Canadian — United States
Joint Working Group on Pollution of the Great Lakes

Canadian Sub—Group 9
Pollution from Agricultural, Forestry and Conservation Sources

January 12, 1971

ACKNOWLEDGEMENTS

Grateful appreciation is extended to all those who contributed to the preparation of this report. This includes the members of sub—group No. 9 together with those who assisted them in the preparation of material.

The members of Sub—Group No. 9 are:

Professor T. Lane, Department of Soil Science, University of Guelph;

Dr. M. H. Miller, Head. Department of Soil Science, University of Guelph;

Professor J. B. Robinson. Department of Microbiology, University of Guelph;

Mr. W. A. Steggles. Supervisor, Water Quality Surveys, Division of Sanitary Engineering, Ontario Water Resources Commission;

Mr. S. A. Black, Division of Research, Ontario Water Resources Commission;

Mr. T. M. Kurtz, Assistant Chief Engineer, Engineering Section Conservation Authorities Branch, Ontario Department of Energy and Resources Management;

Mr. B.E. Beeler, Director, Soils and Crops Branch, Ontario Department of Agriculture and Food;

Mr. M. F. McKenna, Farm Economics Branch. Ontario Department of Agriculture and Food;

Mr. K. B. Turner, Forest Protection Branch, Ontario Department of Lands and Forests;

Dr. E. Mastromatteo, Director, Environmental Health Services Branch. Ontario Department of Health; and

Dr. E.Y. Spencer, Director, Research Institute, Canada Department of Agriculture.

Those assisting in the preparation of reports, but not members of the sub—group were:

Mr. Steve Selbach, River Basin Surveys Program Engineer, Water Quality Surveys Branch, Ontario Water Resources Commission;

Mr. W.L. Smith, Chief, Pesticide Control Service, Ontario Department of Health;

Mr. W. Nap, Soils and Crops Branch. Ontario Department of Agriculture and Food; and

Dr. R. Frank, Director, Provincial Pesticide Residue Testing Laboratory, Guelph, Ontario.

CHAIRMAN: Everett Biggs, Deputy Minister, Ontario Department of Agriculture and Food.

TABLE OF CONTENTS

Page

I. Introduction iv

II. Fertilizer Use and Pollution 1

III. Pesticide Use and Pollution 30

IV. Water Pollution Potential of Farm Animal and Poultry Manures 41

V. Problems of Management and Land Use Activities for Non-Agricultural Land (Various Government Levels) 62

VI. Current Planning, Advisory and Regulatory Standards 70

Appendix 'A' - Section 27 (1) Ontario Water Resources Commission Act 75

Appendix 'B' Report Summary Sum-1

Appendix 'C' Joint Canadian—U.S. Recommendations for sub—group 19. Rec-1

I. INTRODUCTION

In June of 1970, a Canada—U.S. Ministerial meeting was held in Ottawa to review what could be done by the two Federal Governments to formalize joint programs of pollution abatement for the Great Lakes. Amongst the Canadian delegation at this meeting were Hon. Mitchell Sharp and the Hon. J.J. Greene. Ontario, acting as advisor to the Federal Government was represented by the Hon. G. A. Kerr. The U.S. was represented by a team of senior officials and was headed by Mr. Russell Train, Chairman of the Council on Environmental Quality.

At the meeting, it was agreed that a Working Group be established to make a further review of this subject in preparation for a second meeting of ministers early in 1971.

At the first meeting of the Working Group in Washington on September 24-25, the assembled officials reached agreement on the future program of work in advance of the final International Joint Commission report on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River which is soon to be released.

The Working Group will report back to the Ministerial Conference which will be reconvened subsequent to the final report of the IJC.

The September meeting agreed on terms of reference for ten sub-groups.

Recognising that agriculture and related activities have been sighted as contributing to the pollution of the Great Lake Waterways, one sub-group (Sub-Group #9) was set up to consider pollution of the Great Lakes from Agricultural, Forestry and Conservation Sources.

The terms of reference for Sub-Group No. 9 were as follows:

Sub-Group No. 9: Pollution from Agricultural, Forestry and Conservation Sources

The examination of land use sources of pollution should be commenced immediately in order to identify the severity of pollution arising therefrom in order to define and assess research and development efforts for the purpose of developing feasible control techniques and practices which may then be incorporated in future advisory, planning and regulatory activities.

The Sub-Group should:

1. Assess pollution problems arising from the release and runoff of nutrients and other substances resulting from the application of fertilizers, pesticides and herbicides, and from poultry and livestock operations, including feedlots.

2. Assess problems arising from the land use activities of local, state and provincial and federal authorities, including those involving the use of herbicides, in relation to their responsibilities for managing public lands, parks and highways.

3. Assess the adequacy of current land use practices, with particular reference to soil erosion.

4. Assess current planning advisory and regulatory standards with reference to agriculture, forestry and conservation.

5. Develop recommendations within the terms of reference and other suitable joint action to meet the above terms of reference.

The Sub-Group felt that the prime contribution to the contamination of the Great Lake Waterways from agriculture and related activities were; runoff of plant nutrients, nitrogen and phosphorus contained in commercial fertilizers and animal wastes together with runoff of pesticides and dissolved organics which deplete water of oxygen. Erosion and resulting sedimentation were also seen as contributors.

The Sub-Group recognized that some controversey exists with respect to the size of the contribution made by agriculture and related activities to the contamination of the Great Lakes Watershed.

Whereas it would be desirable to quantify the extent to which agricultural sources contribute to the contamination of the Great Lakes Watershed, this has not been possible. There is little data available for instance on nitrogen runoff losses resulting from application of fertilizers and animal wastes to field crops.

Nevertheless, research and experimentation have been responsible for enabling estimates to be made with respect to some of these sources of contamination of the waters of the Great Lakes and the following report contains some of the results thereof.

II. FERTILIZER USE AND POLLUTION

Nitrogen (N) and phosphorus (P) are the two ingredients of fertilizers that are of concern from a water pollution standpoint.

Nitrogen is of concern for two reasons. First, nitrogen is essential in water for growth of most algae and other water plants. A level of 0.3 ppm of inorganic nitrogen is commonly regarded as sufficient to produce obnoxious algal blooms. Nitrogen, however, is not now considered to be the factor which governs excess algal growth. This is partly because some algae (blue-green) can obtain nitrogen directly from the air, and partly because the level of nitrogen in most waters is above the minimum level from natural processes such as rainfall, and natural decomposition of organic materials.

The second reason for concern of nitrogen in water supplies is because of the threat to health of ruminant animals and infants from high levels of nitrate nitrogen. In ruminants such as cattle, microorganisms in the ruminant convert nitrate (NO_3) to nitrite (NO_2). Nitrite converts the hemoglobin in red blood cells to methemoglobin which cannot transport the needed oxygen from the lungs to body tissues. In cattle this will cause abortion or, in more severe cases, death. In infants under 3 months of age nitrates may also be converted to nitrites in the stomach causing an affliction known as "methemoglobinemia" commonly called "blue-baby" because of the cyanosis that occurs. Infants suffering from diarrhea are particularly susceptible to this condition.Infants beyond the age of 3-6 months are not afflicted because the nitrates are not converted to nitrites.

The U.S. Public Health Service and the W.H.O. have established a standard of 10 ppm nitrogen as nitrate (NO_3-N) in drinking water as the safe limit.

Phosphorus is of concern as a pollutant primarily because of its effect on growth of algae and other water plants. Phosphorus is required for all forms of life. Very low levels in water (0.01 ppm) are sufficient to support an obnoxious algal bloom in midsummer. Although there are a number of reports suggesting that organic material, not phosphorus is the limiting factor in algal growth, it is generally accepted that high levels of phosphorus in waters are a major contributing factor to excessive algal growth.

A large portion of the nitrogen and phosphorus sold in North America is sold as fertilizer. It is therefore natural that fertilizers should be suspect as a source of nitrogen and phosphorus in our water supplies. This report will deal with these nutrients separately, presenting background information on their reactions in soil, and the potential for pollution from their use as fertilizer. Attempts will be made to indicate the extent of the problem in Ontario and to indicate where our knowledge is lacking.

Nitrogen

Reactions in Soil

The nitrogen contained in soil humus and biological tissues constitutes less than 0.5% of the total supply. Rocks contain 97.8% while the atmosphere contains approximately 1.96%. The nitrogen contained An the soil humus however constitutes a vital link in the life process. This nitrogen which, except for a very small fraction, is bound in organic compounds; is converted to ammonium forms (NH_4^+) by microbial action. The NH_4 in turn is converted to nitrate (NO_3) by further microbial action. This process is called nitrification. Plants can absorb nitrogen in either the NH_4 or NO_3 forms. However, under aerobic conditions, and temperatures above 40°F, NH_4 is rapidly converted to NO_3 so little NH_4 exists. At lower temperatures the rate of conversion is much slower although it can occur at temperatures close to 32°F.

The nitrate formed by nitrification will be removed from the soil by one of the following processes.

1. Absorption by plants or microorganisms and subsequent reconversion to organic forms to be removed from the field in the crop or to be returned to the soil as organic nitrogen. The latter process is termed immobilization.

2. Leached to the groundwater. The nitrate ion, being negatively charged, and hence not adsorbed to a significant extent by soil colloids, is readily mobile in the soil water. If large amounts of nitrate nitrogen are present in the soil during the fall and spring, when the major portion of the movement of water to the water table occurs, nitrates will be carried into the groundwater.

3. Denitrified and released to the atmosphere. Under anaerobic conditions nitrate is converted to nitrogen gas (N_2) or gaseous oxides of nitrogen as microorganism use the oxygen in the NO_3 molecule in their life processes. This process; known as denitrification, releases nitrogen from the soil to the atmosphere. The extent of this process and the factors affecting it under field conditions. are not well understood.

4. Washed off the field by erosional waters.

Nitrogen and Crop Production

Nitrogen is a component of protein and hence essential to plant growth. On a world-wide basis, more crops are deficient in nitrogen than any other element. Thus a protein deficiency occurs in the world with respect to human and animal nutrition.

Plants absorb nitrogen from the soil either as nitrate (NO_3) or ammonium (NH_4) ions. A supply of these ions is therefore required in the soil during the growing season. Because the nitrate ion is mobile in the soil solution a crop can reduce the nitrate content of the soil to a low level. Optimum yields however cannot be obtained unless there is some excess of nitrate in the soil. Also, because nitrification can continue at temperatures close to 32°F whereas crop growth and hence nitrate absorption essentially ceases at 40°F or higher, nitrate levels in the soil will increase in the fall after the crop is harvested or after growth ceases. Thus it is net possible to have productive soils without having some nitrate present in the fall and spring. If, however, nitrogen has been added either as fertilizer, animal waste or through symbiotic fixation in amounts greater than required to produce optimum yields, the amounts of nitrate present in the fall will be very much higher. This has been shown in a fertilizer trial in which various rates of nitrogen have been applied to the same plots since 1964. In the fall of 1970, the nitrate content of the top four feet of soil was determined. This data along with the average yields obtained during the last three years are reported in Table 1.

Table: 1. Yield of Corn and NO_3-N Content of Top Four Feet of Soil as Affected by Rate of Nitrogen Addition*.

Rate. of N lb./ac./yr.	Yield of Grain (196769) (bu./ac.)	NO_3- N content of Soil - Fall 1970 (lb. /ac. @4ft.)
0	73	52
100	102	104
200	107	260

* J.W, Ketcheson. Unharvested data, Dept. of Soil Science Dept., Univ. of Guelph.

Even where no nitrogen has been applied since 1964, nitrates were present following harvet of the corn crop. The addition of 100 lb. N/ac. increased the yield by 24 bu./ac. It also increased the nitrate content of the soil. This clearly indicates that it is impossible to have high yields without increasing the amount of nitrate remaining after the crop is removed. The addition of 200 lb. N/ac. caused only a slight increase in yield (5 bu./ac.) which would not be profitable, It did however cause a much greater increase in NO_3 content of the soil.

Similar results have been shown by Walsh (1970) in Wisconsin on experiments with rates cf nitrogen on several crop rotations. In only one case did the soil solution exceed 45 ppm NO_3 (considered to be the safe upper limit for human consumption) at the 75 lb./ac. rate of nitrogen fertilization. On the other hand the concentration exceeded 45 ppm NO_3 in 3 rotations at the 150 lb./ac. and in 5 rotations at the 300 lb./ac. rate.

Table 2. The Effect of Crop Rotation and Nitrogen Fertilizer on Nitrate in Solution at the 5-6 Foot Depth at the End of the Four Year Rotation, Lancaster, Wisconsin (after Walsh, 1970).

Rotation	ppm NO_3 in solution at 5-6 foot depth			
	lb. of N/ac., supplied annually			
	0	75	150	300
Hay, Hay, Hay, Corn	16	19	22	16
Hay, Hay, Corn, Corn	19	21	32	46
Hay, Corn, Corn, Corn	16	41	47	102
Corn, Corn, Corn, Corn	22	62	77	128
Corn, Corn, Corn, Oats	17	27	49	120
Corn, Corn, Oats, Hay	9	11	18	67
Corn, Oats, Hay, Hay	8	12	13	13

These two examples clearly indicate that the greatest threat of NO_3 pollution occurs when nitrogen is added in an amount greater than that required for most economic production.

It is apparent from the foregoing that we could greatly reduce the threat of pollution from fertilizer application if we could accurately predict the amount of nitrogen required for most economic yield. There is, at present, no satisfactory practical soil test for nitrogen. The determination of nitrate content of the soil just prior to planting would give a fairly reliable measure of the fertilizer nitrogen required. It is however, not feasible to test all fields within a short period prior to planting and allow time for farmers to apply the required fertilizer. No other measures of nitrogen availability have proven reliable. Hence, the recommendations for nitrogen fertilizer made in the Ontario Soil Testing Service operated bÿ the Dept. of Soil Science, University of Guelph, for the Ontario Department of Agriculture and Food are based an understanding of the requirements of the crop and the past management of the field. A basic fertilizer nitrogen requirement has been established for each crop based on measured response under Ontario soil and climatic conditions.

This basic requirement is then adjusted for each field for past management factors such as manure addition, legume crops, and stover plowed down. This adjusted recommendation is that which according to all available research information will give the most profitable yield level under above average management.

Table 3 indicates the average recommendation for corn made by the Ontario Soil Testing Service between July 1, 1969 and June 30, 1970 on the samples submitted from several counties or districts. This table indicates that almost all the fields from which samples were submitted required nitrogen fertilizer. The average recommendation for the counties ranged from 75 lb./ac. in Wellington County to 128 lb./ac. in Elgin County. This range reflects the differences in past management such as manure use, legumes and stover ploughed down. In all of Southern Ontario, 97% of the samples indicated a requirement for nitrogen with the average requirement being 95 lb./ac. The general recommendation for corn established by the Advisory Fertilizer Board for Ontario is 100 lb. /ac. if no manure is applied or no legume sod is ploughed down.

Table 3. Nitrogen Recommendations for Corn by Ontario Soil Testing Service (July 1, 1989 - June 30, 1970).

County or District*	No. of Samples	% of Times N Recommended	Average Recommendation lb. N /ac.
Brant	295	98	104
Elgin	387	100	128
Essex	179	98	10
Haldimand	258	95	92
Huron	305	97	96
Kent.	597	100	119
Lambton	233	99	106
Middlesex	338	93	104
Norfolk	483	99	109
Northumberland	321	95	91
Ontario	560	98	100
Oxford	651	100	105
Perth	193	94	89
Peterborough	202	96	81
Simcoe, N.	217	99	89
Simcoe S.	351	98	100
Waterloo	251	95	87
Wellington	438	97	75
Wentworth	207	98	97
York	275	97	92
Southern Ontario	10,345	97	95

* Only chose counties or districts with more than 150 samples included.

Care must be used in interpreting the data in Table 3 because of the relatively small portion of the farmers represented. It cannot be assumed that these samples are closely representative of the total number of farm fields. Of particular significance is the fact that in most of the counties included in Table 3, less than 20% of the samples submitted indicated the use of manure. The information in the section on animal waste indicates this percentage should be considerably higher. It must be concluded that (1) either the farmers are using manure have not submitted samples, (2) that those who use manure have not indicated this fact when submitting the sample, or (3) farmers who have manure are not applying it to their corn fields. It is not possible to say the extent to which each of these three alternatives is responsible for the discrepancy.

Another significant factor in nitrogen application is timing. Nitrogen should be applied as close as possible to the time the crop requires it to avoid possible pollution. Fall application of nitrogen for corn, while widely recommended in some areas of the U.S., is not recommended in Ontario. Evidence has clearly shown that a fall application is not as efficient for corn production as a preplant or sidedress application.

Nitrogen Balance in Ontario Great Lakes Watershed

Several attempts have been made to develop a nitrogen balance for a region.The main approach has been to estimate the addition of nitrogen through natural processes, fertilizer and manure addition and to deduct the removal by crops. The remainder will be that which is immobilized in the soil through an increase in soil organic matter, leached to the groundwater, denitrified and returned to the atmosphere or lost by erosion. Stanford, England and Taylor developed such a balance sheet for the United States. For 1969 they estimate that the inputs of nitrogen on harvested cropland were 14.8 million tons, 6.8 million tons of which were added as fertilizer. Harvested crops removed 9.5 million tons leaving 5.3 million tons to be immobilized, leached or denitrified.

A similar balance sheet is shown in Table 4 for cropped land in the Ontario sections of the Erie and Great Lakes watershed. The boundaries of these watersheds as used for this purpose are shown in Figure 1.

These balance sheets indicate that there is an excess of nitrogen addition of approximately 30 lb. of N per acre under crops. If all of this nitrogen reached ground or surface water it would be a serious threat to the environment. It is known, however, that a significant portion of this will be denitrified and released harmlessly to the atmosphere while another portion will be immobilized in the soil through an increase in organic matter content. One of the most serious gaps in our understanding of the nitrogen cycle is that we cannot say what proportion is going into each of these processes. Until we can estimate this with some degree of assurance we will not be able to estimate the contribution of nitrogen from our crop land to our water supplies with any degree of assurance.

Nitrogen and Water Pollution

In spite of the statement at the end of the preceding section, there are fragmented pieces of information which give some indication of the relative contribution of crop land to nitrogen in our water supplies.

A study of the mean contribution of nitrogen from some Lake Ontario watersheds revealed that nitrogen in the urban watersheds of German Mills Creek and Highland Creek averaged 34,000 lbs. per square mile per year. On the other hand the predominantly rural watersheds of West Humber River, Little Rouge River, Stouffville Creek, and Altona Creek averaged 3,200 lbs. nitrogen per square mile per year. Thus the nitrogen contribution per square mile from urban watersheds was ten times greater than that of rural watersheds. In general this trend will exist in all comparisons of urban versus rural watersheds.The total area in rural watersheds is however considerably greater than that in urban watersheds.

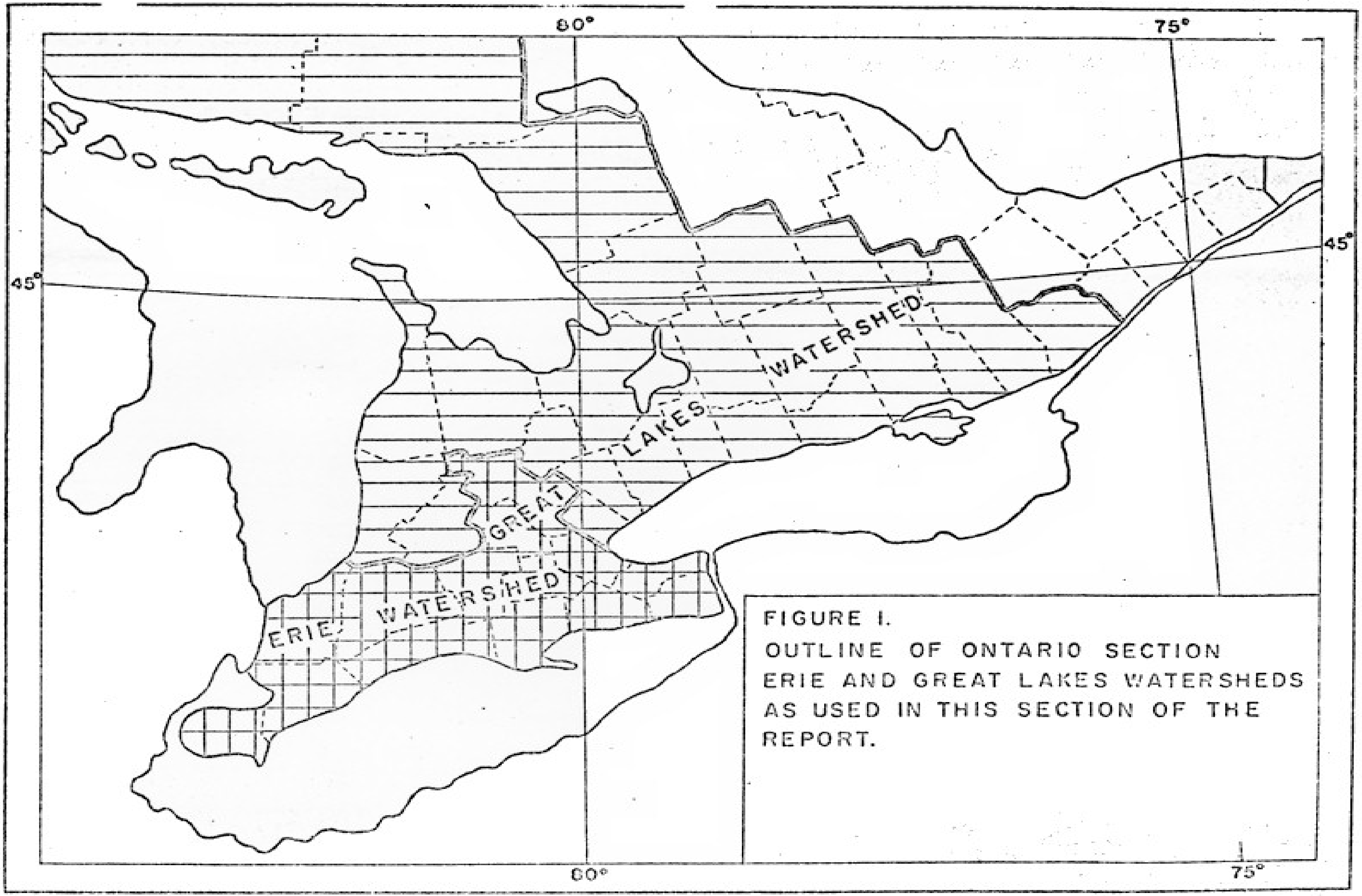

FIGURE I.
OUTLINE OF ONTARIO SECTION ERIE AND GREAT LAKES WATERSHEDS AS USED IN THIS SECTION OF THE REPORT.

Table 4. Nitrogen Balance Sheet for Land Under Crops in Ontario Section of Erie and Great Lakes Watersheds.

	Tons
Erie Watershed	
Nitrogen additions	
Symbiotic fixation [1]	43,950
Non-symbiotic fixation [2]	16,560
Rainfall [3]	11,590
Fertilizer [4]	77,419
Animal Wastes [5]	43,335
Total	192,854
Nitrogen Removal	
Harvested crops [6]	140,876
Addition Less Removal	51,978 tons
Equivalent to 30 lb. N/ac. of land under crops.	
Great Lakes Watershed	
Nitrogen Additions	Tons
Symbiotic fixation	129,302
Non-symbiotic fixation	35,266
Rainfall	24,682
Fertilizer	100,966
Animal waste	102,111
Total	392,347
Nitrogen Removal	
Harvested crops	297,752
Addition Less Removal	94,595
Equivalent to 27 lb. N/ac. of land under crops.	

1. Based on fixation of 100 lib. N/ac. by hay and 60 lib. N/ac, by soybeans.
2. Assuming an addition of 10 lb./ac. of land under crops.
3. Assuming an addition of 7 lb./ac. of land under crops.
4. See Appendix Table A1 for basis of estimation.
5. Obtained from calculation of animal population as shown in Table 12 in section on animal waste.
6. See Appendix Table A2 for basis of estimation.

The question of dividing the rural sources into its various components is more difficult. White-Stevens (1970) reported that the nitrogen contribution to the Connecticut environment due to sources from fertilized agricultural areas was 3.5%. The non-fertilized agricultural contribution was 2.2%. Thus approximately 1.3% of the nitrogen in the environment comes from fertilizer assuming that conditions such as slope, drainage, and farming methods were similar. Thus he concludes that 10% of the nitrogen fertilizer percolates to aquifers, streams and rivers.

The movement of nitrogen fertilizer through tile drains was studied at Woodslee, Ontario (Table 5). Annual applications of 300 lb. of 5-20-10 were made on corn and oats in the rotation of corn, oats, alfalfa, alfalfa, and on the continuous corn and continuous bluegrass sod plots. In addition the corn plots received an additional 100 lb. N per acre.

Table 5. The Average Annual Losses of Nitrogen Through Tile Drains on Brookston Clay 1961-1967

Crop	N (lb. / ac. / yr.)	
	no Fert.	Fert.
Corn	5.0	13.5
Oats - Alfalfa	3.8	5.1
Alfalfa 1st yr.	4.3	3.5
Alfalfa 2nd yr.	4.2	7.7
Cont. Corn	5.9	12.5
Bluegrass sod	0.3	0.6
Average	3.9	7.2

The contribution of nitrogen to the drainage water was increased significantly by fertilization particularly with the corn crop to which most of the fertilizer nitrogen was applied. However, only approximately 5% of the added nitrogen could be accounted for in the tile drainage water.

The contribution of N to the groundwater when excessive amounts of fertilizer nitrogen are applied has been further demonstrated by plots at the University of Guelph as shown in Figure 2. Two hundred pounds of nitrogen as urea (which is quickly converted to the ammonium and thus the nitrate forms) were applied to corn on a Guelph loam in the spring of 1965. There was no increase in yield with this increased nitrogen; thus this represents an excess application of nitrogen. The nitrate-nitrogen content of the surface soil was measured periodically on the fertilized and unfertilized plots. There was a rapid buildup of nitrate in the spring and early summer with a decrease during the growing season probably due to crop utilization. In the early fall, however, the fertilized plot contained a high level of nitrate. This level decreased very rapidly with the onset of fall rains. By December 1, the level was the same as on the unfertilized plot. The nitrate-nitrogen content at the

18 to 24 inch depth in November 1965 was 80 pounds of nitrogen per acre. The following April, the content was approximately 10 pounds of nitrogen per acre. The trial was repeated in 1966 with similar results. In December, 1966, the groundwater contained 66 ppm of nitrogen in the nitrate form. When we compare this level with the 10 ppm considered to be the upper limit for human use we must conclude that at that particular time the groundwater beneath the plot was polluted.

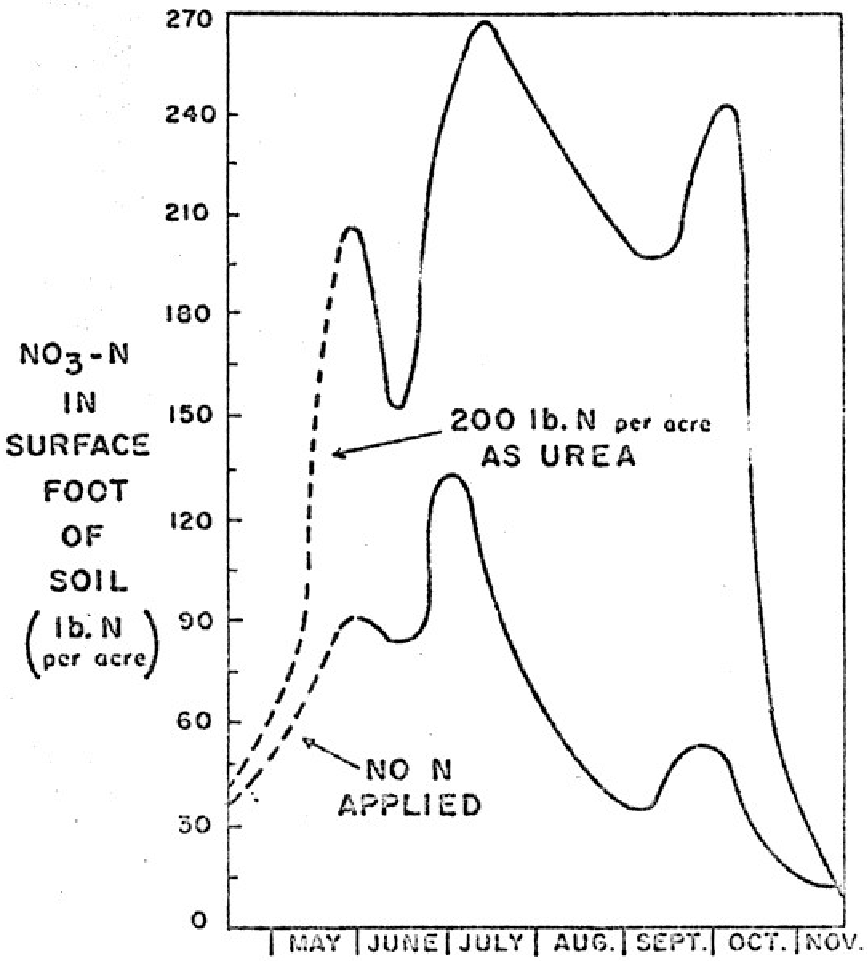

Figure 2. Nitrate-nitrogen content of surface foot of soil on fertilized and unfertilized plots.

This again emphasizes the need to ensure that the rate and timing of nitrogen fertilizer additions are related as closely as possible to the requirements of the crop. In Ontario, there will be very little movement of water through the soil to the groundwater between May 1 and Oct. 1. Therefore, nitrogen fertilizer applied after May 1 will not be leached to the groundwater until fall.

The leaching of nitrogen from additions of poultry manure has been studied at Guelph. Eight natural-core lysimeters of Guelph loam soil, were established in the fall of 1967. Liquid poultry manure was applied in the spring of 1968 and 1969 at four rates. Corn was grown each year and the yield and nitrogen contents were determined. During the summer of 1969 water was added to provide a minimum of 1.5" of precipitation per week.

The percolates from the lysimeters were collected continuously from the spring of 1968 and the nitrogen, phosphorus and potassium contents were determined. Only a small proportion of the added nitrogen was recovered in the percolates up to Oct. 5, 1969 (Table 6). The percentage of the addition recovered appeared to be the same for each amount of N added.

Table 6. Nitrogen Balance From Manure-Treated Lysimeters - Guelph Loam Soil.

	Treatment			
	A check	B	C	D
Nitrogen Added (lb N/ac) 1968 + 1969	0	890	1780	2670
Nitrogen leached (lb N/ac)				
May 1968 to Oct. 5, 1969	67	95	172	194
Oct. 6, 1969 to Dec. 1969	80	287	450	589
Total leached	147	382	622	783
Nitrogen removed by corn (lb N/ac) 1968 + 1969	289	377	388	394
Total nitrogen removed (lb N/ac)	436	759	1010	1177
Total N removed minus check	0	323	574	741
% of added N removed	-	36.3	32.3	27.8

To determine the amount of NO_3 remaining in the lysimeters after the 1969 growing season, 10.5 inches of water were added to each lysimeter in 1-inch increments between Oct. 6 and Nov. 26. With some 15 inches of percolate collected, the nitrogen removed still tends to be a constant percentage of that added (Table 6). In total less than 40% of the added nitrogen could be accounted for. Because most of the nitrates were removed from the soil column with the leaching treatment it must be concluded that the remainder of the nitrogen was either immobilized in the soil or denitrified. This indicates that these two processes can account for very large amounts of nitrogen.

The main concern with nitrogen appears to be movement down the soil profile. Very few data appear to be available with respect to nitrogen lost in runoff water; Enfield (1970) reported that on a 13% slope after 400 lb. per acre of ammonium nitrate were applied and five inches of rain fell in two days, the total loss of nitrate was 6.7 lb. per acre or 1.7% of that applied. It is probably appropriate to assume that since nitrogen in the nitrate form is soluble it will be moved into the soil profile rather than over the soil surface and that fertilizer nitrogen loss through erosion and runoff is less than 2%.

Phosphorus

Reactions in the Soil

The total native phosphorus content of mineral soils in Ontario averages about 1000 to 2000 pounds per acre. Most of the phosphorus present in soils, as with nitrogen, is currently unavailable to plants. About half of the phosphorus occurs in combination with organic matter and is slowly released to available forms. The remainder occurred in fixed mineral combination, some of which is available to plants. Most of the inorganic phosphorus compounds fall into two groups; one group is in combination with calcium, the second group is in combination with iron and aluminum.

Plants absorb phosphorus from the soil solution. In order for the cycle to be complete phosphate must be released from one of its unavailable forms to the soil solution. The soil solution invariably contains less than 0.01 ppm (part per million). For a soil holding 1½ inches of water in the plow layer this amounts to about 0.03 pounds of phosphorus per acre in solution. The soil solution can therefore only be an adequate source of phosphate if soil phosphate goes from the solid to the solution phase as quickly as the crop roots can extract it from the soil solution.

The forms of phosphorus added to the soil in fertilizers are primarily ammonium phosphate, monocalcium phosphate, and dicalcium phosphate. These sources of phosphorus are relatively soluble and thus upset the solubility equilibrium in the soil. The ammonium and monocalcium phosphates quickly react with calcium to form dicalcium phosphate or with iron or aluminum to form nearly insoluble iron and aluminum phosphates. The dicalcium phosphate reacts slowly to form still less soluble calcium phosphates. The conversion of soluble fertilizer phosphorus to less soluble compounds is called phosphorus fixation. Generally only 10 to 30% of the fertilizer phosphorus added to a soil is taken up by the following crop. The remaining phosphorus added is held rather tightly by the soil but may become a source of available phosphorus for crops in subsequent years.

Phosphorus and Crop Production

Phosphorus, although just as essential as nitrogen for crop production, is required by the crop in much smaller quantities. Because phosphorus is immobile it will move to the root from only a few millimeters. The plant root. system contacts only a small fraction of the soil volume; thus the amount of "available" phosphorus required in the soil is many times the amount absorbed by the crop.

Unlike nitrogen, there is a satisfactory soil test for phosphorus. This test (Olsen sodium bicarbonate extractable) has been found to give a good measure of the available phosphorus in Ontario soils. Through extensive research on farm fields in Ontario, this test has been calibrated against yield response to applied phosphate for sever. crops. This information has been used to develop fertilizer requirement tables which indicate the amount of fertilizer phosphorus required to produce the most profitable yield at any given soil test level.

The objective in a crop production program should be to increase the available soil phosphorus to the level that will produce the most profitable yield and then to add fertilizer as required to maintain that level. The optimum phosphorus level varies from crop to crop being much higher for potatoes and tobacco for example than for corn and alfalfa. Thus the fertility level should be increased to the optimum level for the crop in the rotation which has the highest requirement.

The average phosphorus test, the percent of samples Indicating a need for fertilizer phosphorus addition and the average amount of fertilizer phosphorus required are indicated in Tables 7, 8 and 9 for corn, hay-pasture and potatoes respectively. From these tables it can be noted that the average phosphorus level of the samples submitted for corn was H- or higher for all but one of the counties included in Table 7. However, over half of the samples indicated a requirement for phosphorus in all but one county. This indicates that although the average test may be high, there are a large portion of the fields that still require phosphorus addition.

Table 7. Average Phosphorus Soil Test Values of Samples From Corn Fields
(July 1, 1969 - June 30, 1970)

County or District*	No. of Samples	Ave. Test	Rating for Corn**	% of Times Fertilizer Recommended	Ave. Rec. lb. P_2O_5/ac.
Brant	295	20	H	58	27
Elgin	387	14	H-	81	37
Essex	179	23	H+	52	22
Haldimand	258	15	H-	79	38
Huron	305	15	H-	78	37
Kent	597	23	H+	51	19
Lambton	236	18	H	75	37
Middlesex.	338	25	H+	68	31
Norfolk	488	18	H	73	33
Northumberland	321	23	H+	46	23
Ontario	560	18	H	63	31
Oxford	651	15	H-	79	38
Perth	198	13	H-	73	39
Peterborough	202	18	H	64	34
Simcoe N.	217	15	H-	75	36
Simcoe S.	351	15	H-	73	36
Waterloo	251	20	H+	56	23
Wellington	438	15	H-	73	38
Wentworth	207	16	H	68	31
York	275	15	H-	73	34
Southern Ontario	10,345	17	H	70	35

* Only counties or districts with 150 or more samples included.

** H+ - very high - above optimum level for crop
H - high - at optimum level for crop
H-, M+, M, M- etc. - below optimum level for crop.

Table 8. Average Phosphorus. Soil Test Values of Samples From Hay-Pasture (½ or more legume) (July 1, 1969 - June 30, 1970).

County or District*	No. of Samples	Ave. Test	Rating** For Hay-Pasture (½ or more legume)	% of Times Fertilizer Recommended	Ave. Rec. lb. P_2O_5 /ac.
Bruce	116	11	M	87	47
Kent	50	12	M+	85	55
Ontario	65	15	H-	77	38
Rainy River	145	10	M	94	66
Simcoe N.	65	12	M+	86	46
Victoria	55	6	L+	98	80
Wellington	235	9	M-	95	60
Southern Ontario	1606	14	H-	66	47

* Only counties with 50 or more samples included.

** H+ - very high - above optimum level for crop
H - high - at optimum level for crop
H-, M+, M, M- etc. - below optimum level for crop.

Table 9. Average Phosphorus Soil Test Values of Samples From Potato Fields (July 1, 1969 - June 30, 1970)

County or District*	No. of Samples	Ave. Test	Rating** For Potatoes	% of Times Fertilizer Recommended	Ave. Rec. lb. P_2O_5 /ac.
Dufferin	39	98	H+	92	107
Rainy River	44	163	H+	52	48
Simcoe N.	35	27	M	100	106
Simcoe S.	91	43	H-	79	69
Sudbury	56	35	M+	82	99
Thunder Bay	34	28	M+	94	111
Waterloo	65	50	H	66	50
Northern Ontario	2	63	H+	76	91
Southern Ontario	541	52	H	76	79

* Only those counties or districts with 25 or more samples included.
** H+ - very high - above optimum level for crop
H - high - at optimum level for crop
H-, M+, M, M- etc. - below optimum level for crop.

The average phosphorus level of samples submitted for hay-pasture is much lower than that for corn (Table 8), Only one of the counties showed a H- rating for hay-pasture although on the average, Southern Ontario also has a H- rating. Over 75% of the samples submitted indicated a requirement for addition of phosphorus.

Although the average phosphorus test of samples from potato fields is considerably higher than that for corn (Table 9) the potato crop has a much higher requirement. Therefore, the average rating for the various counties tends to be similar to that tor coin with most counties having a H- or higher rating. Again, however, over 50% of the samples indicated a requirement for phosphorus.

Similar data are available for other crops. Samples were tested from 43,390 fields between July 1, 1969 and June 30, 1970. These samples indicated that 66% of the fields required phosphorus for the crop to be grown. The average requirement was 47 lb. P_2O_5 per acre.

Phosphorus Balance in Ontario Great Lakes Watershed

A balance sheet has been developed for phosphorus in the Ontario portion of the Erie and Great Lakes watersheds in a similar manner as that for nitrogen. This balance sheet (Table 10) is less complex than that for nitrogen because there are no natural processes adding phosphorus to the soil. From this table it can be noted that addition of phosphorus exceeds removal by about 37 lb, P_2O_5 per acre under crops in the Erie watershed and by about 27 lb. P_2O_5 per acre under crops in the total Great Lakes watershed.

In the previous section it was noted that 66% of the samples tested by the Ontario Soil Testing Service indicated a requirement for additional phosphorus fertilizer for the crop that was to be grown. Provided the phosphorus that is being applied in excess of that removed is being applied to those fields that have a requirement and not to the fields that are already above the optimum level, the excess addition over removal is justifiable from a crop production standpoint.

Phosphorus and Water Pollution

It was noted in the section on reactions in soil that phosphorus is only very slightly soluble in soil and that fertilizer phosphorus reacts very quickly to form nearly insoluble compounds. Because of this, there is little downward movement of phosphorus in soils.

This has been demonstrated by many experiments which are reported in the literature. Four sets of results from Ontario will illustrate this point.

The data in Table 1.1 show the effect of phosphorus fertilization on the available phosphorus content of a sandy soil at various depths.

Table 10. Phosphorus Balance Sheet for Land Under Crops in Ontario Section of Erie and Great Lakes Watershed Section of Erie and Great Lakes Watershed.

Erie Watershed	Tons
Phosphorus Additions	(as P)
Fertilizers[1]	33,269
Animal Waste[2]	14,199
Total	47,468
Phosphorus Removal Harvested Crops[3]	19,269
Addition Less Removal	28,199 tons
Equivalent to 17 lb. P (40 lb.P_2O_5) per acre of land under crops.	
Great Lakes Watershed	**Tons**
Phosphorus Additions	(as P)
Fertilizer[1]	48,153
Animal Waste[2]	32,352
Total	80,505
Phosphorus Removal Harvested Crops[3]	39,594
Addition Less Removal	40,911
Equivalent to 11.6 lb. P (27 lb, P_2O_5) per acre of land under crops.	

1) See appendix Table A-1 for basis of calculation.
2) Obtained from calculation of animal population as shown in section on animal waste.
3) See appendix Table A-2 for basis of calculation.

Table 11. The Effect of Rates of Phosphorus Fertilizer on Phosphorus Distribution With Depth in a Sandy Soil After Eleven Years of Phosphorus Fertilization at Harrow, Ontario.

Depth (in.)	Available Soil Phosphorus (lb/ac.)			
	0 lb.P_2O_5/ac.	40 lb.P_2O_5/ac.	80 lb.P_2O_5/ac.	120 lb.P_2O_5/ac.
0-6	85.0	92.8	106.8	119.4
6-12	63.0	68.4	79.0	90.0
12-18	33.2	34.6	38.0	42.2
18-24	28.0	31.4	32.2	34.0
24-30	26.6	29.4	30.8	31.0
30-36	26.6	28.0	29.8	30.8

The movement of an ion in solution is greatest in light textured, sandy soils. The downward movement of phosphorus would therefore be greatest under these conditions. After eleven years of fertilization the phosphorus content at the 36 inch depth only increased by 4.2 lb./ac. with the annual application of 120 lb.P_2O_5 per acre. The distribution of fertilizer phosphorus in a loam soil to which 300 pounds of phosphorus P/ acre were applied over a seven-year period is shown in Figure 3. There was little increase in the soil phosphorus test below the 12-inch depth. The soil was cultivated to a depth of 6-8 inches.

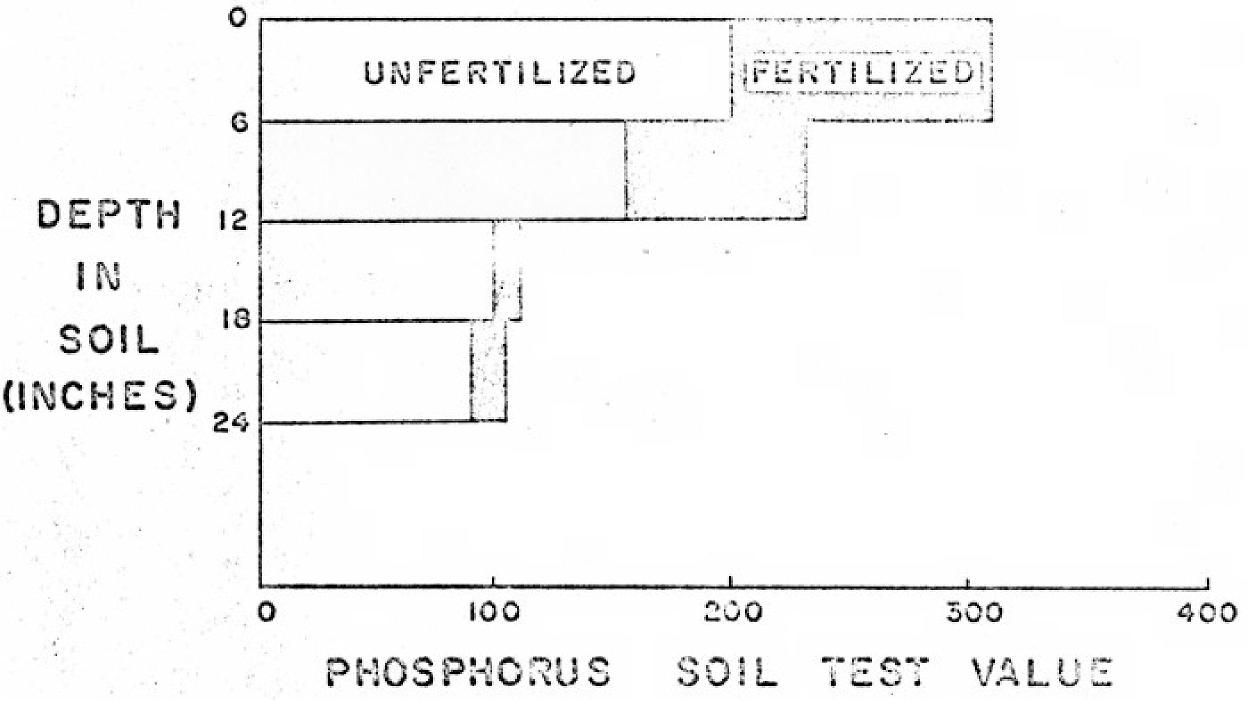

Figure 3. Distribution of fertilizer phosphorus in a Burford loam to which 300 lb. P/ac were applied over a seven-year period. (From 1966 Progress Report, Dept. of Soil Science, Univ. of Guelph).

The phosphorus content of tile drainage waters has been measured at Woodslee, Ontario (Table 8). There was only a very slight increase in phosphorus in the tile drainage water from the addition of fertilizer at the rate of 60 lb. P_2O_5/ac./yr.

Table 12. The Average Annual Loss of Phosphorus Through Tile Drains on Brookston Clay (1961-1967) at Woodslee, Ontario.

	P in Drainage Water	
Crop	No Fertilizer	Fertilized
	(lb. /ac. /yr.)	
Corn	0.12	0.21
Oats - alfalfa	0.12	0.12
Alfalfa - 1st yr.	0.12	0.13
Alfalfa - 2nd yr.	0.07	0.20
Cont, corn	0.23	0.26
Bluegrass sod	0.01	0.11
Average	0.11	0.17

The amounts of phosphorus leached from natural-core lysimeters to which varying amounts of poultry manure had been added are reported in Table 13. The poultry manure was added in two applications, in the spring of 1968 and 1969. In the fall of 1969, approximately 10 in. of water was added to increase the intensity of leaching. There was however, essentially no increase in the amount of phosphorus in the percolate from the phosphorus contained in the poultry manure.

Table 13. Phosphorus in Leachate From Lysimeters at Guelph, Ontario (May 1968 to Dec. 1969).

Phosphorus added in poultry manure (lb. P/ac.)	0	320	640	960
Phosphorus in leachate (lb. P/ac.)	0.22	0.43	0.19	0.30

From these and similar data it can be stated that there is essentially no movement of phosphorus from fertilizer or animal waste through the soil into the groundwater.

Because there is little vertical movement of phosphorus in soil, fertilization increases the phosphorus content of the surface soil. Therefore, soil carried by surface runoff or erosion from fertilized from fertilized fields will be higher in phosphorus than that unfertilized fields. If fertilizer use is contributing to buildup of phosphorus in our water supplies, it will be in this manner.

Certainly there may be considerable loss of soil from cultivated land by surface runoff. The problem is to determine how much of this soil reaches our streams. The movement of soil from the top to the bottom of a slope, while undesirable from a crop production standpoint, will not contribute to pollution unless the sediment is carried directly into a stream, pond or lake. Several studies of the phosphate level in streams have been conducted. Missingham (1967) found that the phosphorus content of the Grand River increased by a factor of 10 when the river passed from a predominantly agricultural watershed into more populated areas. Owen and Johnson (1966) measured the phosphate level in several streams flowing into Lake Ontario. The amount of phosphorus from predominantly agricultural watersheds varied between 97 and 200 pounds of phosphorus per square mile per year.

Two predominantly urban watersheds (Highland Creek and German Mills Creek) yielded 7,000 and 9,700 pounds of phosphorus per square mile per year. The amount from the Stouffville Creek which drains a predominantly agricultural watershed but receives wastes from the village of Stouffville was intermediate. In the Highland Creek watershed, the yield of phosphorus from urban land drainage was 5 to 10 times that from agricultural land drainage. The authors concluded that "although the yield of phosphorus from rural land drainage is doubtless a significant contribution it would represent a very small proportion of the amount of fertilizer which is added to the lend in contemporary agriculture. Actually the yield could be attributed just as logically to streambank erosion".

The report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River* presents estimations of the source of phosphorus in Lake Erie and Lake Ontario. This data is summarized in Table 14.

Table 14. Annual Input of Phosphorus to Lake Erie and Lake Ontario.

Lake Erie (excluding that from Lake Huron)	Tons/year	% of Total
Municipal	19,090	68.5
Industrial	2,030	7.3
Land Drainage	6,740	24.2
Total	27,860	100.0
Lake Ontario (excluding that from Lake Erie)		
Municipal	7,410	85.8
Industrial	410	4.7
Land Drainage	820	9.5
	8,640	100.0
Lakes Erie and Ontario Combined		
Municipal	26,500	72.6
Industrial	2,440	6.7
Land Drainage	7,560	20.7
	36,500	100.0

* Prepared by the International Lake Erie Water Pollution Board and the International Lake Ontario - St. Lawrence River Water Pollution Board. 1969.

The proportion attributed to land drainage (20.7%) in the Report of the International joint Commission includes phosphorus carried in sediments from erosion of streambanks, road construction sites and ditches as well as surface erosion from farm fields. It also includes "contributions from cottages and homes on septic tanks, small industries located outside municipal boundaries and small municipalities where no sewage treatment facilities are provided".*

Studies have shown that the suspended sediment load carried by Buffalo Creek, N.Y. was reduced 40 per cent as a result of streambank erosion control measures on only 20 per cent of the streambank within a 145 square mile watershed. Hardin and Bennett and Bennett (1969) report that 66 - 90% of the sediment load in many streams comes from streambank and streambed erosion in the western United States. They further report on the sources of sediment into the Middle Fork Eel River in California, Watershed slopes contributed 13.5% of the sediment, landslides 22.5%, streambanks 63.0% and major roads 1.0%. While this data cannot be directly applied to Ontario it does indicate that a significant portion of the sediment comes from streambank erosion.

A study of land drainage in Metropolitan Detroit by Thompson (1970) indicated that the erosion from areas under urban development contributed 69 tons of sediment per acre per year compared with an overall average erosion rate of about 3.0 tons per acre per year for the metropolitan area and an overall average erosion rate of 2.6 tons per acre per year for south-east Michigan. Thus road construction and urban development will account for significant amounts of sediment even though the total acreage under construction may be relatively low.

From this and similar data it can be conservatively estimated that less than 50 per cent of the sediment in our streams comes from farm fields.

Unfertilized soils contain an average of about 1000 pounds of total phosphorus in the surface six inches. The average rate of application recommended by the Ontario Soil Testing Service during 1968/69 was less than 25 pounds of phosphorus per acre. The average use throughout the province is considerably less than this. At this rate of application over a 10-year period, the amount of phosphorus added as fertilizer would be only about 25 per cent of the natural phosphorus content. (This is assuming no crop removal; in practice, crops would remove a portion of this phosphorus). Although it is impossible at this time to place an accurate figure on the proportion of the phosphorus reaching the lakes that comes from fertilizer application, it is fairly safe to say that less than 12 per cent of the phosphorus in land drainage can be traced to fertilizer use (less than 50 per cent of the phosphorus in land drainage comes from farm fields; less than 25 per cent of the phosphorus from farm fields comes from fertilizer: 0.50 x 25 = 12.5). This means that less than 2½ per cent of the phosphorus reaching Lake Erie and Lake Ontario can be attributed to fertilizer use (12.5% of 20% = 2.5%).

---

* Personal communication from Mr. J. Thon, Program Engineer, Ontario Water Resources Commission to Mr. D.M. Rutherford, Technical Director, Plant Food Council of Ontario.

Studies have been made on the effects of applied phosphorus fertilizer on 230 acres in the Lake Sebasticook area in Maine. An annual application of 16,700 lb. of phosphorus was applied. Assuming an average annual loss of 0.4 lb. P per acre (250 lb. P per square mile) the loss in the Lake Sebasticook area is 100 lb. per year. This amounts to 0.6 of the phosphorus applied and 2% of the annual input into the lake. This agrees closely with the calculation for Ontario in the preceding paragraph.

Because phosphorus is held tightly to soil particles, most of the phosphorus carried into streams and lakes by erosion would be in the sediment rather than in the water and thus would not be directly available for algae growth.

EROSION

The detachment and transfer of soil is termed soil erosion. Only erosion effected by water will be considered here since wind erosion is a very minor problem in isolated areas. Soil erosion usually occurs when more moisture than can permeate into the soil falls on a soil under the following conditions: (1) fallow or sparsely covered land, (2) steep slopes under intensive cultivation, (3) when a thin layer of unfrozen soil receives an intense rainfall, and (4) during storms with high intensities.

Raindrops are erosive agents. They detach the soil particles from the surface and make the soil particles available for transport in water. Hence raindrop impact is the main force causing erosion on cultivated land.

Plant cover controls splash erosion and holds soil in place under field conditions. The effectiveness of plant cover in preventing soil erosion depends on the amount present when rain falls.

The density of crop cover (to act as a shield) and the weight or bulk of the cover (to absorb the energy of the raindrops) are important in protecting the soil from erosion. The more open the canopy the less interception of raindrops by the canopy and the more erosion is likely to occur. Therefore the maximum rate of erosion usually occurs during the period of establishment. This period is characterized by inadequate cover. At other periods in the life of a crop the danger of erosion is very small due to the completeness of cover and bulk of cover during part of the season. Even the most easily detached soil is not disturbed when there is sufficient canopy to intercept the energy contained in a falling raindrop. It is generally recognized that tree crops and grass crops prevent a serious erosion.

Tables 15 and 16 show the effect of crops on soil loss and runoff. The data in Table 15 show soil loss under continuous corn was about half of that under fallow. Other cropping systems which provided more complete cover reduced soil loss even more, with the continuous bluegrass sod having essentially no loss. The data for Ontario exhibited in Table 16 showed only trace amounts of soil loss on the first year hay plots in rotation. The greatest loss was from continuous corn. Thus cropping practices which include large proportions of row crops will increase the amount of sediment reaching streams and lakes from erosion.

Table 15. The Effect of Different Cropping Systems on Runoff & Erosion (after Stallings, 1953).

Treatment	Soil Loss (Tons/ac./yr.)	Runoff (% of rainfall)
Continuous bluegrass	0.34	12.0
Rotation of corn, wheat, clover	2.78	13.8
Continuous wheat	10.09	23.3
Continuous corn	19.72	29.4
Fallow	41.65	30.7

Table 16. The Effect of Different Cropping Systems on Runoff and Erosion in Ontario Over a 10 Year Period.

Cropping Practice	Soil Loss (lb./ac./yr.)	Water Loss inches/year
Continuous hay (establishment period not included)	negligible	negligible
Continuous corn	16,800	1.23
Four year rotation, with-the-slope planting		
corn	1,100	0.23
oats	5,500	0.55
hay 1st year	trace	0.13
hay 2nd year	trace	0.12

The data show the necessity in establishing crops rapidly. Increasing the amount and density of a crop also decreases erosion because it enhances raindrop interception. The addition of fertilizer accomplishes both these goals. High yields and erosion control go hand.

Corn, oats, and hay in a rotation lost 47.21 tons of soil per year when no fertilizer was used. The same rotation using fertilizer on oats only in the rotation decreased the soil loss to 13.13 tons per acre per year. On continuous cornland, the annual use of 200 lbs. of 5-10-5 per acre reduced the soil loss by 2/5 and water loss by ⅓ during a nine year period over unfertilized cornland. The unfertilized area lost 9.5% of the rainfall as runoff and 5,934 pounds of soil per acre per year while the corresponding figures for the fertilized plot were 6.4% and 3,552 pounds per acre per year respectively. The same author reported soil loss reductions by ½ in wheat with a yield increase of 91% due to the use of fertilizer (200 lb./ac. 0-20-10). In oats fertilizer use (200 lb./ac. 10-20-10) reduced soil loss by more than half while increasing yield 77%. These data are averages for 7 years.

It is apparent that the increasing trend to corn and other row crop production in Ontario is likely to increase the amount of erosion. It is not possible with the data available to estimate the amount of sediment from cultivated fields reaching streams and lakes. Estimates can be made of the movement of soil on a slope under a given condition. This movement does not necessarily contribute sediment to waterways. Only when the erosional water flows directly into a stream will there be a contribution to the sediment load.

It is possible from our knowledge of the soils of Ontario and from the inventory of soils in the province provided through the Ontario Soil Survey program to indicate the relative susceptibility of the soils in an area to erosion This is indicated by counties in Figure 4. This map was prepared

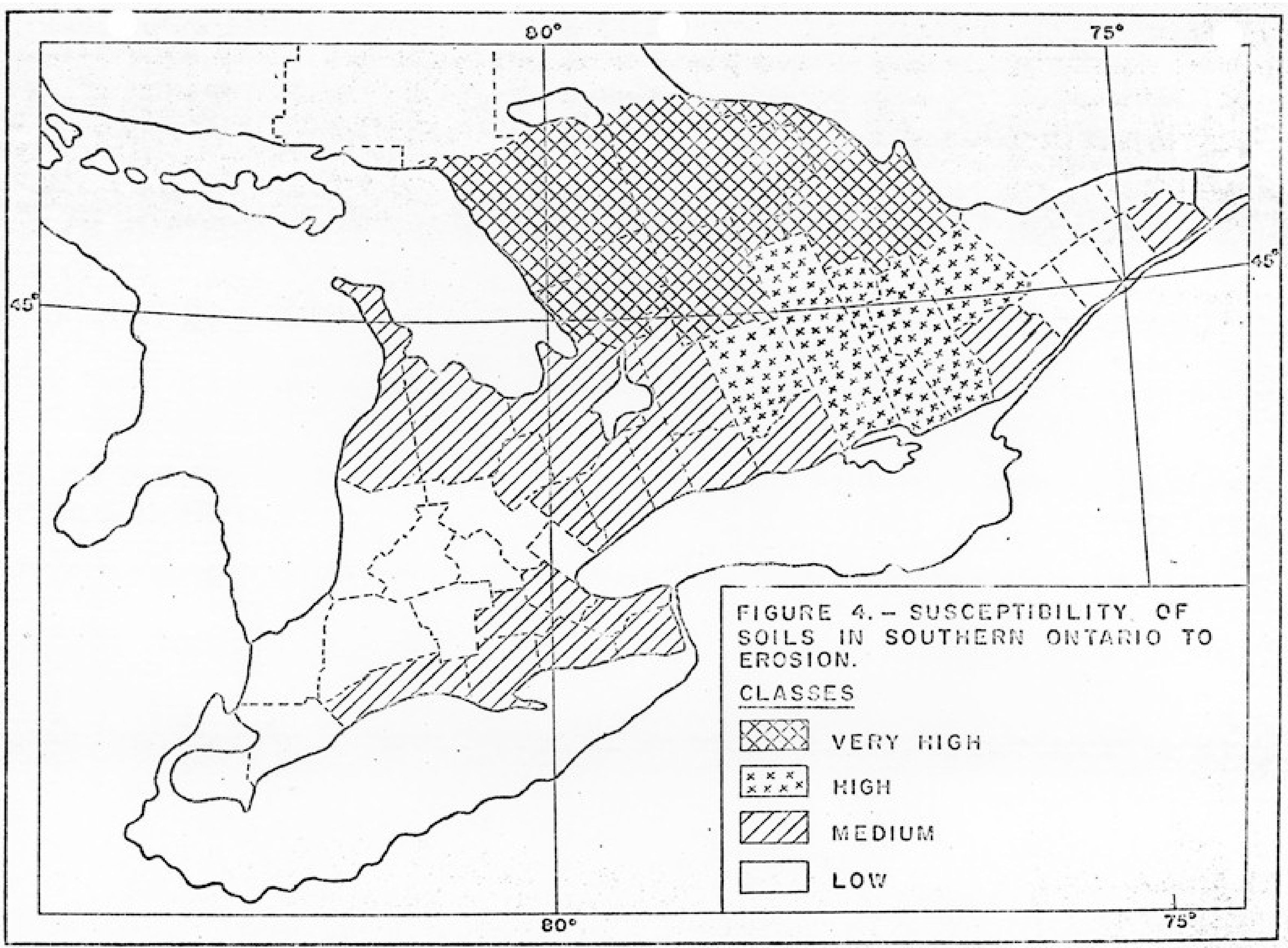

FIGURE 4. – SUSCEPTIBILITY OF SOILS IN SOUTHERN ONTARIO TO EROSION.

by calculating the acreage of each soil type in a county having a high, medium or low susceptibility to erosion. Each county was then rated as to the susceptibility to erosion. This susceptibility rating does not take present land use into consideration. It is based only on inherent soil properties. It does show however that those areas with a high proportion of row crops have a low or medium susceptibility to erosion.

SUMMARY AND CONCLUSIONS

1. Fertilizer use in agricultural production is a potential source of nitrogen and phosphorus pollution of ground and surface waters.

2. The contribution of nitrogen to groundwaters increases rapidly when fertilizer in excess of that required for most profitable crop yields is added. It is therefore important that precise methods for estimating the nitrogen requirement on a specific field be developed.

3. The rate of nitrogen addition to crop land in Ontario from all sources combined (i.e. fertilizers, animal waste, fixation and rainfall) exceeds the rate of crop removal by about 27 lb N/ac. /yr. The proportion of this that reaches ground or surface waters and the proportion that is immobilized in the soil or denitrified cannot be estimated with any degree of confidence. It is therefore essential that increased research effort be directed towards improving our understanding of nitrogen in the biosphere with particular emphasis on the fate of nitrogen in a cropping system.

4. Phosphorus addition from fertilizers and animal wastes on crop land in Ontario exceeds the crop removal by approximately 27 lb P_2O_5/ac/year. However, 66% of the samples submitted to the Ontario Soil Testing Laboratory in 1969-70 had a phosphorus level, below optimum for crop production. Provided the excess phosphorus addition is applied to the areas that are below the optimum level, the excess addition is justified from a crop production standpoint.

5. Phosphorus is held tightly in the soil. There is, therefore, very little contribution of phosphorus from fertilizer use to groundwater supplies.

6. Soil eroded from fertilized fields will contain higher levels of phosphorus than that from unfertilized fields. It is not possible with our present knowledge to estimate the amount of soil that is transported from farm fields to surface waters. Increased effort should be directed to the determination of the proportion of sediment that comes from farm fields compared to that from streambank erosion, highway development etc.

7. The most accurate estimate that can be made at present indicates that less than 22% of the phosphorus going into Lake Erie and Lake Ontario can be attributed to fertilizer use.

8. The increasing trend towards row crops, particularly corn, will tend to increase the amount of sediment and hence phosphorus from farm fields reaching surface waters. Improved management practices must be developed to decrease erosional losses. Accelerated effort is required to implement these practices as rapidly as they can be perfected.

APPENDIX

Table A1. Estimation of Fertilizer Nitrogen and Phosphorus Applied to Crop Land in Erie and Great Lakes Watersheds.

Erie Watershed	Tons
Fertilizer sold[1] (excluding Norfolk County)	462,781
Nitrogen content (ave. of 16% N) [2]	74,045
Phosphorus content (ave. of 6.4% P) [2]	29,618
Fertilizer sold in Norfolk County	61,357
Nitrogen content [3]	3,374
Phosphorus content	3,651
Total nitrogen sold in watershed	77,419
Total phosphorus sold in watershed	33,269
Great Lakes Watershed	
Fertilizer sold [1]	776,660
Nitrogen content (ave. of 13% N)[4]	100,966
Phosphorus content (ave. of 6.2% P)[4]	48,153

1. From Fertilizer Trade. July 1, 1967 - June 30, 1968. Dominion Bureau of Statistics Pub. No. 46-207.

2. Average N and P content of fertilizer sold in region by major fertilizer company.

3. Estimating 75% of fertilizer to be for tobacco with average N content of 2% and average P content of 5.8% (13.4% P_2O_5); remaining 25% to have average N content of 16% and average P content of 6.4% (15% P_2O_5).

4. Average N and P content of all fertilizer sold in Ontario as reported in Fertilizer Trade.

APPENDIX

Table A2. Estimation of Nitrogen and Phosphorus Removed by Harvested Portion of Crops in Erie and Great Lakes Watershed.

Erie Watershed

Crop	Acres[1]	Ave. Yield Per Acre	N Content		P Content	
			lb./ac.	Tons	lb./ac.	Tons
Wheat	256,000	40.6 bu.	49.5	6,336	9.3	1,190
Oats	273,000	55.9 bu.	34.1	4,655	6.7	833
Barley	105,000	50.8 bu.	42.7	2,242	8.6	452
Mixed Grain	227,000	60.0 bu.	43.2	4,903	3.4	953
Soybeans	320,000	23.8 bu.	91.0	14,560	8.8	1,408
Grain Corn	746,000	74.3 bu.	68.4	25,513	11.9	4,439
Silage Corn	227,500	12.4 T.	210.	23,888	27.3	3,105
Hay	687,000	2.9 T.	113.7	39,056	12.2	4,191
Total	2,841,500			121,153		16,571

Total acres in crop in watershed = 3,312,951.

Total nitrogen contained in crops $121{,}153 \times \frac{3{,}312{,}951}{2{,}841{,}500} = 140{,}876$ tons

Total phosphorus contained in crops = 19,269 tons

Great Lakes Watershed

Crop	Acres[1]	Ave. Yield Per Acre	N Content		P Content	
			lb./ac.	Tons	lb./ac.	Tons
Wheat	357,300	39.3 bu.	48.6	8,682	9.2	1,643
Oats	634,200	52.8 bu.	32.2	10,210	5.8	1,839
Barley	282,700	50.0 bu.	42.0	5,936	8.5	1,201
Mixed Grain	1,090,000	58.5 bu.	42.7	23,271	8.2	4,469
Soybeans	321,720	23.8 bu.	91.0	14,638	8.8	1,415
Grain Corn	824,200	75.1 bu.	69.1	30,894	12.0	5,365
Silage Corn	460,600	12.7 T.	214.6	49,422	27.9	6,425
Hay	2,393,000	2.74 T.	107.4	128,504	11.5	13,759
Total	6,433,720			271,557		36,115

Total acres in crops in watershed = 7,052,196

Total nitrogen contained in crops $271{,}557 \times \frac{7{,}052{,}196}{6{,}433{,}720} = 297{,}752$ tons

Total phosphorus contained in crops = 39,600 tons

---

[1] From Agricultural Statistics for Ontario, 1969. Pub. 20, Ontario Department of Agriculture and Food.

III. Pesticide Use and Pollution

1. Background

Pesticides include a large number of biologically active chemicals which have been instrumental in protecting public health and increasing agricultural production by reducing the depredations of pests. While there is no question of these benefits, there has been increasing concern over evidence of environmental contamination from a few of these compounds in the Great Lakes Basin.

The term pesticide may be subdivided into more specific subgroups including insecticides, miticides, nematocides, herbicides, fungicides, rotenticides and fumigants. A simple classification system for insecticides alone shows the diversity of chemical forms:

Inorganic chemicals	Lead arsenate, sodium fluoride, thallium sulphate
Natural botanical products	Rotenone, pyrethrum, strychnine
Natural organic chemicals	Kerosene, naphthalene
Synthetic organic chemicals	Chlorinated hydrocarbons, organic phosphorus compounds, carbamates
Microbial agents	*Bacillus thuringiensis*

The main emphasis in this report will be with those compounds that persist and have entered the Ontario environment. Only DDT with its metabolites, and dieldrin, have been widely found in the aquatic environment. Others such as lindane and heptachlor have been found but confined to local, isolated areas. Instances of localized pollution of water from industrial sources have been rare.

Episodes of abuse and misuse including the discarding of excess spray material into water courses and the improper disposal of "empty" pesticide containers have sporadically occurred in the province from time to time. Some of these spillages have been accompanied by the loss of fish on a small scale.

The relative contribution of environmental contamination of the Great Lakes resulting from agricultural use, as opposed to industrial and domestic use, is difficult to assess. In general, about 75% of all pesticides used in Ontario are for agricultural purposes and this serves to draw greater attention to agriculture as the source of this contamination. That applied to rich agricultural soils not prone to erosion has presented little hazard to the environment compared to that applied to soils easily eroded by water or wind or where application has been made to thin soils and rock out-crops. In the latter, rapid movement into the water environment has given serious contamination in one area.

2. History

Following the conclusion of World War II, DDT was widely adopted by the agricultural industry to replace such insecticides as lead arsenate, nicotine sulphate and paris green. Its wide spectrum of activity and much lower toxicity made its acceptance rapid. The first spray calendar recommendation by the Ontario Department of Agriculture appeared in 1947 for its use on many vegetables. It controlled the major pests of potatoes, the Colorado potato beetle, tarnished plant bug and aphids, as well as insects on peas, beans, corn and cole crops.

The following year, it appeared on the spray calendar for fruit for use in apple orchards for the control of codling moth and apple maggot, the two most serious insect pests. For peaches, it was recommended for the control of Oriental fruit moth and other pests. DDT was also found to be effective for the control of soil pests such as wireworms and cutworms. The livestock industry found it to be effective for the control of flies in barns and on animals.In the period 1949-1954, its use in agriculture was almost universal.

Signs of insect resistance of DDT was detected in the early 1950's and very soon growers were forced to switch to alternatives for some pests. Aphids on such crops as potatoes were one of the first to show this in the field and by 1955, malathion was used instead. Flies in barns showed resistance to DDT after only a few seasons of use and it was replaced by various organophosphates in the 1950's. The greater effectiveness of the cyclodienes, a sub-group of the organochlorines which includes aldrin, dieldrin, heptachlor, for the control of most soil insects resulted in less use of DDT by the late 1950's.

Only the emergence of the darksided cutworm as a major pest in tobacco, not controlled by the cyclodienes, caused an almost complete return to the use of DDT for this particular crop. The vegetable processing industry had used DDT widely for the control of aphids on peas, and cornborer and corn earworm on sweet corn. About 1958 it became evident that if corn stover or pea vines were treated with DDT and subsequently fed to livestock, a definite residue problem resulted. The introduction of an alternative, carbaryl (Sevin) for corn enabled growers to discontinue the use of DDT by 1962. The use on peas was greatly reduced at the same time, but did not cease entirely until 1964.

The introduction of the organic phosphates in the 1950's and of the carbamates in the

1960's, along with the development of resistance, led to a decrease in the number of uses of DDT in agriculture starting in the late fifties. Only in tobacco production had there been a need for an increase in use. Nevertheless, the increased use for this problem and for the control of non-agricultural insect problems, such as biting flies and protection of shade trees, resulted in a steady increase in the quantity of DDT being used up to and including 1969. The use of aldrin reached a peak in 1968 (Table 1). The sudden drop in sales reflects the restrictions on uses described in Section 4.

Table 1: Total Sales of Chlorinated Hydrocarbons in Ontario
Actual Toxicant Sold (lbs.)

Material	1968	1969	1970
DDT and DDD	296,274	463,139	85,112
Aldrin	3,263,447	26,857	none
Dieldrin	297	806	none

3. Monitoring the Ontario Environment

The Provincial Pesticide Residue Testing Laboratory, Ontario Department of Agriculture and Food, was established in 1966. Its function has been to serve all Departments of the Ontario Government in investigating the pesticide residue situation in Ontario. Since its inception, approximately 9,000 samples have been analyzed.

Data are included in this section of the report which reflect the situation for the Great Lakes Drainage Basin of Ontario.

Water:

Water samples have been collected in the Great Lakes Basin area, the area of highest population and highest pesticide use in Ontario.

Samples were collected from rivers and potable water supplies. The total pesticide load was found to be very low; averaging 14 parts per trillion. Two types of chlorinated hydrocarbons were found, DDT with its metabolites and dieldrin (See Table 2). Because the amount of dieldrin used in Ontario is insignificant compared to aldrin, the dieldrin appearing in samples is assumed to be the metabolite of aldrin.

River Sediment:

Sediments were taken from rivers and streams where contamination of fish was known to be relatively high. 93% of the sediments contained measurable residues - with an average of 0.084 ppm. (Table 2). These residues occurring in sediment are the reservoirs that give a measure of danger to the aquatic organisms.

Soil:

Soil samples were collected from both urban and agricultural areas of the Great Lakes Basin area. Soil residues were greatest in orchard and vegetable crop soils. (Table 3). The area covered by agricultural land in Ontario represents 15% of the total. The area represented by orchard and vegetable crops amounts to 4% of the agricultural land - in other words, 0.06% of the province.

The data shows that DDT residues are low on 96% of the agricultural land of Ontario, indicating widespread but not concentrated use of the chemical.

Of the DDT present in the soil, the largest portion is present as DDT (66%) with smaller percentages of DDD (6%) and DDE (28%) .

Provincial Milk Survey:

A province-wide survey on milk was carried out between 1967 and 1969. During that time, samples were taken so that each of the 27,000 milk shippers was sampled once.

DDT (with its metabolites) and dieldrin were present in all milk fats tested; lindane and heptachlor epoxide were found in 8% and 3% of the samples respectively.

In all, only 20 herds were found with residues in the butterfat that exceeded the administrative tolerance of 0.1 ppm for dieldrin and heptachlor and 1 ppm for lindane and DDT (with metabolites). Since the milk supply (butterfat) acts as a "sink" for any misuse of chlorinated hydrocarbon pesticides in agriculture, it can be concluded there is not a significant problem with misuse of the chemicals in Ontario (Table 4).

Fish:

Fish caught in four major areas were compared in 1968 - 1969. These areas included the Muskoka Lakes (a non-agricultural area), Bay of Quinte, Trent River system, Holland Marsh, Lake Simcoe and the Great Lakes. In the compilation, many species and many ranges of size were included (Table 5). The total DDT residue in all except one area (Muskoka) fell below 1 ppm in the muscle tissue. When these results are based on extractable fat, the levels ranged from 4 to 29 ppm on a fat content varying from 1.75 to 4.25%. There is evidence that the reproduction of trout in the Muskoka Lakes has been affected. These areas have been intensively developed for recreation and annually sprayed for the control of mosquito and black fly for several years. Additionally, the Muskokas are plagued with periodic outbreaks of forest tent caterpillar. Because of the geological features of the landscape, DDT can be moved readily from a terrestrial to an aquatic environment. Exposed bedrock is common, soils are often thin and surface movement is possible.

The data presented represents the most complete survey of the Great Lakes Basin relative to pesticide levels. It is apparent that no major problems exist as a result of agricultural use of pesticides.

4. Government Action in Ontario

The Ontario Department of Health took the first official step to restrict the use of DDT and TDE in the province under the Public Health Act of 1954.

In 1956, the Ontario Department of Health gave further recognition to the whole subject of pesticides by transferring these matters from the Public Health Act into a separate legislative program, The Pesticides Act. The Act has been modified in 1964, 1967, 1969 and 1970.

The Ontario Water Resources Commission Act of 1956 provided that: "No person shall add any substance to the water of any well, lake, river, pond, spring, stream, reservoir or other watercourse for the purpose of killing or affecting plants, snails, insects, fish or other living matter or thing therein without a permit issued by the Commission." Since 1966, the Commission has not issued any permits for the use of DDT in water.

In 1957, as a result of finding dieldrin in dairy products in Western Canada, a survey was made throughout Canada for dieldrin and other chlorinated hydrocarbons. Joint Federal and Provincial Departments of Agriculture reduced the uses of DDT and dieldrin on animals and animal feeds.

In 1961, the Ontario Department of Agriculture and Food Protection Committee recommended the use of DDT after the second cover spray for peaches be deleted and by 1963 a considerable amount of the DDT used in apple production was replaced by carbaryl (Sevin). In the same year, DDT was deleted from the controls recommended in the spray calendar against armyworms.

In 1966, the Department of Lands and Forests discontinued using DDT for control of mosquitoes and black flies, and at the end of the 1967 season, discontinued the use of DDT entirely in all of its programs.

In 1967, the Pesticides Act restricted the application of DDT by aircraft, concentrated air blast machine and power duster to a permit basis, which could be refused if the application could not be carried out safely. Furthermore, the DDT had to be applied in liquid or granular form and records of all such applications had to be kept by the applicator.

In 1967, the O.D.A.F. spray calendar recommendation for DDT for the control of corn borer on field corn was deleted. In the following year, the use of DDT was minimized in the spray calendar and it was not recommended for many agricultural crops. The use on apples after July 20 was deleted, and DDT had already been replaced by carbaryl (Sevin) and azinphos-methyl (Guthion) in much of the spraying done before that time of year. Less persistent insecticides were recommended as a substitute for DDT on many vegetables. In the field crops, there were no recommended uses except for tobacco.

In 1969, the use of DDT was deleted from the O.D.A.F. spray calendar recommendations for corn borer and corn earworm on corn, and for all insects generally on beans, cabbage, cauliflower, Brussels sprouts, lettuce, peas, peppers and tomatoes. In the case of peaches, all uses were deleted except for plant bugs.

In May 1969, aldrin, dieldrin and heptachlor were prohibited for use in agriculture. The small package trade was given until January 1, 1970, to dispose of existing stock on hand. Therefore, the only legal use remaining for aldrin, dieldrin and heptachlor in Ontario is for control of termites by licensed structural exterminators.

In September 1969, the uses of DDT were severely restricted in Ontario and the only uses now permitted are for cutworm control in tobacco, plant bug control in apple and bat control by structural exterminators. For these uses, a permit is required. For use on tobacco, which is temporary until an effective alternative insecticide is found, the rate of DDT is reduced from 4 lbs. to 1 lb. per acre. Application to tobacco is further restricted to boom-type sprayers. These restrictions should have the effect of eliminating potential contamination in the Great Lakes from sources in Ontario.

The sales of DDT, aldrin, and dieldrin in Ontario for 1968, 1969 and 1970, appears in Table 1. In Ontario, all sales amounts (in any concentration) of 4 lbs. or more of dusts, powders or granule and 160 fluid oz. or more of solutions or emulsifiable concentrates must be recorded. This requirement formed the basis for determining the amount sold in Ontario. Unfortunately, the figures do not include all sales as most household and garden products would be exempted because of the amounts in the container which are sold. The figures, however, serve to indicate a clear picture of the trend of those sales in Ontario.

From the monitoring done in Ontario in 1969 and 1970, it would appear that the levels found in Ontario soil and surface water in the Great Lakes area are relatively low and would not contribute significantly to direct contamination in the Great Lakes basin.

Table 2. Pesticide Residues in Water and Sediments - Ontario, 1968-69

Sample	Number Analyses	Content in water (ppb) and sediment (ppm)			Measurable residue (%)	Non Measurable residue (%)
		DDE, DDD, DDT	Dieldrin	Other chlorinated hydrocarbons		
Well water	14	Trace	--	--	7	93
Potable water	11	0.015	0.009	--	73	27
Raw river water	40	0.019	0.006	--	45	55
Average	65	0.014 [a]	0.004	--	42	58
River sediment (dry)	84	0.080 [b]	0.004	--	93	7

a - The 0.014 ppb consisted of 0.007 ppb DDE (50%), 0.002 ppb DDD (14%) and 0.005 ppb of DDT (36%).

b - The 0.080 ppm consisted of 0.020 ppm DDE (25%), 0.049 ppm DDD (61%) and 0.011 ppm of DDT (14%).

Table 3 . Pesticide Residues in Soil - Ontario 1968-69

Sample	Number Analyses	Content on dry weight basis			
		DDE, DDD, DDT (ppm)	DDT (%)	Cyclodienes (ppm)	Dieldrin (%)
Orchard soils	14	10.4	63	0.313	100
Vegetable soils	13	4.24	81	0.845	33
Field Crop soils	20	0.057	54	0.057	59
Pasture and improved land	12	0.020	55	0.001	100
Urban, non-agric.	7	0.103	59	0.091	75

Table 4 . Pesticide residues in animal milk and meats

Sample	Number analyses	Content in whole tissue			Content in fat			
		DDT and metabolites (ppm)	DDT (%)	Cyclodienes (ppm)	Fat* (%)	DDT and metabolites (ppm)	Cyclodienes (ppm)	Lindane (ppm)
Bovine - Milk	1651	0.005	26	0.001	4.0	0.134	0.032	0.005
- Fat	132		30		100	0.263	0.031	0.017

* Based on extractable fat

Table 5. Pesticide residues in fish - Ontario, 1968 - 1969

Location	Number analyses	In muscle tissue (ppm)		Fat [1] (%)	In fat	(ppm)	DDT (%)
		DDT, DDD, DDE	Dieldrin		DDT, DDD, DDE	Dieldrin	
Trent River - Bay of Quinte	329	0.507	0.004	1.75	29.0	0.23	32
Holland Marsh & Lake Simcoe	312	0.682	0.023	2.77	24.6	0.83	27
Muskoka Lakes and Rivers	519	7.97	0.030	3.60	221.4	0.83	63
Great Lakes	404	0.750	0.025	4.25	17.6	0.59	44
Ottawa River	57	0.118	0.009	3.22	3.66	0.28	36

[1] Based on extractable fats.

IV. WATER POLLUTION POTENTIAL OF FARM ANIMAL AND POULTRY MANURES

Farm animal and poultry manures are of major concern in the abatement of water pollution. Over 90 million farm animals and birds produce in excess of 38 million tons of manure annually in the Canadian portion of the Great Lakes Basin. About 40 percent of this is produced in the Lake Erie Watershed area alone.

The trend in livestock, milk, poultry and egg production is towards automation and centralization. The production of animals has emerged from the small, individual farm operation into a large-scale industrial enterprise involving hundreds of animals and frequently very few acres.

Intensive confinement housing of animals and poultry creates a waste disposal problem. Ordinarily, these wastes are used as a fertilizer source for field crop production and if the farmer grows his own feed, there is generally sufficient land available for this method of disposal. However, many poultry and hog producers do not grow their own feed and rely on commercially available feedstuffs for their feed requirements.

Thus, they frequently do not have adequate land of their own for the disposal of the manure produced. The cash crop farmer, on the other hand, can usually buy and apply chemical fertilizers more cheaply than he could use free sources of animal manures.

(A) The Characteristics Of Animal Manures

There are many criteria which may be used for assessing the water pollution potential of farm manures. The general criteria used in sewage treatment are biochemical oxygen demand (BOD), suspended solids (SS) and coliform bacteria. More recently nutrient relationships have become important especially those of nitrogen and phosphorus. While these criteria may also be applied to farm manures it should be stressed that manure unlike domestic sewage is not normally discharged to surface water.

In the following tables both sewage treatment criteria and plant nutrients have been used to characterize farm animal wastes. These figures represent total production values and do not represent quantities reaching water. As is pointed out later proper manure management would prevent all, or a very large proportion of these potential pollutants from reaching receiving waters.

Table 1 expresses, in units of pounds per day per animal, the production quantities of the various manure components mentioned above. These figures have been used in calculating the data presented in Table 2 and 3 for the Lake Erie Watershed (refer to Figure 1, section on Fertilizer Use and Pollution) and in Tables 4 and 5 for the Great Lakes Basin.

Table 1. Production Quantities and Characteristics of Livestock Manures

	Total Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
Bulls Cows (milk) Cows (beef)	90	1.45	1.95	0.33	0.13	0.03
Steers (beef) Heifers (milk) Heifers (beef)	50	1.65	2.05	0.16	0.10	0.01
Calves	25	0.36	0.52	0.03	0.03	0.01
Pigs (Feeder)	10	0.38	0.34	0.06	0.04	0.006
Sows	14	0.41	0.18	0.062	0.042	0.008
Sheep (Ewes)	12	0.32	0.21	0.05	0.03	0.002
Sheep (Lambs)	8	0.22	0.11	0.03	0.02	0.001
Horses & Ponies	55	1.40	1.90	0.26	0.09	0.01
Hens (Layers) Chickens (Hatchery) Turkeys (Heavy)	0.31	0.025	0.013	0.004	0.0028	0.00025
Hens (Pullets)	0.16	0.013	0.011	0.0015	0.0008	0.00018
Turkeys (Broiler)						
Chicken (Broiler)	0.09	0.009	0.008	0.0033	0.0002	0.0001
Turkeys (Hatchery)	0.31	0.03	0.02	0.0046	0.00041	0.0004

Units = lb/day/animal

Table 2. Components Of Animal Manures Produced On Farms In The Lake Erie Watershed

	Numbers	Manure (lb/day)	BOD (lb/day)	SS (lb/day)	Nitrogen (lb/day)	P_2O_5 (lb/day)	Sodium (lb/day)
Bulls	6,200						
Cows (milk)	248,000						
Cows (beef)	85,000						
	339,200	30,528,000	491,840	661,440	111,936	44,096	10,176
Steers (beef)	230,000						
Heifers (milk)	73,300						
Heifers (beef)	87,300						
	390,600	19,530,000	644,490	976,500	62,496	39,060	3,906
Calves	178,400	4,460,000	64,224	92,768	14,272	5,352	1,484
Pigs (feeder)	1,588,000	15,830,000	603,440	539,920	95,280	63,520	9,528
Sows	198,500	2,779,000	81,385	35,730	12,307	8,337	1,588
Sheep (ewes)	34,000	408,000	10,880	7,140	1,700	1,020	68
Sheep (lambs)	31,100	248,800	6,842	3,421	933	622	31
Horses & Ponies	22,200	1,221,000	31,080	42,180	5,772	1,998	222
Total Animals		75,054,800	1,934,131	2,359,099	304,696	164,005	27,003

Table 3. Components Of Poultry Manures Produced On Farms In The Lake Erie Watershed

	Numbers	Manure (lb/day)	BOD (lb/day)	SS (lb/day)	Nitrogen (lb/day)	P_2O_5 (lb/day)	Sodium (lb/day)
Hens (layers)	3,965,331						
Chickens (Hatchery)	656,912						
Turkeys (Heavy)	1,819,366						
	6,441,609	1,996,899	161,040	83,741	27,055	18,036	1,610
Hens (Pullets)	2,960,000						
Turkeys (Broilers)	3,464,229						
	6,424,229	1,039,392	111,363	74,242	11,136	5,140	1,134
Chickens (Broilers)	33,016,660	2,971,449	297,150	264,133	10,895	6,603	3,302
Turkeys (Hatchery)	290,259	83,780	8,108	5,405	1,243	1,108	108
Total Poultry		6,091,570	577,661	427,521	50,521	30,387	6,154
Total Poultry & Animals (lbs/day)		81,146,370	2,511,842	2,786,620	355,025	194,892	33,157
(Tons/year)		14,809,212	458,411	508,558	64,792	35,567	6,051

Table 4. Components Of Animal Manures Produced On Farms In The Great Lakes Basin

	Numbers	Manure (lb/day)	BOD (lb/day)	SS (lb/day)	Nitrogen (lb/day)	P_2O_5 (lb/day)	Sodium (lb/day)
Bulls	24,400						
Cows (milk)	663,700						
Cows (beef)	327,000						
	1,019,100	91,809,000	1,479,145	1,939,195	336,613	132,611	30,603
Steers (beef)	609,300						
Heifers (milk)	189,700						
Heifers (beef)	269,900						
	1,068,900	53,445,000	1,763,685	2,191,245	171,024	106,890	10,689
Calves	578,000	14,450,000	203,080	300,560	46,240	17,340	5,780
Pigs (feeders)	3,039,200	30,392,000	1,154,896	1,033,328	182,352	121,563	18,235
Sows	379,500	5,313,000	155,595	68,310	23,529	15,938	3,036
Sheep (ewes)	118,600	1,423,200	37,952	24,906	5,930	3,558	237
Sheep (lambs)	105,400	843,200	23,183	11,594	3,162	2,108	105
Horses & Ponies	53,700	2,953,500	75,180	102,030	13,962	4,833	537
Total Animals		200,628,900	4,897,701	5,721,168	783,833	404,847	69,222

Table 5. Components Of Poultry Manures Produced On Farms In The Great Lakes Basin

	Numbers	Manure (lb/day)	BOD (lb/day)	SS (lb/day)	Nitrogen (lb/day)	P_2O_5 (lb/day)	Sodium (lb/day)
Hens (layers)	7,386,556						
Chickens (hatchery)	1,295,755						
Turkeys (heavy)	3,489,897						
	12,173,208	3,773,694	304,330	158,252	51,127	34,085	3,043
Hens (pullets)	5,356,000						
Turkeys (broilers)	4,716,199						
	10,072,199	1,611,552	171,227	101,794	13,094	8,058	1,812
Chickens (broilers)	63,447,476	5,710,273	571,027	507,580	20,933	12,689	6,344
Turkeys (hatchery)	299,966	92,989	9,000	6,000	1,380	1,230	120
Total Poultry		11,138,508	1,055,584	773,626	36,539	56,062	11,319
Total Poultry & Animals (lbs/day)		211,817,408	5,953,235	6,494,794	869,372	460,909	80,541
Tons/year		38,656,668	1,036,474	1,185,300	158,660	84,116	14,699

(B) SOURCES

Nitrogen may well be the most important of the potential pollutants in farm animal manures. It is present in extremely high concentrations and is readily carried by water. A convenient way to present the intensity of nitrogen production by manures on farms in Ontario is to establish a livestock distribution pattern for the Great Lakes Basin.

Table 6 shows the quantities of nitrogen and phosphorus excreted by different kinds of livestock and, since there is considerable variation in the production of manure between different species and ages of livestock, the concept of the "animal unit" has been developed. An animal unit will produce the amount of nitrogen normally sufficient to bring a one-acre crop of corn to maturity.

Table 7 gives the animal unit equivalent of the various classes of farm animals and poultry.

Tables 8 and 9 show the animal units in the Great Lakes Basin broken down by county. The Lake Erie Watershed (refer to Figure 1, section on Fertilizer Use and Pollution) because of its special significance, is given as a percentage for the total of the Basin in Table 9. Commercial farm acreage in these tables were obtained from the 1969 Farm Statistics for Ontario. The acreage concentrations of animal units shown in the final column of each table suggests that there is ample land available for the effective utilization of the manure being produced in the Great Lakes Basin.

The maps in Figure 1 and Figure 2 graphically illustrate the distribution of the livestock populations and their concentrations on an animal unit basis. The data for these figures were taken from Tables 8 and 9.

Table 6. The Nitrogen and Phosphorus Excreted by Different Kinds of Livestock

Kind of Livestock	N	P
	lb	lb
1000 chicken broilers (60 days) (0 to 4 lb)	155	31
100 laying hens (365 days)(5 lb)	125	44
10 feeder hogs (140 days) (30 to 200 lb)	115	29
2 beef steers (365 days) (400 to 1100 lb)	140	29
1 dairy cow (365 days) (1200 lb)	140	29

Table 7. Animal Unit Equivalents of Various Classes of Livestock

1 dairy cow	1 animal unit (365 days)
2 heifers (for milk purposes)	1 animal uiunit365 days)
4 calves (under one year)	1 animal unit (365 days)
1 beef cow	1 animal unit (365 days)
2 beef steers (400-1100 lb.)	1 animal unit (365 days)
2 beef heifers (400-1000 lb.)	1 animal unit (365 days)
1 bull	1 animal unit (365 days)
1 horse (includes ponies)	¾ animal unit (365 days)
4 sows	1 animal unit (365 days)
10 feeder hogs (30-200 lb.)	1 animal unit (140 days)
4 sheep (ewes and rains)	1 animal unit (365 days)
6 lambs (to 100 lb. market weight)	1 animal unit
100 hens (layers)	1 animal unit (365 days)
100 hens (breeders)	1 animal unit (365 days)
300 pullets	1 animal unit (160 days)
1000 chicken broilers (0-4 lb.)	1 animal unit (60 days)
300 turkeys (broilers)	1 animal unit (85 days)
100 turkeys (heavys)	1 animal unit (160 days)
75 turkeys (breeders)	1 animal unit (365 days)

Table 8. Livestock Populations (Animal Units) by Counties in the Great Lakes Watershed not including Lake Erie Watershed - Ontario

County or District	Poultry	Pigs	Dairy	Beef	Sheep	Horses	Animal Units Total	Commercial Farms (acreage)	Animal Units (per 100 acre)
Bruce	3,491	16,850	49,400	89,950	1,800	1,350	162,841	616,921	26.4
Dufferin	1,964	8,150	15,400	24,100	1,650	750	52,014	236,107	22.0
Grey	6,391	17,975	48,100	62,000	4,658	1,575	140,699	653,114	21.5
Halton	5,692	3,675	11,950	5,850	1,333	825	29,325	116,349	25.2
Huron	17,998	29,875	51,550	66,500	1,242	1,125	168,290	678,300	24.8
Peel	2,233	2,100	17,575	12,050	1,033	975	35,966	163,489	22.0
Perth	17,034	38,500	71,750	31,700	717	1,500	161,201	470,738	34.2
Simcoe	5,783	20,050	40,275	45,000	4,467	1,800	117,375	486,944	24.1
Durham	3,940	4,400	13,350	22,250	1,033	750	45,723	200,442	22.3
Haliburton	--	90	575	1,150	30	150	1,995	4,741	42.0
Hastings	3,934	5,375	30,275	12,400	975	975	53,984	318,984	16.9
Muskoka	300	210	2,525	1,050	170	215	4,470	28,484	15.7
Northumberland	4,740	5,500	26,300	15,000	703	900	53,158	274,793	19.3
Ontario	5,214	9,925	27,700	21,300	2,175	1,350	67,664	274,440	24.6
Parry Sound	---	315	4,825	5,050	333	450	10,973	77,365	14.2
Peterborough	1,547	2,050	15,950	15,150	742	825	36,264	181,742	20.0
Prince Edward	1,967	2,010	16,100	3,750	717	300	24,844	163,274	15.2
Victoria	1,734	4,225	12,400	32,800	2,400	750	54,309	290,913	18.7
York	8,583	11,900	20,300	12,500	1,450	3,225	57,958	226,174	25.6
Frontenac	553	1,050	21,625	11,200	742	825	35,995	189,601	19.0
Leeds	3,192	1,625	32,300	8,550	817	1,050	47,534	244,696	19.4
Lennox-Addington	2,014	2,225	19,750	8,950	592	675	34,206	200,023	17.1
Algoma	--	190	5,100	5,600	471	300	11,607	79,457	14.6
Manitoulin	1,608	1,125	4,075	12,100	2,258	225	21391	182,081	11.7
Rainy River	--	145	5,400	10,000	950	300	16,795	103,572	16.2
Sudbury	--	400	4,800	3,150	41	225	8,616	64,679	13.3
Thunder Bay	--	435	7,250	2,050	83	225	10,043	81,772	12.4

Table 9. Livestock Populations (Animal Units) by Counties in the Lake Erie Watershed - Ontario

County	Poultry	Pigs	Dairy	Beef	Sheep	horses	Animal Units Total	Commercial Farms (Acreage)	Animal Units (per 100 acres)
Brant	4,805	6,525	14,225	6,750	800	750	33,856	180,999	18.7
Elgin	5,431	10,800	13,700	21,850	1,117	1,350	59,248	359,922	16.5
Essex	3,967	5,575	11,500	4,300	125	525	25,992	319,384	8.1
Haldimand	5,923	6,900	32,250	8,150	1,250	750	46,283	209,260	22.1
Kent	5,539	17,525	5,350	24,320	792	675	55,201	527,041	10.5
Lambton	10,243	21,550	22,575	35,150	2,083	1,500	93,098	501,907	18.5
Lincoln	13,854	5,750	12,050	2,190	416	525	34,785	113,136	29.4
Middlesex	16,553	22,650	47,800	51,170	2,283	1,875	142,336	591,420	24.1
Norfolk	6,063	4,925	10,350	4,950	417	1,275	27,977	296,809	9.4
Oxford	13,763	24,150	57,750	21,200	775	1,125	118,763	397,201	29.9
Welland	6,719	2,425	9,650	1,970^{-}	400	525	21,639	79,483	27.3
Wentworth	8,752	7,075	17,300	5,900	375	825	40,227	133,653	30.1
Waterloo	12,103	33,350	31,100	13,350	375	2,625	99,508	240,446	41.4
Wellington	11,653	39,225	47,050	43,100	1,975	2,325	145,328	471,165	30.8
Erie Watershed (animal units)	126,033	208,425	329,150	250,350	13,683	16,650	944,291	4,426,826	21.3
Great Lakes Basin (animal units)	225,995	398,795	905,750	791,500	47,216	40,265	2,409,521	11,735,521	20.5
Erie as % of Great Lakes	56	52	36	32	29	41	39	38	

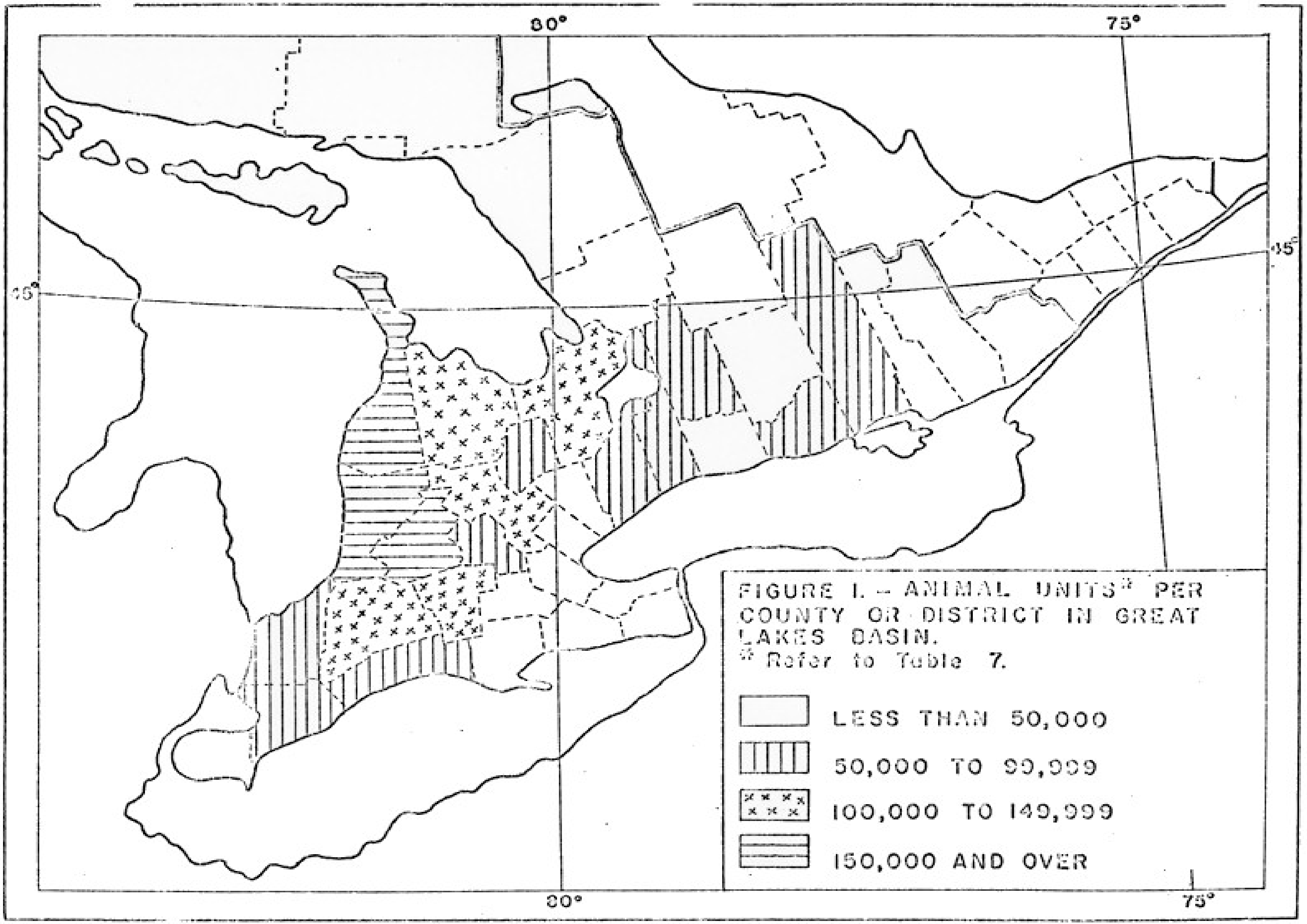

FIGURE I. – ANIMAL UNITS* PER COUNTY OR DISTRICT IN GREAT LAKES BASIN.
* Refer to Table 7.

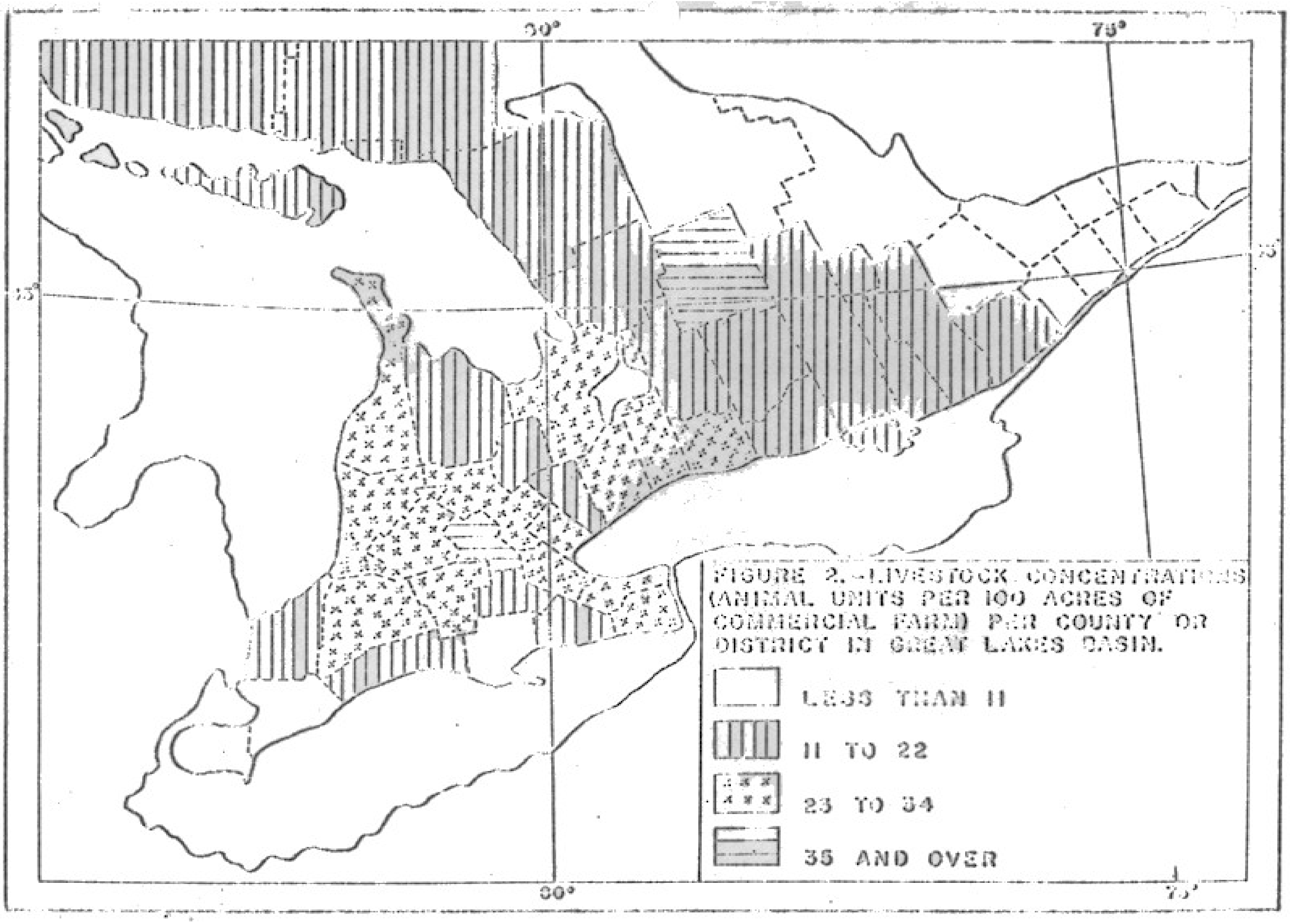

FIGURE 2.-LIVESTOCK CONCENTRATIONS (ANIMAL UNITS PER 100 ACRES OF COMMERCIAL FARM) PER COUNTY OR DISTRICT IN GREAT LAKES BASIN.

On the basis of the livestock populations in both the Lake Erie Watershed and the Great Lakes Basin, an estimate of nitrogen and phosphate production of manure is presented in the following table.

Table 10. Total Nitrogen And Phosphorus Production From Manures

	Lake Erie Watershed tons/year	Great Lakes Basin tons/year
Nitrogen (N)	64,792	158,660
Phosphate (P_2O_5)	35,567	84,116
Phosphorus (P)	15,649	35,911

Since many classes of livestock such as heifers, calves, beef cows, sheep and horses are on pasture for 6 months of each year, a considerable portion of the nitrogen and phosphorus produced from their manure would not be available for crop acres and, therefore, not replace commercial fertilizer.

It is estimated on the above basis that in the Erie Watershed and the Great Lakes Basin the following quantities of nitrogen and phosphorus are excreted annually on pastures and do not replace fertilizer applications on cropped land.

Table 11. Nitrogen And Phosphorus In Manures Deposited Directly On Pastures (Estimated)

	Lake Erie Watershed tons/year	Great Lakes Basin tons/year
Nitrogen (N)	7,012	22,512
Phosphate (P_2O_5)	3,295	10,568
Phosphorus (P)	1,450	4,659

The total nitrogen production from manure should be discounted at least 25% for losses during handling and storage of manure and again this amount would not replace commercial nitrogen fertilizers applied to cropped land. It cannot, of course, be argued that this nitrogen does not affect water quality since part of it may leach into the soil as nitrate.

Figures in Table 12 show the quantities of nitrogen and phosphorus produced in the Great Lakes Basin discounted as described above.

Table 12. Nitrogen And Phosphorus Production From Manures As Replacement For Commercial Fertilizer

	Lake Erie Watershed tons/year	Great Lakes Basin tons/year
Nitrogen (N)	43,335	102,111
Phosphate (P_2O_5)	32,272	73,528
Phosphorus (P)	14,199	32,352

(C) IMPACT

The massive potential of farm animal and poultry manures to pollute the waters of the Great Lakes Basin has been established in the preceding sections. Unlike most industrial and municipal wastes, however, farm manures are not normally discharged to receiving waters. The percentages of pollution materials which reach watercourses from livestock operations are dependent upon a great diversity of factors, hence it is very difficult to determine with any degree of reliance the amount of pollutant materials from manures reaching the Great Lakes Watershed.

The characteristics of farm animal manures having the potential for the greatest impact on the pollution of the Great Lakes Basin are outlined in the following sections.

Biochemical Oxygen Demand

The Biochemical Oxygen Demand, or BOD of a waste is a measure of the amount of oxygen required to biologically oxidize the material. Such oxidation processes occur naturally in receiving waters and if the organic pollution is excessive the natural oxygen content of the receiving stream may be depleted. Under such conditions aerobic stabilization is displaced by anaerobic processes with the resultant release of foul smelling gases and unsightly floating masses of decaying solids. Another result of conditions of depleted oxygen is the death of fish and other aerobic organisms trapped in that body of water. Both the aesthetic as well as the practical values of the watershed may thereby be seriously affected.

The BOD of farm manures is extremely high being in excess of 200 times that of domestic sewage therefore uncontrolled discharge of manures to a watercourse may have devastating effects.

Suspended Solids

Turbidity of a water body is a measure of the extent to which suspended matter inhibits the penetration of light because of particle scattering and absorption. Increases in turbidity result from suspended materials being carried into lakes and rivers through soil erosion, land runoff, water turbulence, plankton growth and the suspended solids content of waste effluents discharged to the water. Turbidity reduces the aesthetic quality of the water and endangers spawning beds where deposition and sedimentation occur.

The suspended solids content of farm manures is extremely high, reaching concentrations of 50,000 ppm or more, and direct discharge results in intolerable suspended solids levels in receiving water.

Nitrogen

The nitrogen component of animal wastes is voided largely as uric acid (birds) or as urea (mammals). Both these compounds are quickly decomposed by microorganisms in the manure with the result that ammonium salts accumulate. The ammonium ion is more or less rapidly converted to nitrate depending on availability of oxygen and the nitrate, being an anion, is free to move with any water which leaches through the accumulated waste since nitrate is not absorbed to clays and other reactive sites as is the ammonium ion. Water moving through manure may then be enriched with nitrogen even if it does not carry any of the carbonaceous or other components of the manure, and this nitrogen may find its way to ground water if conditions permit.

If manure is spread relatively thinly over soil, in quantities not greatly exceeding the requirements of plant production, most of the nitrate is removed by plants or lost from the soil by reduction of the nitrate to nitrogen gas. However, wherever manure is concentrated in direct contact with soil the possibility of leaching of nitrate to ground water must be considered as well as the possibility of direct surface transport of nitrogen, phosphorous and organic material to watercourses.

Excessive concentrations of nitrates in groundwater used for drinking purposes may be biologically converted to nitrites in the digestive system and can cause methemoglobinemia in both livestock and humans.

Nutrients

With the present emphasis on eutrophication, the nutrient contribution of farm manures to surface waters is now recognized. Although nitrogen and phosphorus are the principal elements involved, other nutrients are also important and farm animal manures contain virtually all of the macro-nutrients as well as the trace elements required to promote algal growth.

At low concentrations, these nutrients are essential in providing aquatic growths as food for fish. In excessive concentrations they permit an over-abundance of growth and algae blooms frequently develop causing serious aesthetic and economic considerations. When streams and lakes reach the "pea soup" stage of algae growth, the odour of decaying plants becomes extremely offensive, fish are killed because of the reduced oxygen content of the water and the water is reduced in its economic and aesthetic importance.

Because of their high concentrations of nitrogen and phosphorus, farm manures have frequently been blamed for localized extreme algae blooms in ponds, or small lakes where significant runoff has been allowed to enter such water bodies. The nutrient content of farm manures is therefore of great importance in the assessment of their water pollution potential.

Infectious Agents and Allergens

Agricultural losses caused by infectious agents of livestock, poultry, wildlife and man carried by water have been well documented. Some of the diseases so transmitted are salmonellosis, leptospirosis, hog cholera, foot-and-mouth disease, tuberculosis, brucellosis and anthrax. A number of these may infect humans.

Waters receiving direct discharges of farm manures must therefore be considered as hazardous to the health of farm animals and humans if used for drinking purposes. Farm wells may also become contaminated from the drainage from feed lots.

(D) CURRENT PRACTICE

An ideal system of animal waste management would incorporate the following concepts: the waste would be allowed to accumulate in a water-tight storage to prevent seepage. The storage would be large enough to hold an amount of waste sufficient to obviate the necessity of spreading it on land during winter (when ground is frozen and run-off in Spring can occur) or during wet periods (when leaching might result). The waste would be spread on land at seasons when crop uptake would be expected to be maximum and at rates not exceeding those necessary to achieve maximum crops. No animal wastes would be spread on slopes subject to run-off to watercourses.

While practices approaching the ideal are current on some farms in the Ontario Great Lakes basin, animal production units often fall short in some important aspects. Unfortunately, statistics are, for the most part, unavailable and, because of the very dynamic state of animal management concepts, it is difficult even to generalize. A description of some of the waste-handling practices in the study area is all that can be attempted.

I Storage of Manure

1. Housed Animals

(a) Solid wastes: Most of the chicken and turkey broilers in Southern Ontario; many laying flocks; many breeding swine herds and many dairy herds are housed with litter or bedding in such a way as to permit wastes to be handled as a solid. Similarly most beef cow-calf enterprises and some feeder pig operations are on solid waste handling. In some of these latter establishments some liquids may be drained away from the solids and collected in a tank. In all cases, the solids are moved outside the building periodically and may be stored, often on the bare ground but sometimes on a concrete slab, for some period before being spread on land. There are no regulations presently in Ontario regarding storage of solid animal wastes although such storage areas must be deemed potential sources of nutrient enrichment of both surface and groundwater.

So far as the authors are aware, few establishments follow the practice of storing manure on an impervious slab from which fluids can be drained for storage in an approved way. Nor are manure piles covered to prevent the leaching action of rain. In certain areas where broilers are reared in high density conditions on many small farms, manure has been moved by a contractor to a storage area and piled on bare ground in very large quantities for periods of a year or more.

(b) Liquid Wastes: There is a growing trend in Ontario, among egg producers and pig feeders particularly as well as among dairy producers to manage manure in a liquid or slurry form. While this system has disadvantages in that odour problems are likely to be enhanced there is generally considered to be an economic advantage over solid handling. Early attempts at liquid handling involved the use of lagoons but these were so often undersized, subject to overflow and odour problems that their use has largely been abandoned. Current practice usually involves storage of the liquid or slurry in concrete tanks, often below grade. Provided these are of durable construction they satisfactorily prevent contamination of ground water.

No regulations govern the size or construction design of manure storage tanks in Ontario, however, where new facilities are being constructed an approval should be obtained from the Air Management Branch of the Dept. of Energy and Resources Management. The Code of Practice followed by the A.M.B. requires that the storage provides capacity for 6 months accumulation of manure.

2. Feed Lots

As elsewhere in North America there is a trend in Ontario to produce beef cattle under confined conditions with minimum shelter. Typically, cattle are held in a yard on a concrete floor (or on a partially paved surface) with access to a partially open shelter. No bedding is used and manure is removed periodically and is usually spread on land immediately. In some cases a larger feeding area is used and no floor is provided. The manure solids may accumulate over long periods. At least one operation in the Ontario Great Lakes basin has been constructed on a zero-housing basis. On this farm 1000 steers are confined on a one-acre un-roofed concrete slab, manure is removed daily and stored as a thin slurry in a concrete tank.

In general, feed lots are potential sources of surface water pollution since there is only rarely any effort made to collect water which runs off the holding area. Much of this water may percolate into the soil as does contaminated water leaching through unpaved feeding areas and it poses the same threat to ground water purity as was described above. The location of the feed lot in relation to water courses as well as the characteristics of the soil are important considerations in evaluating the impact on the environment of these establishments.

So far as we are aware, there are no specific regulations applying to the location or manure handling practices of feed lots other than the general regulations of O.W.R.C. in regard to surface water quality.

II Land Disposal/Utilization of Animal Wastes

All animal manure produced in the Ontario Great Lakes Basin should be returned to the land. Ideally, as pointed out earlier in this report, manure would be spread in such a way that the nutrients it contains would be utilized in crop production and no run-off would occur. Because this requires careful timing of manure applications as well as some knowledge of the nutrient content of the manure, the ideal is not easily achieved. In our opinion the practices which have the greatest potential adverse impact on water quality are those of winter spreading of manure; storing or accumulating manure uncovered on the ground; spreading manure at very high application rates, and permitting run-off from feeding areas. Each of these practices is common in the study area and none of them are specifically regulated.

The Air Management Branch Code of Practice calls for sufficient land to be available for complete utilization of the manure produced on each farm receiving a permit, however, the rate and timing of manure application are not regulated.

In connection with land disposal of animal wastes, one particular practice may be singled out for special criticism since, while it is relatively rare, it seems to us to be particularly inadequate. We refer to the use of septic tank systems for disposal of veal calf wastes and milking parlour wastes. This kind of installation has the effect of concentrating large quantities of nitrogen in a very small area. For example, a veal calf unit. of 200 capacity puts out about 6-8 lbs. of nitrogen per day or 1-1.5 tons per year which when distributed in a weeping tile bed covering 4500 sq. ft. is equivalent to a rate of nitrogen application of 10-15 tons per acre. Wastes from milk houses also contain large quantities of manure and urine as well as milk solids and are often handled in septic tank-weeping tile systems.

Septic tank installations in the Province are regulated by local Public Health authorities who may not always be aware of problems associated with nutrient enrichment of water.

III Treatment of Manure Prior to Disposal/Utilization

It seems generally to be recognized in Ontario that there is little possibility for the complete treatment of animal waste to permit liquid fractions to go directly to receiving waters. Treatments of manure have therefore been designed to render the waste less odorous during storage or to improve the efficiency of handling for ultimate land disposal/utilization.

An exception to this general rule may be the use of lagoons for the treatment of water containing relatively small quantities of manure and other waste solids. Some specialized animal production facilities (e.g. duck farms) where large quantities of water are required, may separate solids from the liquid (settling or mechanical means) and then aerate the liquid by mechanical devices or in aerobic lagoons to produce acceptable effluents. This procedure may have application to wastes from milk houses but is certainly not yet widely applied.

Aeration of liquid manure during storage not only helps to control odour but has the potential for reducing the quantity of nitrogen in the stored manure and therefore reducing the potential impact of the manure on water quality when the waste is spread on land. While aerators have not been widely installed there is a growing interest and a number of mechanical devices are in service on farms in the Great Lakes Basin.

Manure drying and composting and re-cycling by feeding to other animals are other forms of treatment which so far have not been widely exploited and which are likely to have a relatively small role in manure management in the study area over the next ten years.

Summary of Current Practices and Ontario Agencies with Advisory, Regulating and Research Interests in Animal Wastes

1. There are no processes which will satisfactorily treat manure for disposal directly to surface water. Manure in the Ontario Great Lakes Basin in disposed of or utilized by returning it to the land.

2. The major inadequacies (in terms of water quality) of current practice are:

    (a) the potential for run-off or percolation from carelessly piled solid manure,
    (b) the practice of spreading manure at rates greatly exceeding the ability of vegetation to remove the nutrients contained in the manure.
    (c) the practice of spreading manure at inappropriate times of the year,
    (d) the practice of permitting run-off and percolation of water from feed lots.

(e) the inadequate retention and treatment of largely fluid wastes (as from milk houses) containing some manure solids.

3. Advisory, regulatory and research organizations with an interest in the handling of animal manures in the Ontario Great Lakes Basin are:

- Ontario Department of Agriculture and Food – advisory through its extension service, particularly the Agricultural Engineering Service.

- Air Management Branch, Ontario Department of Energy and Resources Management - chiefly concerned with odour and other air quality problems arising from manure management practice. A 'Suggested Code of Practice' is in operation which deals with the establishment of new livestock buildings, renovation or expansion of existing buildings and disposal of animal wastes.

- Ontario Water Resources Commission. Ontario Department of Energy and Resources Management - through its general responsibility for water quality in the Province is interested in manure management practice and its impact on water quality.

- Ontario Department of Public Health - has powers through the Public Health Act (revised 1967) to regulate waste disposal and public health nuisances which have not been widely applied to animal manure management practices.

- Ontario Committee on Utilization of Animal Wastes - a committee made up of personnel from all agencies above as well as the Universities of Guelph and Toronto which helps to coordinate research on animal wastes in the Province.

- Ontario Advisor Committee on Pollution Control - an inter-departmental committee of senior administrators to the Ontario Cabinet.

V. Problems of Management and Land Use Activities for Non-Agricultural Land (Various Government Levels)

(A) Pesticide, Fertilizer Use in Parks, Highways and Other Lands

The total area of Ontario is 264 million acres, comprising 220 million acres of land and 44 million acres of water. About 25 percent or 55 million acres of this land area drains into the four Great Lakes bordering Ontario (the Ottawa River drainage is excluded). Of the 55 million acres of land, 39 million acres are forest, which includes almost all of the parkland, and a maximum of one million acres are devoted to rights-of-way. Therefore the land management matters under study involve some 40 million acres. Specifically, the following substances might be regarded as having a potential to pollute the waters of the Great Lakes. Each is assessed as to its probable actual contribution to pollution.

1. PESTICIDES

(a) Insecticides: In protecting the forests within the Great Lakes drainage, including the parks, the current average acreage sprayed each year is about 15,000. This is 0.04% of the forested area. DDT has not been used since the 1967 field season, and the short-lived insecticides now being used to control defoliating insects are chosen carefully for minimum hazard to the environment.

In addition to the foregoing protection of trees, there is a small use of approved, safe, quick-breakdown insecticides to combat biting flies around camp-grounds in some recreational areas.Insecticides are not used in the management of rights-of-way.

Monitoring and other field studies permit the conclusion that current programs using insecticides do not result in significant detrimental effects on the enviroment, not only in the Great Lakes, but at the point of application.

(b) Fungicides: There is no field use of fungicides in forest management in Ontario.

(c) Herbicides: Within the Great Lakes drainage, the following is the estimated annual use of herbicides by land management agencies.With the exception of the herbicide "Tordon", the use of which is increasing in the maintenance of rights-of-way, the herbicides in general use (2,4 -D and 2.4,5-T) are relatively short-lived (usually between 1 and 2 months) and are held by the organic material in the soil. The possibilities for contaminating waterways are therefore minimal.

MAP OF THE
PROVINCE OF ONTARIO

Forestry	-15,000 acres @ 1.5 lbs. acid per acre
Parks	-none
Rights-of-Way	-none
Roads	-115,000 acres @ 2.0 lbs. acid per acre
Power-Lines	- 32,000 acres @ 2.8 lbs. acid per acre
Others	- 13,000 acres @ 2.0 lbs. acid per acre
Total	-175,000 acres @ about 2 lbs. acid per acre
	This is 0.4% of 40 million acres.

The relatively small scale of herbicide work in Ontario, and the remote possibility of significant amounts of herbicide reaching the Great Lakes, would indicate a very low potential for affecting water quality.

2. FERTILIZERS

The use of fertilizer is not yet a significant factor. Some small-scale experiments are underway in forestry in which nitrogen is applied by aircraft at a rate of 100 lbs. per acre. These total about 500 acres in the Great Lakes drainage.

3. EROSION FROM FORESTRY SOURCES

Within the Great Lakes drainage, logging to various intensities occurs on about 185,000 acres annually. Although it is conceivable that logging may cause some erosion, particularly in hilly areas, we are not aware of a measurable problem. With very few exceptions, streams and rivers in forested areas are relatively free of suspended particles of soil. Current improvements in forest practices, especially the rapid decline of river driving and the increasing attention to the development of protection forests, will virtually eliminate any future potential for erosion.

(B) Land Erosion: A discussion of erosion from agricultural and forestry sources was covered earlier in this report and this section therefore will not deal with those aspects in particular.

Erosion, from a biological viewpoint, has various effects depending on the type of material entering the body of water. A shifting sand bottom is sterile and of no use to aquatic organisms. Clay particles may be in suspension and reduce fish popultions.If they coagulate and drop to the bottom they may cover aquatic organisms, also reducing fish populations. The suspended colloidal clay along the inshore waters of Lake Ontario is considered to be one of the major factors contributing to the disappearance of the landlocked salmon population about 1890.

On the other hand, clean gravel supplies spawning beds for trout and other fish. Although a stream-bed which is partly mud usually has a good fish population, bank erosion by itself usually provides little nutrients to the stream.

In general, erosion probably does more harm than good to the ecology of a water system.

Erosion and resultant sedimentation within the Great Lakes Basin may be divided generally in two areas (a) stream, and (b) lake.

(a) Stream Erosion and Sedimentation: Sediment deposited and carried in a stream may come from two sources: land surface erosion and stream-bank and bed erosion.

  (i) Land Surface Erosion: Contributors to this source of erosion in Ontario are: agricultural lands; developing urban and industrial lands; municipal works projects including roads, bridges, sewers, watermains, dams, etc., and mining and forestry activities.

  (ii) Stream-Bank and Bed Erosion: All streams in Ontario experience stream erosion to some degree as a natural phenomena. In some areas this natural process of erosion has been aggravated by such things as: cattle and other animals grazing on river banks; boating; indiscriminate dumping of fill and diversion of the natural stream course; poorly designed bridges and logging operations; and increased run-off volumes from urbanization.

(b) Lake Shore Erosion and Sedimentation: Sediments accumulate in lakes from three sources:

1) stream discharge,
2) bluff erosion, and
3) submarine erosion.

The relative contribution from each of these varies throughout the entire length of the shoreline of the Great Lakes and depends on the composition and topography of the shoreline, lake bottom and adjacent drainage areas; on the current patterns in each area; and on the hydrology, land use and stream characteristics of the contributory drainage basins. Little is known about the effects of the sediment load in specific areas but, in general, as mentioned previously, a high sediment load has an undesirable effect on the ecology of the water body.

The exact extent of the erosion problem in Ontario has not been determined but one need not search far to observe some of the detrimental effects that it has had on stream life, water use, and land use.The Water Survey of Canada is attempting to quantify the extent of the erosion problem by measuring both sediment load in streams and the rate of deposition in reservoirs.This program is being carried out with the co-operation and assistance of the Department of Energy and Resources Management and the local Conservation Authorities. In the meantime, attempts are being made through education, grants for erosion control works, and legislative means to encourage the use of erosion control works.

Existing Legislation Affecting Erosion Control: Several pieces of Provincial legislation deal either directly or indirectly with erosion control on land surfaces, stream-banks and lake shores. The most powerful Acts, although not necessarily the most widely used, in this regard are as follows:

(i) The Ontario Water Resources Commission Act: Under Section 27 (1) of this Act (see Appendix 'A') the OWRC has virtual control of all land use and land development in the Province. This power, as regards erosion control, has seldom, if ever, been used.

(ii) The Planning Act: This Act provides that all proposed development of official plans, zoning by-laws, etc., be approved by the Minister of Municipal Affairs. In order to implement this Act, the Department of Municipal Affairs circulates each proposal to the appropriate Provincial and local agencies for comment and recommendations. Development conditions are then set by the Minister of Municipal Affairs. This process is gaining increasing importance as a tool in erosion control management.

(iii) The Conservation Authorities Act (1968)
Under this Act, local Conservation Authorities may control the dumping of fill in designated areas and prohibit construction in the floodplain.This control has proved extremely successful in some areas but it is limited to those areas which are within a Conservation Authority and it is also dependent on the willingness and financial capability of the local Authority to administer these regulations.

(C) Management Practices: Erosion and sediment control are two aspects of water resources management that have received too little attention in Ontario. With increasing urbanization and industrialization greater demands are being placed on the land by public and private interests. In order to prevent further land and water deterioration a program for erosion and sediment control is needed.

The key to successful erosion and sediment control is wise land management. Land cover is the major deterrent to sediment production. Much technical progress has been made in recent years so that control techniques are now well-developed.The major problem that still remains is the establishment of an administrative framework for regulating and controlling sediment.

Some planning authorities in the United States already are requiring that builders adhere to specific regulations in developing an area for construction. For example, some agencies insist that subdivision planning be based on a scientific soil approved prior to construction.

Sediment traps and debris basins are being required and used by contractors in some areas to reduce the flow of sediment from land during construction. Keeping protective cover on construction sites as long as possible, and restoring cover quickly after construction are also recommended steps to keep sediment yields to a minimum.

As discussed under Section 11(b) some administrative control is being exercised under the Planning Act and the Conservation Authorities Act.

Sediment Control Measures

Techniques of sediment control have been well established for many years especially in rural areas where such methods as land treatment (grass waterways, contour ploughing, etc.) and slope stabilization are used to prevent erosion and sedimentation. However, the application of these methods to urban areas where sediment is becoming an increasing problem requires modifications and/or new control techniques.

The technical principles of an erosion and sediment control program that can be universally applied involve (1) reducing the area and duration of exposure of soils, (2) covering the soils with vegetation, (3) mechanically retarding the rate of runoff water, and (4) trapping the sediment in the runoff water.

Stabilization of land undergoing development is often essential during the construction stage due to the long time periods which are sometimes involved between the time when a tract is levelled and graded prior to construction and the time when development is complete. The costs of sediment control on lands being developed for subdivision have been estimated by the Soil Conservation Service in the United States at approximately one-third of one per cent of each lot's value for a new satellite city development of 16,000 acres in Maryland. If the developer were made responsible for implementing sediment control measures, it is obvious that the total cost would be only a very small proportion of his profits.

At present there is little or no control over land developers who are often finished with a project before the effects of inadequate sediment control are noticed. Local municipalities either do not enforce sediment control or only require that the developer provide adequate drainage and carry out such tasks as flushing sewers of sediment accumulated during construction. Little attention is given to the potential effects on downstream users of inadequate sediment control. Of course, it should be recognized that is is often difficult to pinpoint the source of sediment that has accumulated downstream, and for this reason the courts have sometimes refused to consider damage claims. It is apparent then that sediment control in urban areas can best be achieved by cooperation in the planning stages of all concerned including the local Conservation Authority, municipality and land developer.

TECHNICAL CONTROL

A. Structural Measures

The major structural elements in a sediment control program are as follows:

a) reservoirs,
b) channel improvement and stabilization works,
c) debris and sedimentation basins, and
d) other structural measures.

Many of these are, of course, multi-purpose in nature with the most important use being water control and/or storage. However, their usefulness as sediment control structures should not be overlooked at the planning stage.

a) Reservoirs: Reservoirs provide barriers to the transport of sediment that originates in upstream areas. Multi-purpose reservoirs generally have storage capacity allocated for such things as floodwater detention, municipal water supply, irrigation water and recreation. Additional capacity should also be allocated to sediment storage.

b) Channel Improvement and Stabilization Works: Stream channel improvement and stabilization projects are constructed to increase the capacity of the channel and to retard the bank erosion process. In some areas bank erosion is a major contributor to downstream sedimentation so that the use of gabion baskets, concrete lining materials, and other channel stabilization works is a major factor in sediment reduction. Care should be taken in design to tailor the components to watershed conditions since increased velocities associated with channel improvement projects may promote further degradation and erosion downstream.

c) Debris Basins: A debris basin is a reservoir designed specifically to trap sediment. These can be used, where site conditions and topography allow, on large construction sites as temporary control measures. After the critical, "erosion-prone" period of development they can be removed or graded and landscaped.

B. Non-Structural Measures

Non-structural measures for sediment control imply some form of land treatment. In areas where the primary source of sediment is sheet or land erosion, land treatment measures have a significant effect on reducing sedimentation damages. Before any land treatment practices are attempted sediment control measures should be designed in light of the existing or proposed land use.

The major non-structural elements in a sediment control program are as follows:

a) vegetative treatment,
b) protection of existing vegetative cover, and
c) mechanical practices.

a) Vegetative Treatment: The establishment of vegetative cover on land subject to erosion may include the planting of grass, sodding and tree planting.Generally, these treatment methods reduce erosion and sedimentation in the following manner. The plant materials intercept rainfall and reduce the effect of raindrop impact. Infiltration is increased and the rate of surface runoff reduced. The plants help to bind the soil into an erosion-resistant mass and the roughness of the ground surface is increased, reducing the velocity of overland flow and thereby its capacity to erode and transport sediment.

b) Protection of Existing Vegetative Cover: The control of erosion and sediment yield on forest, brush and grassland can be achieved by measures to protect the existing cover.Conventional fire protection techniques as practiced by the Department of Lands and Forests, and land use controls such as the prevention of grazing on critical sediment-producing areas are two common methods used to protect existing land cover.

c) Mechanical Practices: Mechanical practices refer to such techniques as terracing, grassed waterways, ditches and grade stabilization structures.

Administrative Control

The key to the implementation of successful sediment control program is the co-operation and co-ordination of the efforts of all concerned.This must involve the assistance of any or all of the following organizations:

Ontario Department of Energy & Resources Management, Conservation Authorities Branch, Local Conservation Authorities, Local Municipalities, Canada Department of Energy, Mines & Resources Water Survey of Canada, Sediment Surveys Section.

In addition, the co-operation of the provincial departmens of Municipal Affairs, Highways, Agriculture, Lands and Forests and the Ontario Water Resources Commission may be required depending on the circumstances of the particular sedimentation problem.

Legislation specifically designed to control erosion and sedimentation is being considered in the Provincial Government and it will hopefully provide for a workable administrative framework for the successful control of management practices.

VI CURRENT PLANNING ADVISORY AND REGULATORY STANDARDS

(a) Water Quality Standards

The guidelines for the control of water quality in the tributary basins as well as near-shore waters of the Great Lakes contained in the Guidelines and Criteria for Water Quality Management in Ontario (Ontario Water Resources Commission, 1970) set out the procedure for the establishment of water quality standards in Ontario waters. The criteria for water quality are the scientific requirements for the preservation of aquatic life and wildlife and the use of water for a variety of needs including water supplies for agricultural purposes. The criteria for each use category, if met, would ensure that the water is suitable for that use.

The OWRC uses these criteria when it establishes water quality standards for drainage basins or parts thereof, following consultation with agencies or persons having an interest or responsibility in the present or future use of the water in the basin for which the standards are to be established. The set of standards established depends on the existing and probable future uses of the resources of the basin. The requirements for waste effluents and land drainage are based on these standards or criteria where such standards do not exist.

1. POINT SOURCES vs NON-POINT SOURCES

Major types of pollutants - nutrients (nitrogen and phosphorus), solids, pesticides, oxygen demanding organics.

Livestock enterprises accumulate large quantities of wastes which are utilized mainly as land fertilizer. Agricultural operations may give rise to non-point sources of pollution as a result of nutrient losses from eroded lands or lands fertilized with animal wastes or commercial fertilizers and pesticide residues.

Nitrogen may leach to groundwater which usually resurface eventually and be carried with the surface drainage. Nitrogen, phosphorus and oxygen consuming organic wastes may be carried in surface drainage, where animal wastes have been washed or carried with soil eroded from the land surface and particularly if applied to frozen soil in advance of a spring melt. The timing and rate of application of fertilizers are important factors in considering the polluting potential of these materials. Odour problems may also be associated with the application of animal wastes.

Animal wastes and commercial fertilizers have been cited as contributing to the nutrient enrichment of the lower Great Lakes drainage system. It has been estimated by Miller (1970) (1) that less than 2.5 percent of the phosphorus reaching Lake Ontario and Lake Erie can be attributed to fertilizer use. This estimate gives an indication of the average phosphorus drainage of the lower Great Lakes. The contribution of nutrients form each tributary can be expected to vary significantly depending upon local land use patterns. Terry and Salbach (1970) (2) have shown that considerable nutrient enrichment occurred in rural land drainage from the Duffin Creek (Lake Ontario) and Catfish Creek (Lake Erie) basins. About 95 percent of the total nitrogen load and over 75 percent of the total phosphorus load carried by Catfish Creek was attributed to sources other than municipal sewage and industrial wastes.

Other sources of phosphorus include municipal sewage, detergents and industrial wastes, which altogether, contribute to the accelerated eutrophication of the lower Great Lakes. Aside from replacement of phosphorus in detergents and control of nutrients in effluents from sewage treatment plants, efforts to reduce the pressure of loadings of nutrients on the Great Lakes System should include improved animal husbandry and land management practices.

The use of organic and inorganic compounds as pesticides has been expanding rapidly. With their use, problems of contamination of air, water and soil have occurred. Pesticides are spread either as aerial sprays or by direct land application with spray tanks or other means. Pollution of water by pesticides usually can be attributed to careless handling and disposal of spray tank residues and containers or drifting sprays.

2. IMPACT ON AGRICULTURE

It can be generally said that the installation of facilities for the treatment of animal wastes designed to produce an effluent suitable for discharge to a watercourse is not within the economic realm of an agricultural operation. Treatment methods presently employed have as a primary objective, the maintenance of acceptable environmental conditions during the storage period until the wastes can be spread on land. It is generally recommended that storage facilities with a retention capacity of six months be provided.

The desirable practice is to promote the establishment of confined livestock enterprises only if sufficient, land is available to spread these wastes. Field spreading of manure, properly applied, should provide a satisfactory solution to the handling and final disposal of animal wastes, while adding necessary plant nutrients to the soil. Thus, manure disposal, in many cases, may become the economic factor limiting the size and/or location of a livestock enterprise. The objective for a producer who promotes a new enterprise must be disposal of wastes, at least cost, doing so with the approval of the regulatory agencies concerned with air, water and soil management.

Most waste treatment methods presently in operation utilize biological processes, including anaerobic digestion, lagoon treatment and aerobic systems. The oxidation ditch is receiving wide-spread attention as a reasonably suitable waste treatment system. Nevertheless, these treatment methods are not used for, or are they capable of producing effluents suitable for discharge to a watercourse. They are effective in preventing nuisance conditions or health hazards during storage for eventual disposal to land. Research is being carried out by the Ontario Department of Agriculture and Food, University of Guelph and others on improving treatment methods for the disposal of wastes from farm animals.

CHLORIDE POLLUTION AND IMPACT ON AGRICULTURE

There has been a steady rise in the concentration of chlorides in the lower Great Lakes (Summary Report to IJC) since the turn of the century. Long-term monitoring studies reveal that the chloride content of Lake Ontario & Lake Erie started to rise noticeably about the year 1900 and has risen at a fairly uniform rate since 1915. Contributing to this rise have been industrial wastes, increasing urbanization and related population concentrations and in recent years, the increased use of salt for de-icing municipal roads and highways.

The desirable criteria for chloride in water used in the irrigation of crops is recommended to be less than 70 gm/L with a special requirement for tobacco of less than 20 mg/L (OWRC Guidelines and Criteria for Water Quality Management in Ontario). The lower Great Lakes are already approaching concentrations of chlorides that limit the usefulness of these waters for certain types of irrigation. The tributary streams exhibit large seasonal fluctuations in chlorides with higher levels occurring both during the winter and summer months. In winter, road salting is largely responsible while during the irrigation period in summer, low streamflows provide reduced dilution of materials carried in the streams.

A rough estimate of the amount of road salt used on all roads within the Great Lakes drainage is 500,000 tons annually. This is applied in varying amounts to about 30,000 miles of road. However, probably 80% of this total would be used on roads immediately adjacent to Lake Ontario and Lake Erie.

Until more is known about the role of chloride in a fresh water system, prudence would indicate that use of road salt should be held to the minimum which will ensure adequate travel safety.

The Ontario Department of Highways is presently studying the use of dome structures to cover salt and sand stockpiles as a means of reducing pollution of ground and surface waters as well as improving winter operations. The results available to date are very promising.

It is doubtful if much can be done about the input of chlorides from municipal waste sources as technology has not been developed in this field. However, industrial sources of chlorides probably are more amenable to control. Present day efforts in pollution control have been directed to reduce the discharge of excessive coliform organisms, BOD, suspended solids, phenols, nutrients, toxic elements, etc. Increasing attention should be given to the control of chlorides from waste effluents.

(b) Control Measures (Affecting Watershed Management) Federal or Provincial Legislation - Standards or Guidelines

The guidelines and legislation which apply to the control of pollution of the environment from agriculture include the following:

1. Suggested Code of Practice - Ontario Department of Energy and Resources Management & Ontario Department of Agriculture & Food.

2. The Ontario Water Resources Commission Act - Ontario Department of Energy and Resources Management

3. Pesticides Act - Ontario Department of Health

With respect to agricultural buildings there is in existence a "Suggested Code of Practice". The code was produced by the Ontario Department of Agriculture and Food and the Ontario Department of Energy and Resources Management with assistance from the Ontario Water Resources Commission. The code deals with the establishment of new livestock buildings, renovation or expansion of existing buildings and disposal of animal wastes, and provides guidelines for the control of pollution from confined livestock operations. It suggests the acreage required for disposal of manure, makes recommendations on storage of liquid wastes and provides guidance for practices that minimize air pollution. The latter is done in cooperation with the Air Management Branch.

Section 27 (1) of the OWRC Act, prohibits the discharge of any material to a watercourse that may impair water quality. The section could clearly apply to the discharge of wastes from confined livestock operations, the application of fertilizer and subsequent runoff and the use of pesticides as any of these uses may cause water pollution. Section 50 (1) requires satisfactory enterprises. It is considered that this section should also apply to intensive livestock operations when impairment of water quality may result.

Under Section 47 (1) (G), the Commission may prescribe standards of quality for sewage, industrial waste effluents receiving streams and watercourses.

Under Section 28 (2), no person shall take more than 10,000 gallons per day of water without a permit issued by the Commission. The control of water taking minimizes conflicts of water use through depletion of streamflow.

Through the Pesticides Act, the use of pesticides is regulated by issuing exterminator licenses. The Ontario Department of Health provides short courses, and rigid examinations for licensees and every license is reviewed each year by the Department.

The Ontario Department of Agriculture and Food also provides a spray calendar which recommends policies for the application of pesticides to field crops, fruit and vegetable productions and for insect and disease control. The recommendations contained in this calendar are reviewed annually by the Ontario Crop Production Committee. The recommended chemicals (pesticides) include only those registered with the Canada Department of Agriculture under the Pest Control Products Act.

Considerations in Conclusion

Are codes of practice for land disposal of animal wastes and the use of fertilizers on land sufficient measures for the control of pollution or are more specific controls required? While requirements will be developed for the discharges of point sources of municipal and industrial wastes, at very least there appears to be a need for a clear set of guidelines or a code of practice in managing land to curb erosion and to control pollution through losses of nutrients from the use of agricultural chemicals.

Appendix 'A'

Section 27(1)
Ontario Water Resources Commission Act

Discharge of polluting material prohibited.

27.- (1) Every municipality or person that discharges or deposits or causes or permits the discharge or deposit of any material of any kind into or in any well, lake, river, pond, spring, stream, reservoir or other water or watercourse or on any shore or bank thereof or into or in any place that may impair the quality of the water of any well, lake, river, pond, spring, stream, reservoir or other water or water course is guilty of an offence and on summary conviction is liable to a fine of not more than $1,000 or to imprisonment for a term of not more than one year, or to both. 1961-62, c.99, s.5.

APPENDIX “B”
Working Group on Great Lakes Pollution, Canadian Sub-Group No. 9
Pollution from Agricultural, Forestry and Conservation Sources

Report Summary

With the increasing trend towards intensification of agricultural practices, and the transfer of land from rural to urban use, agriculture and related land use sources have been sighted today as having a greater potential for contaminating our environment than at earlier times. It was with this recognition that the Joint Working Group on Great Lakes Pollution established Sub-Group No. 9 to deal with pollution of the Great Lakes from Agriculture, Forestry and Conservation sources (excluding processing).

Sub-Group No. 9, had as its terms of reference, an examination of land use sources of pollution of the Great Lakes System in order to identify the severity of pollution arising therefrom.

Together with other objectives, the sub-group was to assess pollution problems arising from the release and runoff of nutrients and other substances resulting from the application of fertilizers, pesticides and herbicides and manure applications from poultry and livestock operations including feedlots.

The Sub-Group was also to assess the adequacy of current land use practices with particular reference to soil erosion and to assess current planning, advisory, and regulatory standards with reference to Agriculture, Forestry and Conservation.

The following represents a summary of some of the deliberations of the Sub-Group.

Fertilizer

Nitrogen (N) and phosphorus (P) are the two ingredients of fertilizer that are of most concern from a water pollution standpoint. Nitrogen is of concern since it is essential in water for growth of most algae and other water plants and because of the threat to the health of infants and ruminant animals from high levels of nitrate nitrogen.

Phosphorus is of concern as a pollutant primarily because it is generally accepted that high levels of phosphorus in waters are a major contributing factor to excessive algae growth.

Agricultural practices do contribute nitrates to the groundwater but the extent of the contribution is difficult to measure. It is, however, apparent that the contribution will increase sharply if nitrogen is applied at rates above those necessary for most profitable yield levels.

A nitrogen balance sheet for cropped land in the Ontario sections of the Erie and Great Lakes watersheds indicates that the addition from commercial fertilizer, animal wastes and natural sources exceeds that removed by approximately 30 lbs. of N per acre under crops.

If all of this nitrogen reached ground or surface water it would be a serious threat to the environment. It is known, however, that a significant part of this will be denitrified and released harmlessly to the atmosphere while another portion will be immobilized in the soil through an increase in organic matter content. A serious gap in our understanding of the nitrogen cycle is that we cannot say what proportion is going into each of these processes. Until we can estimate this with some degree of assurance we will not be able to accurately estimate the contribution of nitrogen from our crop land to our water supplies.

We also need to increase our ability to determine the amount of fertilizer nitrogen required on a given field for most profitable yields. This is necessary to permit continued efficient food production without causing unnecessary contributions of nitrate to groundwaters.

Phosphorus is used in much smaller quantities although it is just as essential. A balance sheet developed for phosphorus in the Ontario portion of the Erie and Great Lakes Watersheds shows that the addition of phosphorus from commercial fertilizer and animal wastes exceeds that removed by about 37 lbs. P_2O_5 per acre under crops in the Erie Watershed and by 27 lbs. P_2O_5 per acre in the total Great Lakes Watershed. The balance sheet is less complex than that for nitrogen because there are no natural processes adding phosphorus to the soil.

Although it is impossible at this time to accurately estimate the proportion of phosphorus reaching the Lakes that comes from fertilizer applications, it is fairly safe to say that approximately 12 per cent of phosphorus in land drainage can be traced to fertilizer use (less than 50% of the phosphorus in land drainage comes from fields; less than 25% of the phosphorus from farm fields comes from fertilizer: 50% x 25 = 12.5%). Using the IJC estimate that land drainage accounts for about 20 per cent of the phosphorus added to Lake Erie, Lake Ontario and International Section, of the St. Lawrence River, only 2½ per cent of phosphorus reaching Lake Erie and Lake Ontario can be attributed to fertilizer use (12.5% of 20% = 2.5%).

The amount of phosphorus applied as fertilizer and animal waste in the Great Lakes Watershed exceeds that removed in crops. The excess application of phosphorus is acceptable from a crop production standpoint provided it is being applied to those fields with levels of phosphorus below the requirement for most profitable yield. Adherence to the soil test recommendations available through the soil testing program in Ontario would preclude such an eventuality.

Poultry and Animal Wastes

It is estimated that over 90 million farm animals and birds produce in excess of 38 million tons of manure annually in the Canadian portion of the Great Lakes Basin. About 40 per cent of this is produced in the Lake Erie Watershed alone. An increasing proportion of this livestock and poultry production is taking place in confinement and consequently there is also a trend towards the adoption of liquid manure handling systems.

Nitrogen may well represent the most important of the potential pollutants in farm animal manures since it is present in extremely high concentrations and is readily carried by water.

Table 1 presents volumes of nitrogen and phosphorus production from manures that are available as a replacement for commercial fertilizer in the Lake Erie and Great Lakes Basin. These levels were estimated after adjustment was made for the volume of manure produced on pasture and after allowance was made for nitrogen losses during handling and storage.

Table 1. Nitrogen and Phosphorus Production from Manure as Replacement for Commercial Fertilizer

	Lake Erie Watershed tons/year	Great Lakes Basin tons/year
Nitrogen (N)	43,335	102,111
Phosphorus (P)	14,199	32,352

Unlike most industrial and municipal wastes, farm manures are not normally discharged to receiving waters and since the percentages of pollution material from livestock operations which reach water courses are dependent upon a great diversity of factors, it is very difficult to determine with any degree of reliance the amount of pollutant materials from manures that reach the Great Lakes.

The practices which have the greatest potential impact on water quality are those of winter spreading of manure, storing or accumulating uncovered manure on the ground, spreading manure at very high application rates and permitting runoff from feeding areas. Each of these is common in the Great Lakes Basin area and none of them is specifically regulated.

For operations with liquid manure systems, no regulations govern the size or construction design of manure storage tanks in Ontario. However, a 'Suggested Code of Practice' prepared by the Ontario Department of Energy and Resources Management and the Ontario Department of Agriculture and Food is in operation which deals with the establishment of new livestock buildings, renovation or expansion of existing buildings and disposal of animal wastes.

With respect to manure treatment, it seems generally to be recognized in Ontario that there is little possibility for the complete treatment of animal waste to permit liquid fractions to go directly to receiving waters. Treatments of manure have, therefore, been designed to render the waste less odorous during storage or to improve the efficiency of handling for ultimate land disposal utilization. Experimentation with aerators is taking place and a number of mechanical devices are in service on farms in the Great Lakes Basin, including at least three oxidation ditches.

Pesticides

In recent years the contribution of pesticide application to environmental contamination is receiving closer scrutiny. While they have been instrumental in protecting public health and increasing agricultural production, there has been increasing concern over evidence of environmental contamination from a few of these compounds in the Great Lakes Basin and elsewhere in Ontario.

In general it is estimated that about 75 per cent of all pesticides used in Ontario are for agricultural purposes.

In addition to other Federal and Provincial laboratory activities a Provincial Pesticide Residue Testing Laboratory was established in 1966, whose function it is to serve all Departments of the Ontario Government in investigating amongst other things, the pesticide, PCB and mercury residue situations in Ontario.

Water samples have been collected in the Great Lakes Basin area, which is the area of highest population and highest pesticide use in Ontario. The total pesticide load was found to be very low averaging 14 parts per trillion. Two types of chlorinated hydrocarbons were found; DDT with its metabolites, and dieldrin. Because the amount of dieldrin used in Ontario is insignificant compared to aldrin, the dieldrin appearing in samples is assumed to be the metabolite of aldrin.

Soil samples were collected from both urban and agricultural areas of the Great Lakes Basin area. Soil residues were greatest in orchard and vegetable crop soils. The orchard and vegetable crop area represents 4 per cent of the agricultural area in Ontario while in turn only 15 per cent of the total land area is represented by agricultural land. Of the DDT present in the soil, the largest portion is present as DDT (66%), with smaller percentages of DDD (6%) and DDE (28%).

Again fish caught in a number of major areas were compared in 1965-69. These areas included the Muskoka Lakes (a non-agricultural area) and the Great Lakes. The total DDT residue in all except one area (Muskoka) fell below 1 ppm in the muscle tissue. The Muskoka area has been intensively developed for recreation and annually sprayed for the control of mosquito and black fly for several years. Additionally, the Muskokas are plagued with periodic outbreaks of forest tent caterpillars. The data collected in this research effort represents the most complete survey of the Great Lakes Basin With respect to pesticide levels. It appears that no major problems exist as a result of agricultural use of pesticides in that area.

The Ontario Department of Health took the first official step to restrict the use of DDT and TDE in the province under the Public Health Act of 1954. These matters were transferred in 1956 to the Pesticides Act which has been modified four times since then.

Since 1966, the Ontario Water Resources Commission has not issued any permits for the use of DDT in water. In 1967 the Department of Lands and Forests discontinued the use of DDT entirely in all of its programs. In September 1969, the uses of DDT were severally restricted in Ontario. The only uses now allowed require a permit. They are for cut worm control in tobacco, and plant bug control in apples together with bat control by structural exterminators.

Applications on tobacco have been reduced from 4 lbs. to 1 lb. per acre until an effective alternative is found. Earlier in 1969, aldrin, dieldrin and heptachlor were prohibited for all uses in Ontario, except for termite control by licensed exterminators.

These restrictions should have the effect of eliminating DDT contamination of the Great Lakes from Ontario sources. From monitoring conducted in 1969-70, it would appear that levels found in Ontario soils and surface water in the Great Lakes are relatively low and would not significantly contribute to direct contamination in the Great Lakes Basin.

Pesticide applications for non-agricultural uses are also of importance. Of the 55 million acres of Ontario that drains into the Great Lakes (the Ottawa river drainage is excluded), some 40 million acres are covered by forest.

In protecting these forest lands within the Great Lakes Drainage, the current average acreage sprayed each year represents only 0.04 per cent of the forested area. Short-lived insecticides now being used to control defoliating insects are chosen carefully for minimum hazard to the environment. Monitoring and other field studies permit the conclusion that current programs using insecticides do not result in any significant detrimental effects on the environment, not only on the Great Lakes but at the point of application.

There is no field use of fungicides in forest management in Ontario. The principal herbicides in general use for non-agricultural purposes within the Great Lakes Drainage System (2,4-D; 2,4,5-T) are relatively short-lived and are held by the organic material in the soil and the possibilities for contaminating waterways are therefore minimal. An estimate is that some 175,000 acres are treated annually at about 2 lbs. of active material per acre. This represents 0.4 per cent of the 40 million acres under forest. The relatively small scale of herbicide work in Ontario and the remote possibility of significant amounts of herbicides reaching the Great Lakes would indicate a very low potential for affecting water quality.

Erosion

Erosion of agricultural and non-agricultural land has also been seen as contributing to the contamination of our environment. Within the Great Lakes Basin, erosion and resulting sedimentation may be generally divided into three sources: (a) stream erosion, (b) lake erosion, and, (c) surface erosion. The relative contribution from each source of sediment varies throughout the entire length of the shoreline of the Great Lakes and depends on various conditions and practices, but at present it cannot be accurately determined. Little is known about the effects of the sediment load in specific areas but, in general, a high sediment load has an undesirable effect on the ecology of the water body.

With respect to fertilizer nutrients the main concern with nitrogen appears to be movement down the soil profile. However, very little data appears to be available with respect to nitrogen lost in runoff water. It is probably appropriate to assume that since nitrogen in the nitrate form is soluble, it will be moved into the soil profile rather than over the soil surface and that fertilizer nitrogen loss through erosion is low. An estimate is that it is less than 2 per cent.

With phosphorus on the other hand, it can be stated that there is essentially no movement of phosphorus from fertilizer or animal waste through the soil into the groundwater. Because there is little vertical movement of phosphorus in soil, fertilization increases the phosphorus content of the surface soil. Therefore, soil carried by surface runoff or erosion from fertilizer fields will be higher in phosphorus than that from unfertilized fields. If fertilizer use is contributing to buildup of phosphorus in our water supply, it will be in this manner. It is recognized that there may be considerable loss of soil from cultivated land by surface runoff. The problem is to determine how much of this reaches our streams. An estimate made earlier in the report indicated, however, that less than 2% per cent of phosphorus reaching the Great Lakes can be attributed to phosphorus applied in commercial fertilizer.

In forested areas, with few exceptions, streams and rivers are relatively free of suspended particles of soil. Present improvements in forest practices, especially with the rapid decline of river driving and the increasing attention to the development of protection forests will virtually eliminate any future potential for erosion.

The Water Survey of Canada is attempting to quantify the extent of the erosion problem by measuring both sediment load in streams and the rate of deposition in reservoirs. This program is being carried out with the co-operation and assistance of the Ontario Department of Energy and Resources Management and the local Conservation Authorities. In the meantime, attempts are being made through education, grants for erosion control works and legislative means to encourage the use of erosion control works.

Chlorides and Road Salt

Chlorides have shown a steady rise in concentration since the turn of the century in the lower Great Lakes. Contributing to this rise have been industrial wastes, increasing urbanization and in recent years the increased use of salt for de-icing municipal roads and highways. An estimated 500,000 tons of road salt are applied annually in Ontario and some 80 per cent of this is estimated to be applied on roads immediately adjacent to Lake Ontario and Lake Erie.

Difficulty is encountered in attempting to measure the effect of road salt use on Great Lake waters and there appears to be uncertainty regarding the impact that it makes. However, it might be pointed out that high chloride levels have been measured in the tributary waters in winter months and it is believed that they are related to road salt applications, particularly in urban areas. Prudence would suggest that use of road salt should be kept at a minimum that will ensure traffic safety.

Standards and Regulations

The guidelines for the control of water quality in the tributary basins as well as near-shore waters of the Great Lakes contained in the Guidelines and Criteria for water quality are the scientific requirements for the preservation of aquatic life and wildlife and the use of water for a variety of needs including water supplies for agricultural purposes.

The set of standards established depends on the existing and probable future uses of the resources of the basin. The requirements for waste effluents and land drainage are based on these standards or criteria where such standards exist.

In Ontario, concurrent federal and provincial jurisdiction exists to legislate in relation to agriculture, though federal legislation prevails in the case of conflict. Under the Canada Water Act, the purpose is to provide for federal water resource management which is defined as the "conservation, development and utilization of water resources". Joint water resource management under a federal-provincial agreement is authorized for any waters "where there is a significant national interest in their management".

Under the British North America Act, the federal government can legislate for the enforcement of standards of water quality and control of pollution for certain purposes. The Inland Fisheries and the Navigation and Shipping Acts come under this Act.

Specific Ontario guidelines and legislation which apply to control of pollution of the environment from agriculture include the following:

1. Suggested Code of Practice - (Ontario Department of Energy & Resources Management & Ontario Department of Agriculture and Food).

2. The Ontario Water Resources Commission Act (Ontario Department of Energy and Resources Management).

3. Pesticides Act (Ontario Department of Health).

Problems associated with air pollution from livestock enterprises are being administered through a ‘Suggested Code of Practice’ at the present time.

The code, prepared by the Ontario Department of Energy & Resources Management and the Ontario Department of Agriculture & Food deals with the establishment of new livestock buildings, renovation or expansion of existing buildings and disposal of animal wastes.

Livestock producers are encouraged to apply for a "Certificate of Approval" from the Air Management Branch of the Ontario Department of Energy & Resources Management before commencing construction. The Certificate of Approval is intended to give the farmer a considerable measure of protection if, in future, there should be any dispute regarding air pollution.

The OWRC Act prohibits the discharge of any material to a watercourse that may impair water quality. The section could clearly apply to the discharge of wastes from confined livestock operations, to application of fertilizer and subsequent runoff and the use of pesticides as any of these uses may cause water pollution.

Under the Pesticides Act, the use of pesticides including restriction and prohibition is regulated. Commercial application must be licensed. The Ontario Department of Health provides short courses and examinations for licenses.

With respect to conservation matters and problems of erosion several pieces of provincial legislation deal either directly or indirectly with erosion control on land surfaces, stream banks and lake shores. Included here would be the following:

1. The Ontario Water Resources Commission Act,
2. The Planning Act,
3. The Conservation Authorities Act (1968).

Under the OWRC Act (aforementioned), the OWRC has virtual control of all land use and land development in the province in so far as it may effect water quality. As regards erosion control this power has seldom if ever been used.

The Planning Act provides that all proposed developments, official plans, zoning by-laws, etc. be approved by the Minister of Municipal Affairs. This process is gaining increasing importance as a tool in erosion control management. While the Act demands that approval be sought it does not as yet demand that the developer produce an erosion control plan and this may be seen as a weakness at the present time.

Under the Conservation Authorities Act (1968) local Conservation Authorities may control the dumping of fill in designated areas and prohibit construction in the flood plain.

Techniques of sediment control have been well established for many years especially in rural areas where such methods as land treatment (grass waterways, etc.) and slope stabilization are used to prevent erosion and sedimentation.

Nevertheless, the key to a successful sediment control program in Ontario requires the assistance of a large number of groups including the following:

- Ontario Department of Energy and Resources Management Conservation Authorities Branch,
- Local Conservation Authorities
- The Municipalities,
- Canada Department of Energy, Mines and Resources,
- Water Survey of Canada - Sediment Surveys Section.

In addition, the co-operation of the provincial departments of Municipal Affairs, Highways, Agriculture, Lands and Forests and the Ontario Water Resources Commission may be required depending on the circumstances of the particular sedimentation problems. Legislation specifically designed to control erosion and sedimentation is being considered in the provincial government and will hopefully provide for a workable administrative framework for the successful control of management practices.

At all levels of government in Canada and in Ontario, there has been a growing recognition of environmental problems and the heed for control and abatement of their impact.

In response to this development, the Federal Government are soon to have a Department of the Environment which amongst other things will have jurisdiction over:

a) sea coast and inland fisheries,

b) renewable resources,

c) water, and

d) protection and enhancement of the quality of the natural environment including water, air and soil quality.

In Ontario, the Department of Energy and Resources Management might be said to have developed as the Department most directly involved in contamination problems of our environment.

In Ontario, research is underway with respect to pollution problems caused by the misuse of fertilizers, pesticides and animal wastes and into related erosional problems in the Great Lakes region. The University of Guelph, the Provincial Pesticide Residue Testing Laboratory and a number of departments of the Ontario government are prominent in this effort.

APPENDIX "C"

Joint Recommendations of Canadian and U.S. Sections of Sub-Group No. 9

The following recommendations contained in this sub-section are directly concerned with pollution from agricultural activities (including forestry and other related land-use activities). It is recognized, however, that certain of these recommendations also relate to other sub-groups, including those in water quality standards, institutional arrangements, and hazardous materials pollutants. This interrelationship reflects the diverse character of agricultural sources of pollution as they affect organizational and scientific elements.

Recommendations: It is recommended:

A. That the IJC consider the incorporation of a pollution advisory capability to deal specifically with pollution from agriculture, forestry and other related land-use activities. The group would be comprised of technical and administrative personnel from each National Government and the various States of the Great Lakes and the Province of Ontario. Basic responsibilities would include the determination of joint international research and surveillance activities, advice on criteria for non-point source pollutants, and activity in the collection and dissemination of relevant technical and legal information to interested parties.

B. Each country should develop the following plans in agriculture, forestry and other related land-use sources:

1) the establishment of a five year plan for joint research and development activities to provide improved means for controlling pollution from these sources.

   Primary emphasis should be given to:

   (a) the development of improved nutrient, sediment and pesticide runoff predictive technology using mathematical models as tools to provide quantitative estimates of surface and sub-surface runoff under various soil, climatic, and management circumstances. Such tools would particularly enhance development of possible agricultural-chemical registration requirements by the States and the Province of Ontario which could translate into prescribed, standardized laboratory and field tests for use by manufacturers to define the fate and effect of these chemicals prior to their approval for use.

(b) the development of animal waste management systems with special consideration of those systems which incorporate totally enclosed animal production-waste treatment systems, waste conversion, by-product recovery and re-cycle systems, or other "closed-loop" waste management concepts; and

(c) the development of improved soil and land management and conservation methods to include possible systems of "buffer zone" cultivation, new tillage practices and new or improved soil additives such as soil binders, or polymeric (long-term release) fertilizer compounds.

2) The standardization of criteria for the abatement and control of pollution from these sources.

3) The review of technical, legal and institutional problems of mutual concern with a specific view toward advising in the development of State or Ontario Provincial laws, and enforcement-monitoring programs.

Items of special interest would include, but would not be limited to recommendation on, standardization of policies for sediment runoff or erosion control from public and private lands which would lend impetus to the adoption of soil, water and land conservation and management practices; and advise on any inter-jurisdictional variations in legal requirements governing the use and handling of pesticides.

C. That there be initiated a formal program between the United States and Canada calling for the mutual exchange of current information on, and visits to, research and development projects which involve work on rural runoff, animal feedlots, pesticide management and other aspects of agricultural pollution of mutual interest.

D. That an intensive, joint U.S.-Canadian surveillance effort be undertaken to monitor and quantify the sources of pollution throughout the Great Lakes Basin as soon as possible to define the extent and distribution of problems. Particular emphasis should be placed on defining the effects of current land use and conservation practices, and development of recommendations for additional research, and study needs.

E. That the United States and Canada accelerate the demonstration and expedite implementation of new and existing technology for minimizing pesticide and nutrient pollution, sediment transport and pollution from confined animal operations.

F. That the current U.S. project to develop a mathematical model to determine the effect of point source pollution on the ultimate water quality of Lake Michigan waters be expanded as a joint U.S.-Canadian endeavour for the entire Great Lakes Basin to facilitate management of the total basin resource.

G. That consideration be given to a program to re-evaluate State, Provincial and Federal land classification systems to ensure optimum land uses which are compatible with factors of environmental quality and water quality standards.

H. That necessary funding be made available to carry out responsibilities set forth in these recommendations.