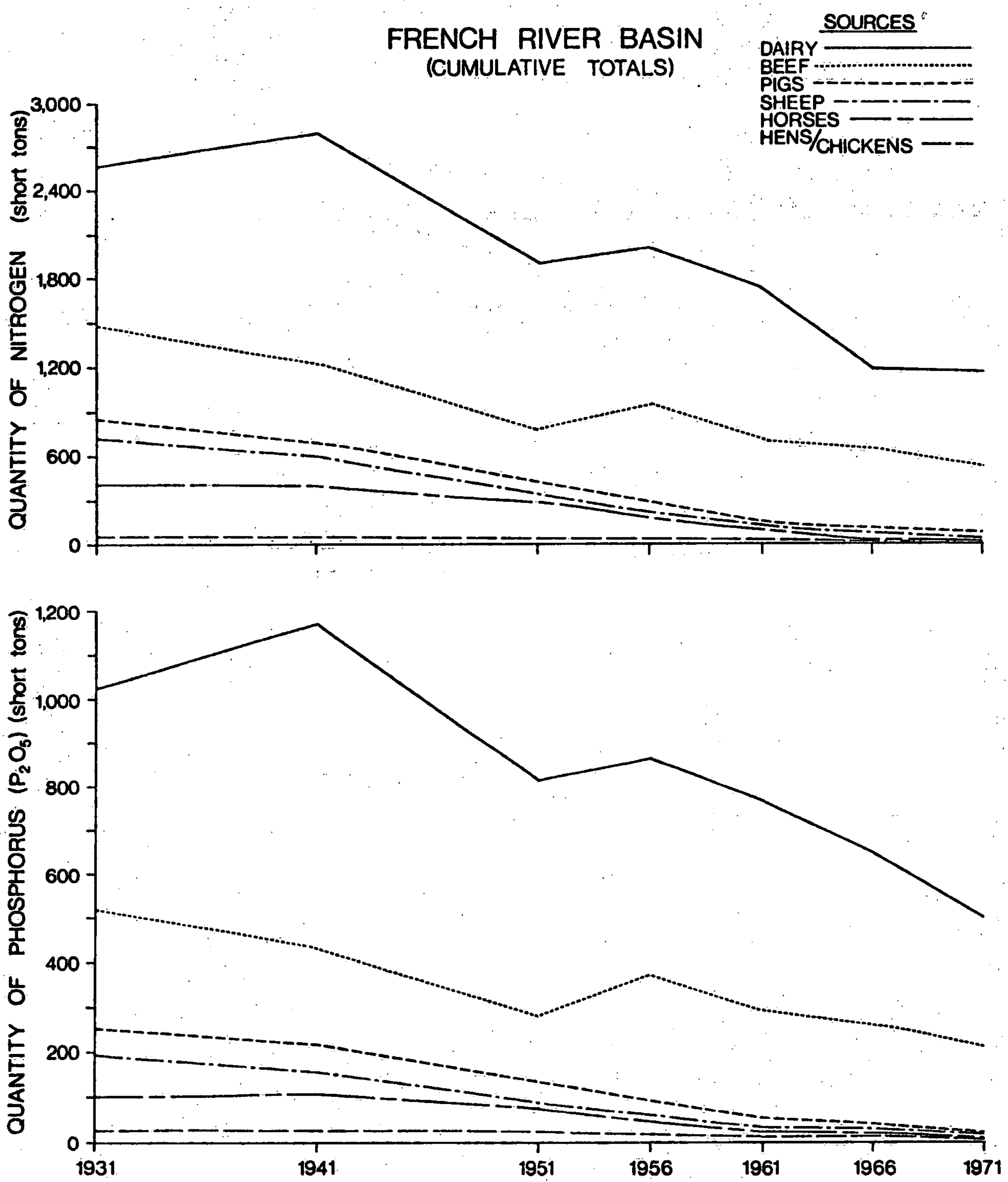
GRAPH 7


GRAND RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
27,000
23,000
19,000
15,000
11,000
7,000
3,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
12,000
10,000
8,000
6,000
4,000
2,000
0
1931
1941
1951
1956
1961
1966
1971

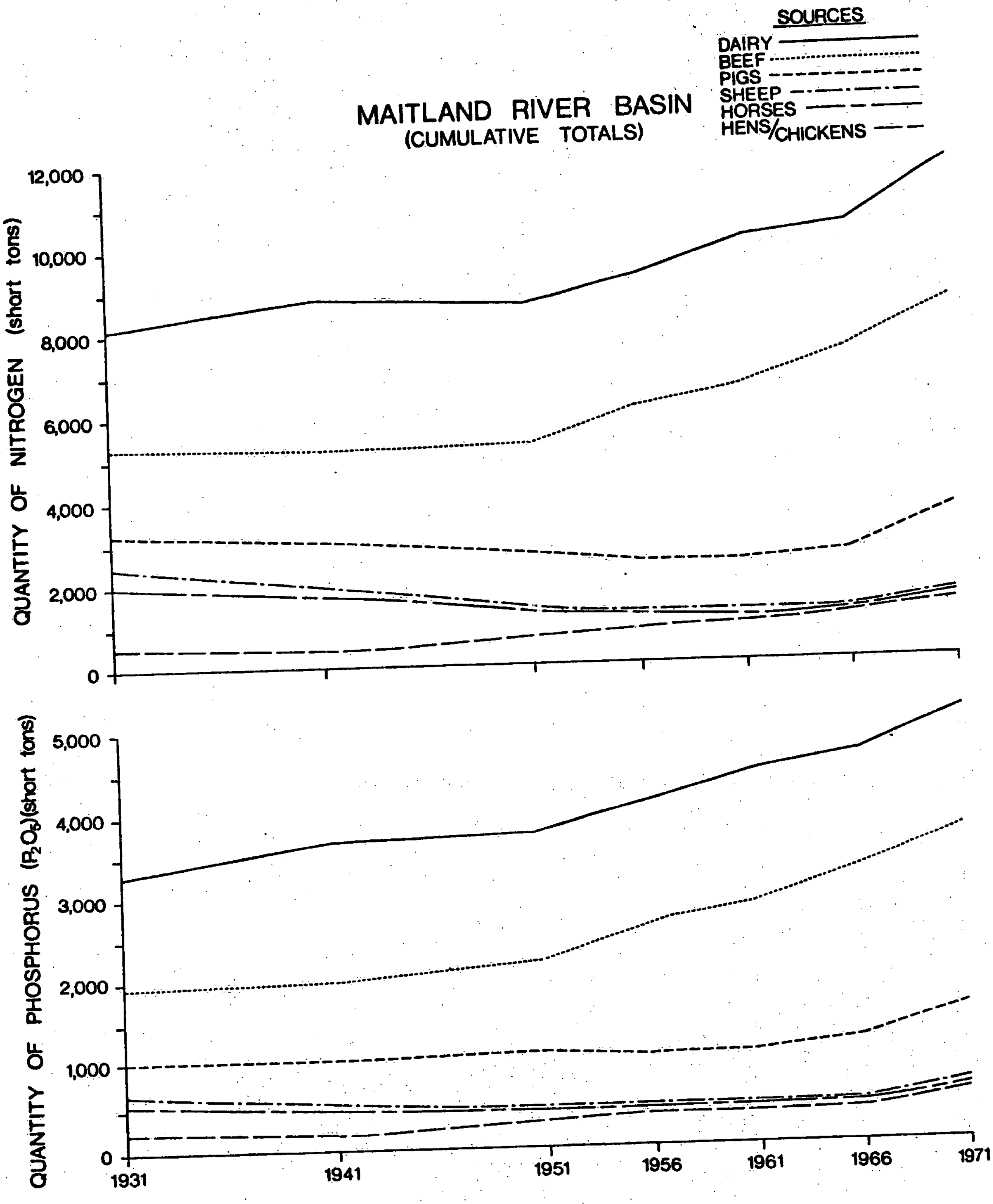
GRAPH 8


THAMES RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
24,000
20,000
16,000
12,000
8,000
4,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
9,600
8,000
6,400
4,800
3,200
1,600
0
1931
1941
1951
1956
1961
1966
1971

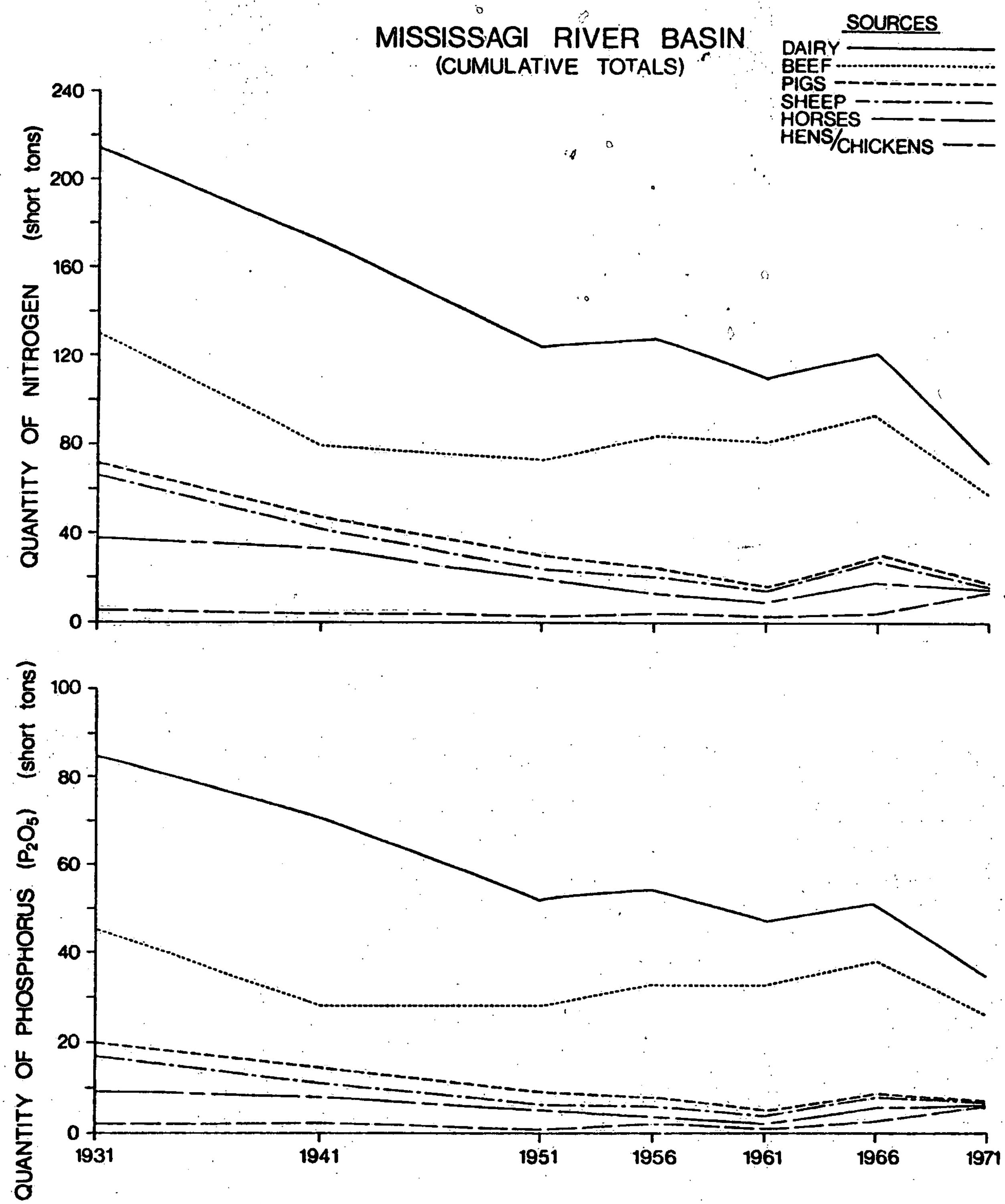
GRAPH 9


FRENCH RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
3,000
2,400
1,800
1,200
600
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
1,200
1,000
800
600
400
200
0
1931
1941
1951
1956
1961
1966
1971

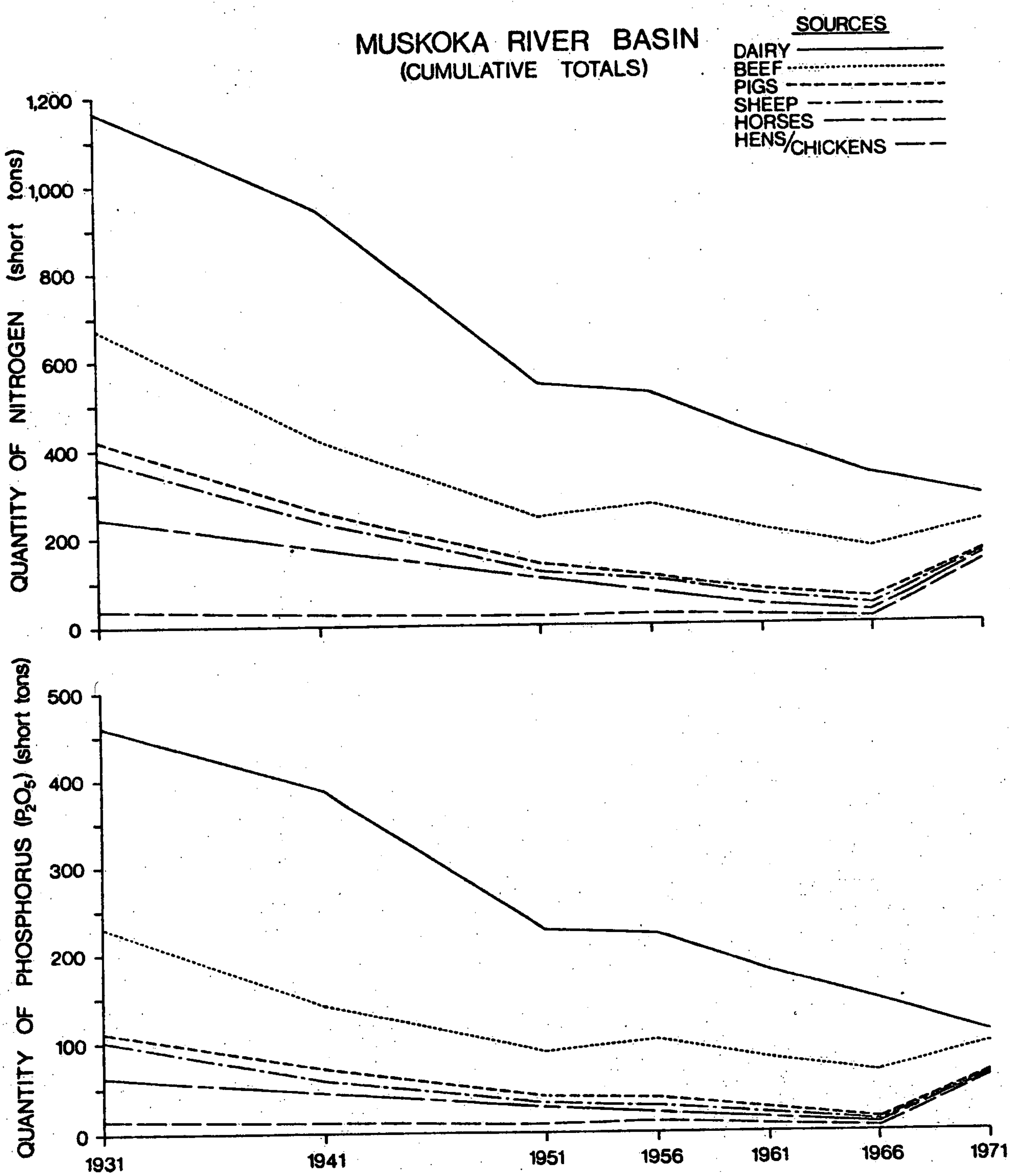
GRAPH 10


SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
MAITLAND RIVER BASIN
(CUMULATIVE TOTALS)
QUANTITY OF NITROGEN (short tons)
12,000
10,000
8,000
6,000
4,000
2,000
0
QUANTITY OF PHOSPHORUS (P_2O_5)(short tons)
5,000
4,000
3,000
2,000
1,000
0
1931
1941
1951
1956
1961
1966
1971

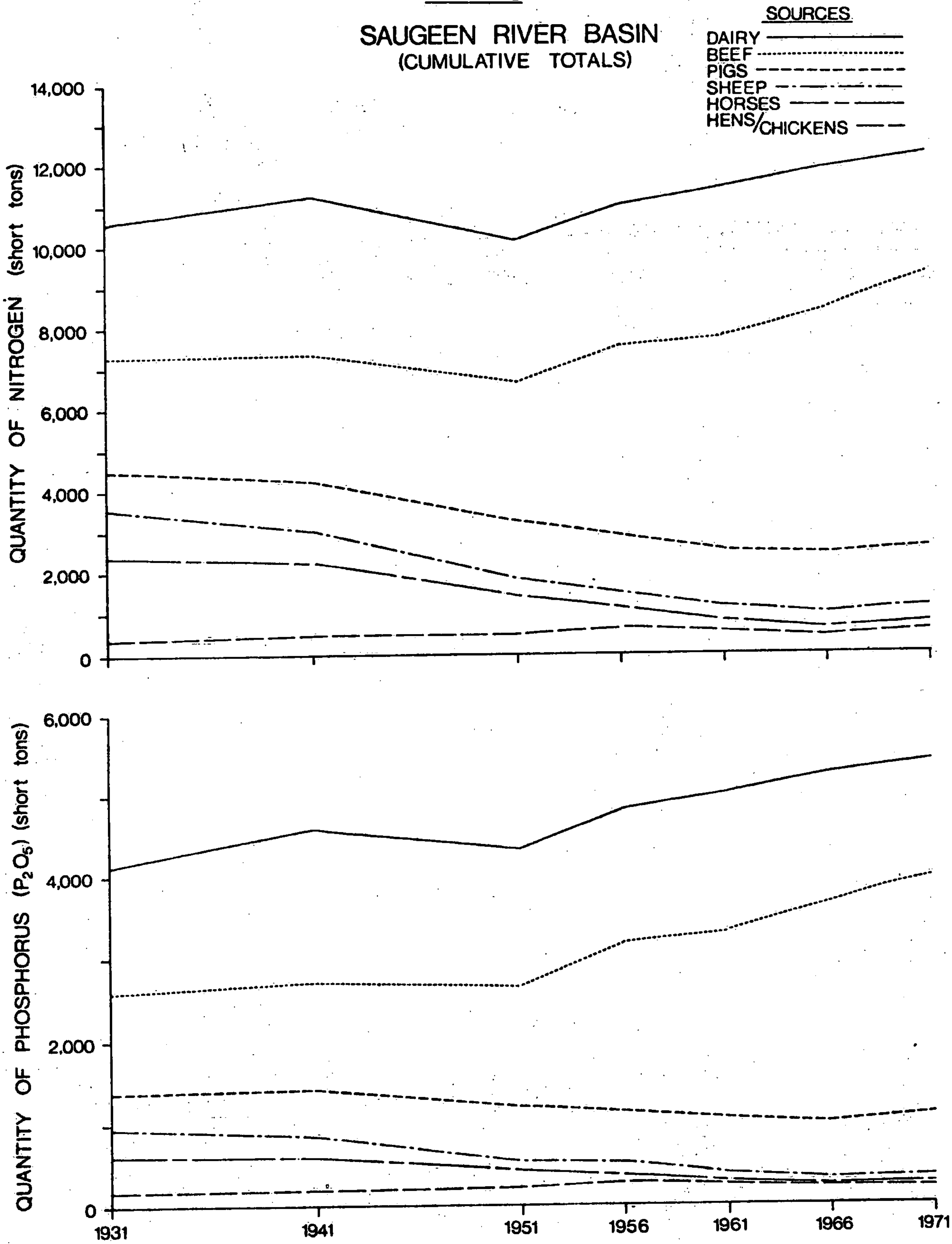
GRAPH 11


MISSISSAGI RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
240
200
160
120
80
40
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
100
80
60
40
20
0
1931
1941
1951
1956
1961
1966
1971

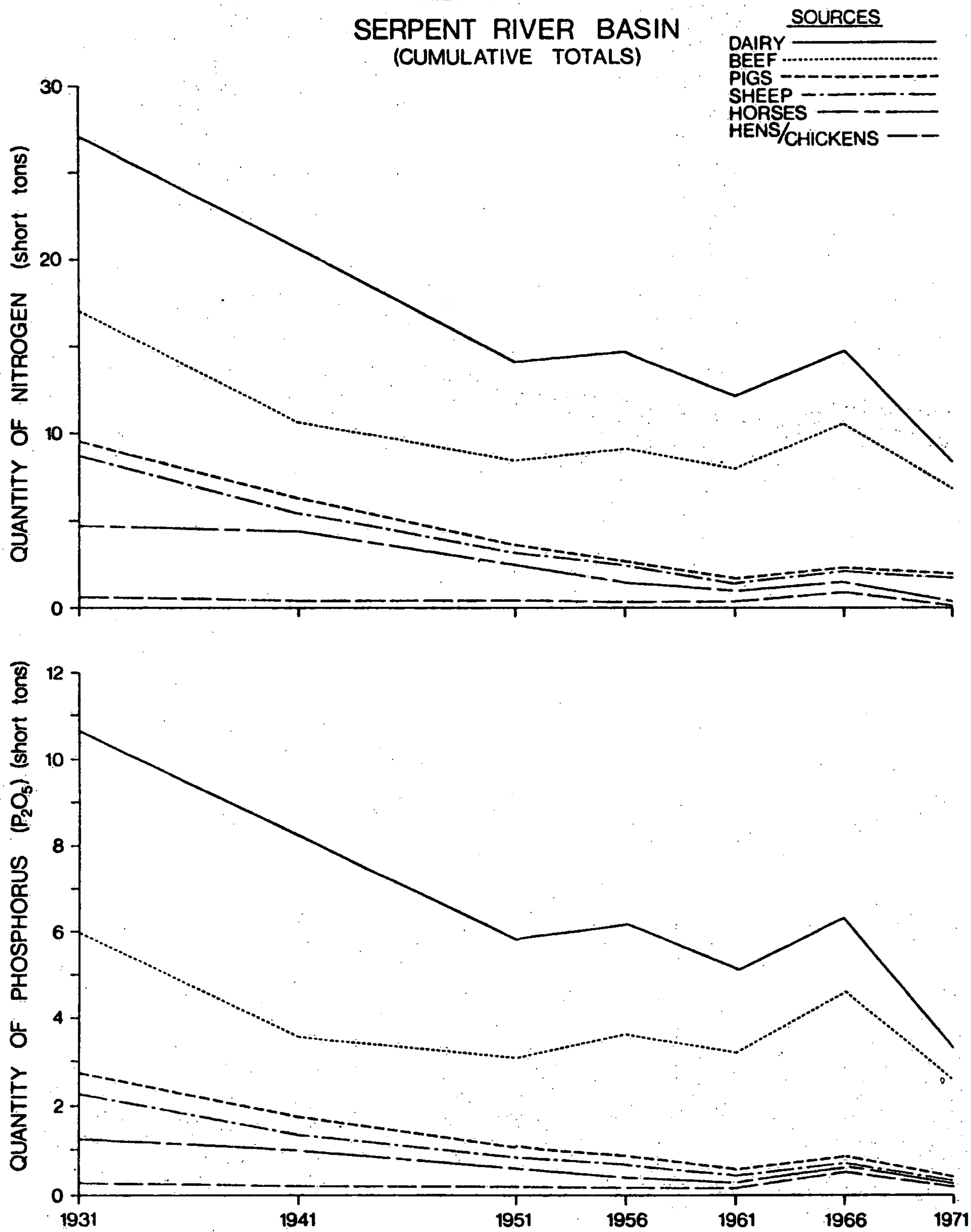
GRAPH 12


MUSKOKA RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
1,200
1,000
800
600
400
200
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
500
400
300
200
100
0
1931
1941
1951
1956
1961
1966
1971

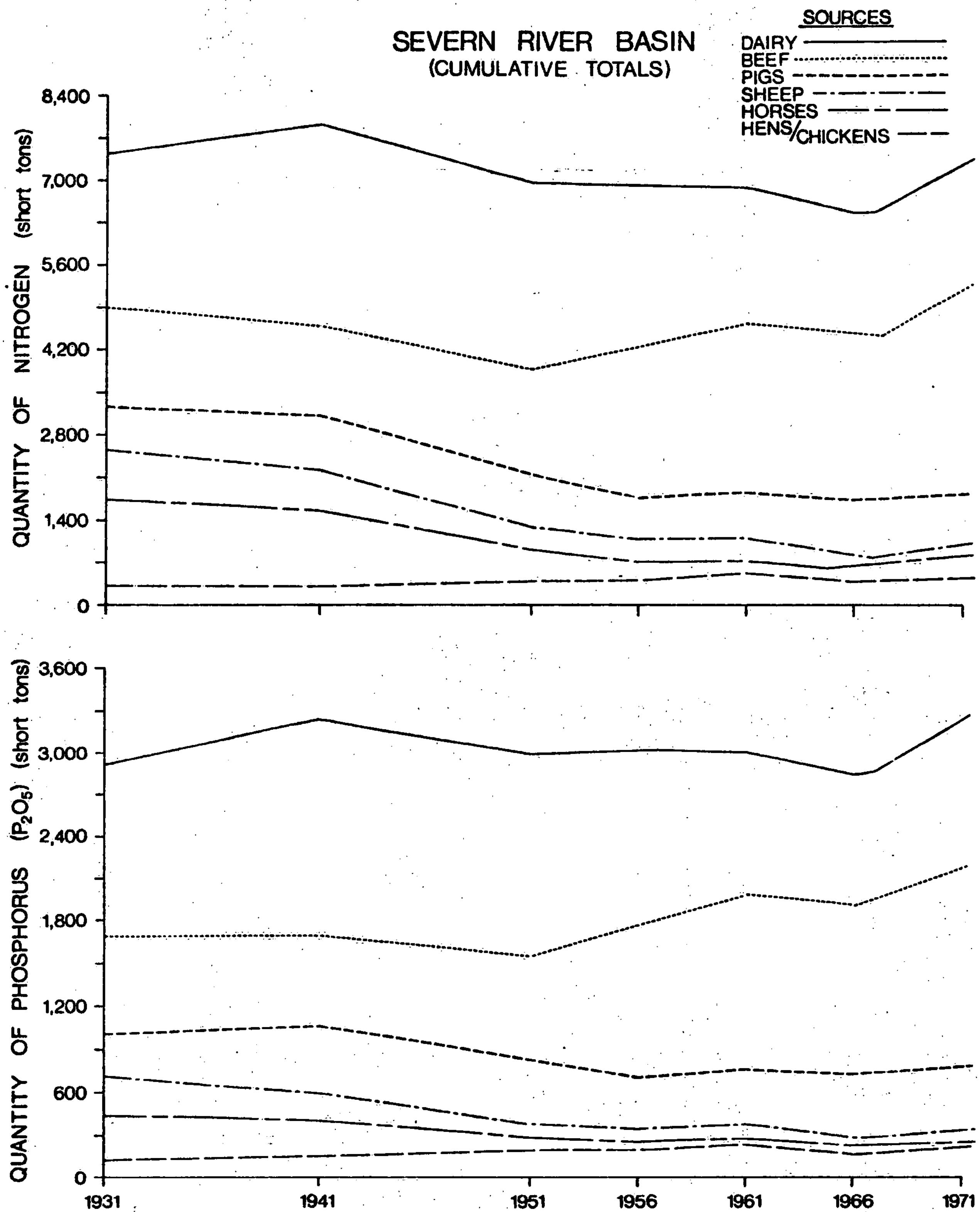
GRAPH 13


SAUGEEN RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
6,000
4,000
2,000
0
1931
1941
1951
1956
1961
1966
1971

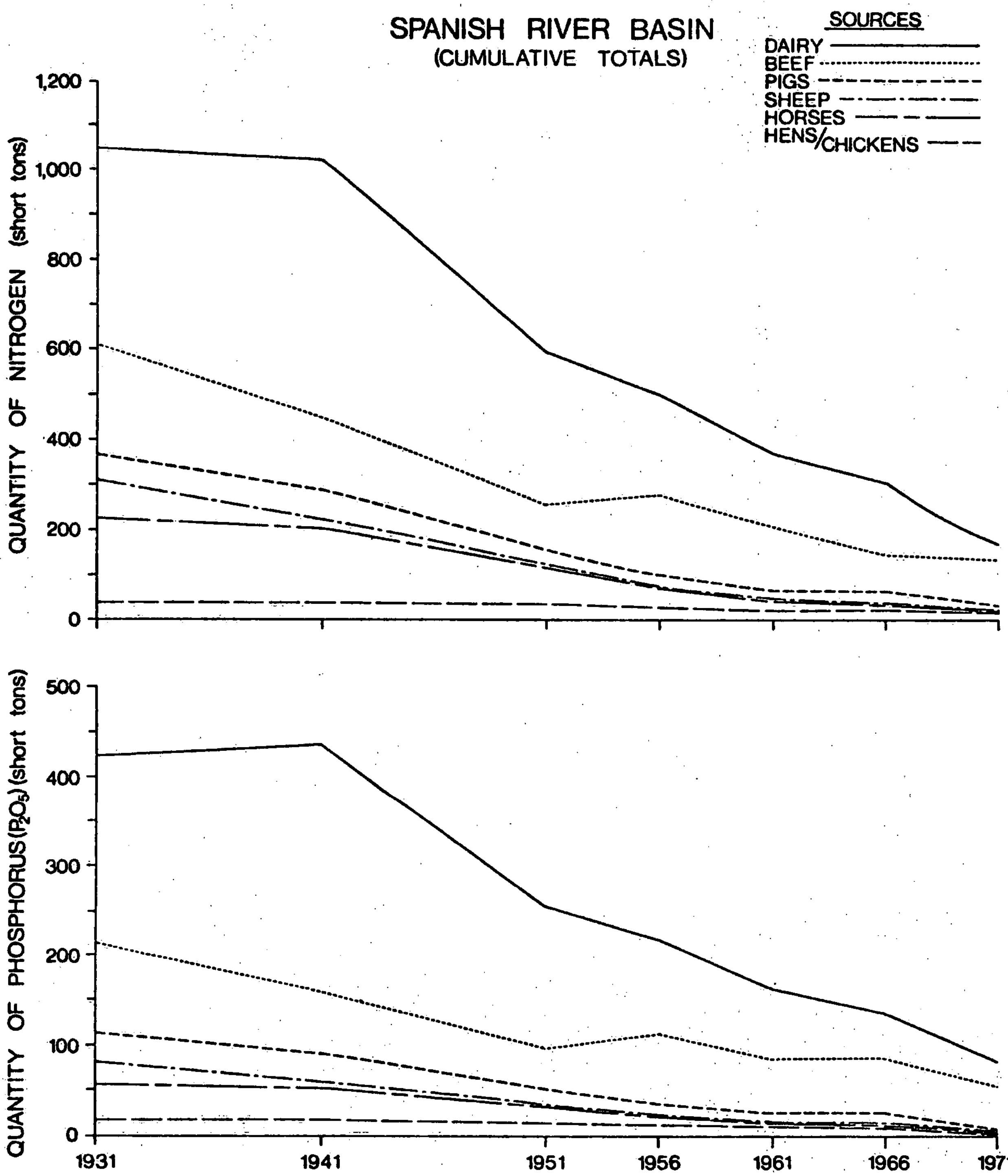
GRAPH 14


SERPENT RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
30
20
10
0
QUANTITY OF PHOSPHORUS (P2O5) (short tons)
12
10
8
6
4
2
0
1931
1941
1951
1956
1961
1966
1971

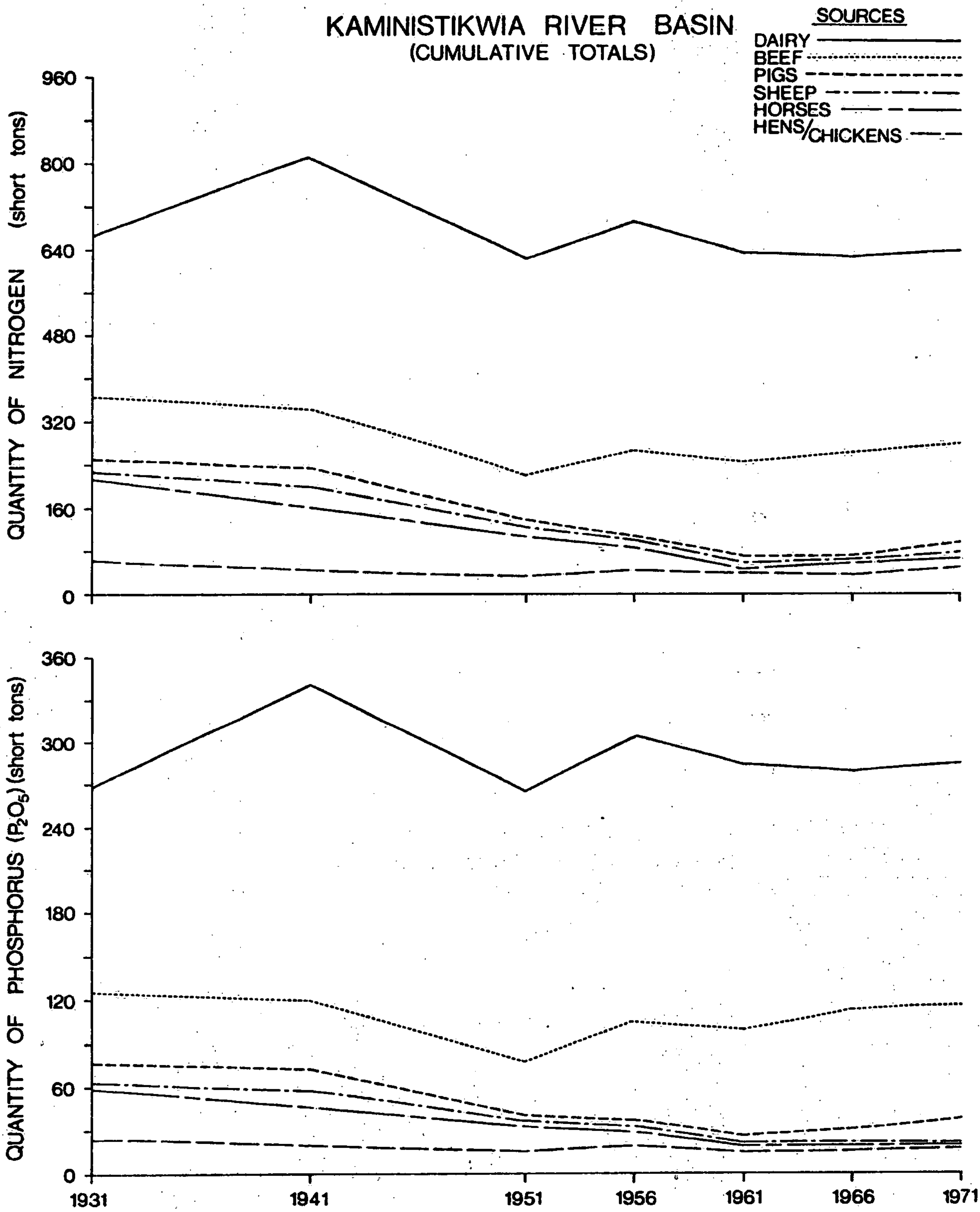
GRAPH 15


SEVERN RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
8,400
7,000
5,600
4,200
2,800
1,400
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
3,600
3,000
2,400
1,800
1,200
600
0
1931
1941
1951
1956
1961
1966
1971

GRAPH 16


SPANISH RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
1,200
1,000
800
600
400
200
0
QUANTITY OF PHOSPHORUS (P_2O_5) (short tons)
500
400
300
200
100
0
1931
1941
1951
1956
1961
1966
1971

GRAPH 17


KAMINISTIKWIA RIVER BASIN
(CUMULATIVE TOTALS)
SOURCES
DAIRY
BEEF
PIGS
SHEEP
HORSES
HENS/CHICKENS
QUANTITY OF NITROGEN (short tons)
960
800
640
480
320
160
0
QUANTITY OF PHOSPHORUS (P2O5) (short tons)
360
300
240
180
120
60
0
1931
1941
1951
1956
1961
1966
1971

SECTION V

CONCLUSIONS

(1) The highly competitive nature of agriculture between regions in Canada and foreign competitors, especially the U.S., will necessitate the adoption of national or, perhaps, international legislation to control the loss of nutrients from agriculture.

(2) The increasing demand for agricultural land for non-agricultural purposes must be controlled if sufficient amounts of land are to remain for the safe handling of the wastes from livestock and poultry. This will require the pursuit of a rigorous land use planning policy at the provincial level.

(3) Unlike human wastes, which are generally collected in centrally located facilities where treatment is easily accomplished, the wastes from livestock and poultry present a diffuse source of pollutants spread throughout the basin. The responsibility for handling these wastes rests with the individual farmer. The management techniques that each individual farmer follows in handling wastes is the

most important factor in determining the potential nutrient runoff from these wastes.

This study has attempted to illustrate the marked differences in pollution potential which exist between basins, their different potentials for future agricultural growth, and the changing importance of the various components of this potential nutrient runoff.

The next step to understanding the potential for nutrient runoff of these basins is to develop an understanding of the different management practices of the individual farmers.

This would necessitate an intensive survey of all farmers in the basin, but its value would not only be important from the viewpoint of estimating nutrient runoff in those basins, but more importantly, this information would provide the basis for a program of farmer education in the problems of restricting nutrient runoff.

FOOTNOTES

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APPENDIX 1

CHANGES IN CENSUS FARM DEFINITIONS

CENSUS FARMS

1931,
1941 - All holdings one acre or more in size, if the production in the previous year was valued at $50.00 or more. Where the farm was made up of several parts located in different municipalities, these parts were counted as separate farms, although the farm area was counted only once.

1951 - The holding may consist of a single tract of land or a number of separate tracts held under different tenures. It must be:

(a) three acres or more in size or

(b) from one to three acres in size, with agricultural production in 1950 valued at $250.00 or more.

Where the farm was made up of several parts located in different municipalities, the 1951 Census reported the complete farm as a unit in the municipality where the headquarters were located.

1961 - Census Farm is defined as an agricultural holding of one acre or more with sales of agricultural products during the past 12 months of $50.00 or more. The definition remains the same regarding parts of the farm.

1966,
1971 - Retained the same definition.

The above listed changes in the Census should be considered when noting the changes in numbers and size of farms. Unfortunately, there is no way of adjusting the data so that it all complies to the one definition.

APPENDIX 2

CANADA LAND INVENTORY SOIL CAPABILITY CLASSIFICATION FOR AGRICULTURE

The data on the soil capability for agriculture was assembled using the facilities of the Geo-Information Systems data base. This data base is operated by the Computer Systems Section, Lands Directorate, Environment Canada, Ottawa. At the time of tabulation, not all of the soil capability information was in the data base, but fortunately, the areas affected were all located on the Canadian shield where, except for a few small pockets, most of the soils are of Class 6 and 7. These two classes have little significance for agriculture.

The soil capability classification system has been used to map the soils of the agricultural portion and adjoining forest fringe areas across Canada. The soil survey data was used as an information base for establishing this classification system, which divides the mineral soils into seven major groups, based on their potentialities and limitations for agricultural use.

The following is a brief outline of the soil capability classes used in the Canada Land Inventory:

CLASS 1 Soils in this class have no significant limitations in use for crops. They are level or have very gentle slopes and suffer little damage from erosion.

CLASS 2 Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices. They may experience moderate rates of erosion with occasional damaging overflow.

CLASS 3 Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices. They may experience moderately severe effects from erosion because of stronger slopes and lower permeability.

CLASS 4 Soils in this class have severe limitations that restrict the range of crops or require special conservation practices or both. They may have experienced severe past erosion or frequent overflow with severe effects on crops.

CLASS 5 Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops and improvement practices are feasible. These soils may be on steep slopes and exhibit severe past erosion.

CLASS 6 Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible. They may have severe gullying problems which restrict the use of farm machinery.

CLASS 7 Soils in this class have no capability for arable culture or permanent pasture.

CLASS 0 Organic soils - no interpretive judgement has been made regarding the capability of these soils.

CAPABILITY SUB-CLASS - TOPOGRAPHY

This sub-class is made up of soils where topography is a limitation. Both the percent of slope and the pattern or frequence of slopes in different directions are important factors in increasing the cost of farming over that of smooth land, in decreasing the uniformity of growth and maturity of crops and in increasing the hazard of water erosion.

SOURCE: The Canada Land Inventory Report No. 2, 1965.
Dept. of Regional Economic Expansion.

APPENDIX 3

CALCULATION OF NUTRIENT COEFFICIENTS

(2) **Beef**

This class is composed of the following sub-classes:

		N (lbs./animal/year)	P_2O_5 (lbs./animal/year)
(a)	Bulls	150	47.45
(b)	Beef Cows	150	80
(c)	Calves	4	2.25
(d)	Yearling Heifers	88	32.5
(e)	Steers	88	32.5

This has necessitated developing a weighted average based on the contribution from each sub-class. Each sub-class was weighted according to the number of animals in that class for the period 1961 to 1970. This resulted in the following equations:

$$\frac{(a)\ (47.45) + (b)\ (80) + (c)\ (2.25) + (d)\ (32.5) + (e)\ (32.5)}{a + b + c + d + e} =$$

= Beef coefficient for Phosphorus (30.47 lbs./yr.)

$$\frac{(a)\ (150) + (b)\ (150) + (c)\ (4) + (d)\ (88) + (e)\ (88)}{a + b + c + d + e} =$$

= Beef coefficient for Nitrogen (71.64 lbs./yr.)

Where (a) is number of Bulls in the Census period 1961 - 1970

(b) is number of Beef Cows in the Census period 1961 - 1970

(c) is number of Calves in the Census period 1961 - 1970

(d) is number of Yearling Heifers in the Census period 1961 - 1970

(e) is number of Steers in the Census period 1961 - 1970.

(3) Pigs

This class is composed of the following sub-classes:

	P_2O_5	N
	(lbs./animal/year)	
(a) under six months*	12	20
(b) over six months	12	20

* Assumes two market cycles/year.

No equation was required for calculating P_2O_5 since both are 12 lbs./yr.

Equation for Nitrogen was weighted according to the number of animals in each class between 1961 - 70.

$$\frac{(a)\ (20) + (b)\ (38)}{a + b} =$$

= Pig coefficient for Nitrogen (23.6 lbs./yr.)

Where (a) is the number of pigs under six months between 1961 - 1970,

(b) is the number of pigs over six months between 1961 - 1970.

(5) Hens and Chickens

This class is composed of the following sub-classes:

		P_2O_5	N
		(lbs./bird/yr.)	
(a)	Layers	.76	1.4
(b)	Broilers*	.28	.85

* Assumes a 10 week market cycle.

Equations were weighted with number of birds in each sub-class for the period 1958 - 1967.

$$\frac{(a)\ (.76) + (b)\ (.28)}{a + b} =$$

= Hens and chickens coefficient for Phosphorus (0.45 lbs./yr.)

$$\frac{(a)\ (1.4) + (b)\ (.85)}{a + b} =$$

= Hens and chickens coefficient for Nitrogen (1.04 lbs./yr.)

Where (a) is the number of layers between 1958 - 1967

(b) is the number of broilers between 1958 - 1967.