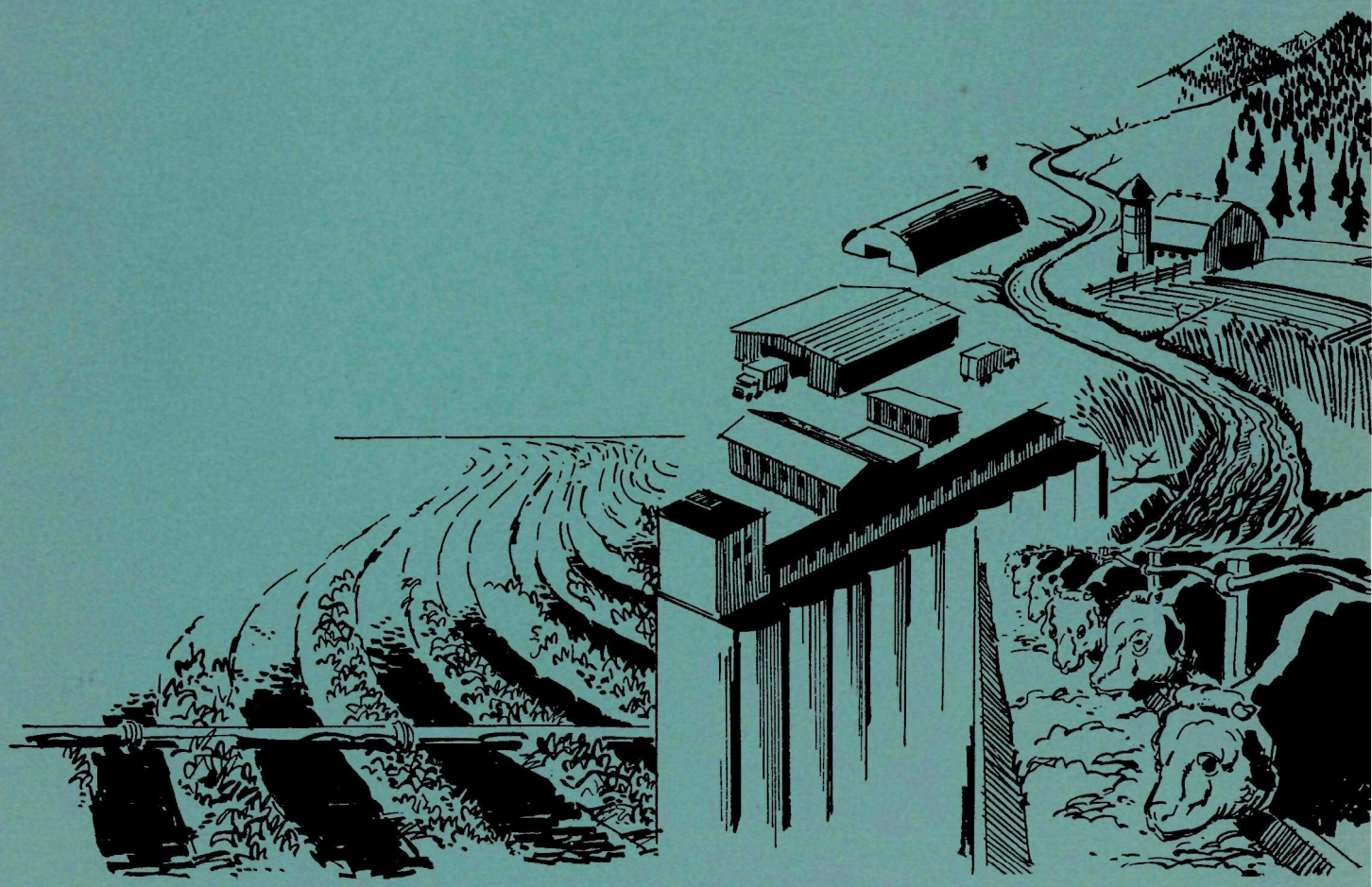
CLEAN WATER

AGRICULTURAL POLLUTION OF THE GREAT LAKES BASIN



ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

AGRICULTURAL POLLUTION

OF THE GREAT LAKES BASIN

Combined Report by Canada and the

United States

July 1, 1971

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CANADIAN

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PART A

UNITED STATES SECTION

INTRODUCTION

This report is intended to be a State-of-the-Art document concerning abatement of pollution of the Great Lakes Basin, as specifically influenced by agricultural and related sources. It was compiled by technical personnel, from appropriate fields in universities and governmental departments in Canada and the United States. Primarily it relates to the identification of the impact of agricultural and related activities on the pollution of the Great Lakes Basin.

The major constituents of these non-point sources of pollution which were studied included: 1) runoff and release of nutrients, pesticides, and herbicides and degradation by-products as a consequence of the application of agricultural chemicals; 2) runoff of pollutants from animal and poultry production operations and from associated animal waste management structures and lands used for ultimate disposal; 3) sedimentation resulting from current land use practices, including land influenced by agricultural activities and by local, state and federal activities on public lands, highways and parks. Also under study was the scope of current planning, advisory and regulatory functions of the United States and Canadian Governments.

The findings of some of the basic research conducted to date by both Nations, and the substance of the programs of the numerous regulatory agencies involved, are presented in this text.

Its purpose is one of motivating development of more comprehensively effective and universally applicable methodology for the management of wastes from agricultural and related activities, and the amelioration of the invaluable water resources throughout the Great Lakes Basin.

II. POLLUTION PROBLEMS

Background

For the purpose of establishing a basis on which to discuss the Great Lakes Basin pollution problems arising from land use activities, such as agriculture and forestry, it will be helpful to briefly consider the geological history and the spread of white-man's civilization throughout the region.

The landscape of the Great Lakes Basin, and indeed the formation of the Great Lakes themselves, owes its present form to the moulding action of the great continental glaciers of the Pleistocene era. Resulting from the sporadic advancement and recession of the ice sheets, many topographical features remain which make the region unique for considerations of soil characteristics and land use. Moraines, formed of ridges of mixed glacial debris (unsorted and unstratified boulders, sand, and silt, collectively called till) stretch for miles and mark the forward positions of the glaciers. Behind them lie striated rock floors strewn with till and erratic boulders. Innumerable lakes and marshes mark places where the vanished glacier gouged its floor, or blocked older drainage with debris, or left a stagnant ice block half buried in an outwash apron. Fans of outwash spread from gaps in the moraine; beyond the fans are sheets of loess (loam consisting chiefly of silt particles carried by the wind) or terraces of silt.

In general then, the Great Lakes Basin is covered by a thick blanket of glacial drift over most of its surface. The soils in the Basin are

developed in a wide variety of material. These materials include stratified glacial drift; undifferentiated glacial till; outwash silt, sand, and gravel; and lacustrine clay, silt, and sand. The soils have great variability in their mode of origin and they range from the sandy-loam to the loamy-sand types. Loamy soils generally adsorb water will, will firmly adsorb phosphates, and have a high natural nitrogen content. These characteristics make the land usually suitable for carrying out general farming, although local conditions such as high clay content or thin topsoil with high rock content may alter the general condition.

Land settlement in the Great Lakes Area began about 1820. Prior to this time the area was inhabited by Indians and a few French fur traders. Except for small cutivated areas around the sites of present large cities and near some Indian villages, nearly all of the area was covered by forests.

The southern half of the lower peninsula of Michigan, northern Ohio, Indiana and southern Wisconsin, had several small open prairies that later became focal points for early settlements. These areas also had substantial oak forests which were favored by early settlers because of the comparative ease with which they could be cleared for farms. Most of the remaining land in the area was covered with mixed hardwoods -- primarily maple, hickory, elm, ash and basswood. Forests containing pines were found in some parts of southern Michigan, for example, in the Saginaw Valley and in sandy areas along Lake Michigan.

Pine was a much more common component of the forests in the northern two-thirds of Michigan, northern Wisconsin and east central Minnesota where they were found associated with stands of other conifers and hardwoods. These were the forests providing the famous pineries that attracted and supported the lumbering business.

The first major change in land use came with land settlement, land clearing and shifting of much of the land into farms. By 1850, 4.4 million acres were in farms and only 1.9 million acres were considered improved farm land. The area increased rapidly to 13 million acres of improved farm land by 1920.

Logging started as early as 1840 and was well past its peak by 1920. The pine and other conifers used for lumber were harvested first, the hardwood and pulp species were logged later. With the exception of a few small areas there are no stands of merchantable virgin timber left. Early logging produced products used in the Civil War and in the rebuilding of Chicago after its fire. The establishment of the mining industry in Minnesota and Michigan was aided by the proximity of a large timber supply.

Following logging of the merchantable timber in the virgin stands, the logging debris (slash) was burned, often because of State law requirements or to clear the land for the agricultural development that was expected to follow the logging. Early observers assumed that farming would naturally follow the lumbering, and timberland owners expected to cut their merchantable timber and then sell the partially cleared

lands to prospective farmers. The next major phase of land use emerged with the problem of these cutover lands.

For various reasons, such as poor soil, lack of markets, and a climate, particularly in northern Michigan, Wisconsin and east central Minnesota, the agricultural development was not successful. Only some farms located on good land prospered.

Newly cleared farms were abandoned rapidly. The demand for cutover land all but disappeared and hundreds of owners stopped paying taxes on any except their choice holdings. In 1932, 17.2 million acres, almost half of the land areas of the State of Michigan, was tax delinquent. By 1941, some 4.5 million acres had reverted to the State. Thousands of additional acres were saved from possible reversion by Federal purchase programs under which lands were acquired for national forests, wildlife refuges and military purposes.

The farm settlement and logging period also brought major changes in water use. The majority of the rivers having flows adequate for power production were dammed for that purpose years ago. With land clearing the area lost much of the cover that had impeded the rapid discharge of flood waters. Soil erosion caused muddy streams and

siltation problems. The growth of cities and industries gave rise to tremendous new demands for water.

II. POLLUTION PROBLEMS

A. Introduction

Any pollutional contribution from agricultural production practices (as distinguished from food processing operations) to the Great Lakes results from substances dissolved in water or transported by water and sediment. Of major concern are plant nutrients (nitrogen and phosphorus), pesticides, and organics which deplete dissolved oxygen. Sediments are important as a physical detriment, as possible carriers for phosphates and pesticides, and because of their economic impact. Each of these pollution problems are associated with crop and livestock management practices.

It would be desirable to be able to quantify and identify the source of each pollutant that enters the Great Lakes. There is, however, little specific data available to permit reasonably reliable estimates, especially for agricultural or non-urban areas. In non-urban areas there is a wide variety of land use ranging from woodland to intensively cultivated areas which makes it difficult to achieve any reliable estimate. Moreover, it is difficult to evaluate contribution from various land-use practices on a large watershed because most of them contain some urban areas.

Considerable data are available on sediment production, and nutrient and pesticide losses in runoff from small plots and small watersheds for some land management systems. In addition, a limited amount of information has been gathered which reliably reflects the impact of

sediment, nutrient, pesticide and feedlot runoff pollution on the Great Lakes.

For the present, broad estimates must be made to define the problem, to plan control measures and recommend an R&D program.

B. Nutrients - Fertilizers

Since much emphasis has been placed on nutrients, agriculture's contribution to the nitrogen and phosphorus content of water must be evaluated.

Nutrients enter surface water by discharges of raw or treated sewage, some industrial wastes, and runoff and seepage from land and animal feedlots. Following rainstorms, there is evidence that runoff of chemical fertilizers from cultivated lands can be a significant source of plant nutrients found in streams and lakes. The variations in the potential for contributions from this source are extensive, however, some limited studies of agricultural watersheds show that fertilizer runoff is likely to be severe following intense storms.

Many attempts have been made to correlate the increased consumption of fertilizers with water pollution. The amounts of fertilizer used in the Great Lakes Basin in 1964 is shown in Table 1. About 83 percent of the nitrogen and phosphorus is used on crop and pasture land, and the remaining 17 percent used on non-farm areas. Fertilizer consumption is increasing and it is estimated that it will continue to increase at the rate of 5 percent per year for the next

few years coincident with the need for increased levels of production. A generalized decrease in the cost of fertilizers, plus higher labor costs have also contributed to increases in fertilizer usage and to a tendency to overfertilize crops. Where high rates of nitrogen fertilization are used, leaching losses may occur. Nitrates are highly soluble and move readily with water. Contributions from fertilizer are difficult to evaluate, however, because losses due to denitrification and gains from fixation processes are difficult to quantify. All of these processes are affected by management practices, soil type and climatic conditions. It is estimated that for average conditions, a crop will use about 60 percent of nitrogen applied as fertilizer. Our present state of knowledge does not permit complete, universal quantification of the disposition of the remaining 40 percent. A pollution hazard can occur when the available nitrogen exceeds withdrawal by the crop and there is an excess of water to cause leaching into groundwater reserves or runoff to rivers.

TABLE 1. -- Fertilizer Use in the Great Lakes Basin by Agricultural Subregions* 1964 (Tons)

	Crop & pastureland			Nonfarm			Total		
	N	P	K	N	P	K	N	P	K
ASR 4	3,243	3,208	5,323	462	278	556	3,705	3,486	5,879
ASR 5	4,695	3,904	5,863	787	254	460	5,484	4,158	6,323
ASR 6	13,345	8,966	15,733	6,746	2,174	3,944	20,091	11,140	19,677
ASR 7	8,646	6,736	10,742	6,212	2,133	4,060	14,858	8,869	14,902
ASR 20	14,148	10,990	22,107	12,150	6,603	6,934	26,298	17,593	29,041
ASR 39	118,601	55,691	99,513	14,043	7,548	17,103	132,644	63,239	116,616
ASR 40	50,184	32,446	54,435	12,535	4,627	8,178	62,719	37,073	62,613
ASR 41	13,776	7,158	13,661	1,037	362	689	14,813	7,520	14,350
ASR 52	33,676	16,983	23,404	4,483	5,075	10,336	38,159	22,058	33,740
ASR 53	19,548	15,627	45,922	1,011	344	711	20,559	15,971	46,633
ASR 54	6,945	5,799	14,010	2,573	1,656	2,136	9,518	7,455	16,146
TOTAL	286,809	167,508	310,713	62,399	31,054	55,107	348,848	198,562	365,920

*See Figure 1 for location of Agricultural Subregion

*Based upon National data, the increase in use is approximately twenty (20) percent for farm and non-farm users by 1970.

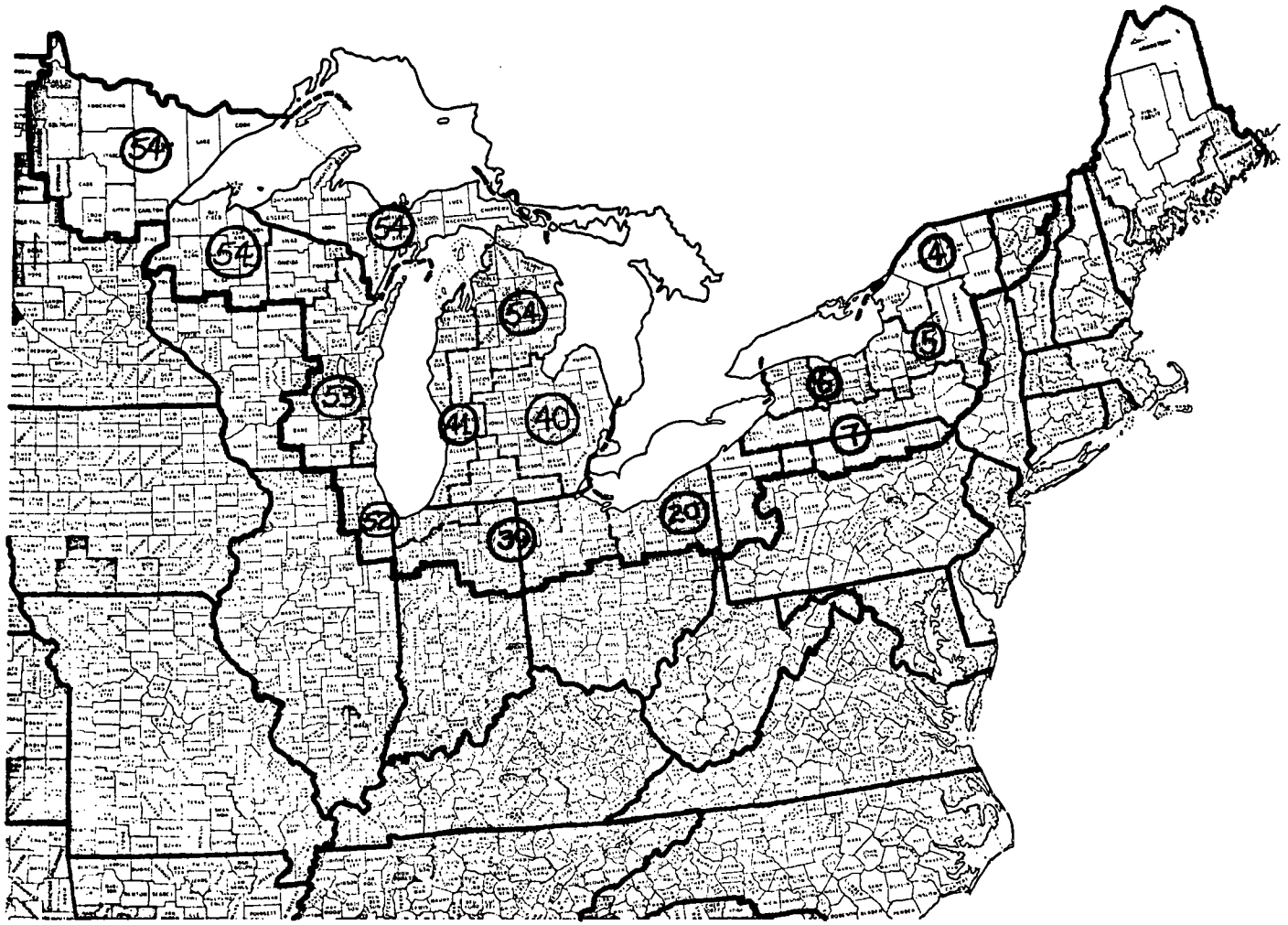

Figure 1 -- Agricultural Subregions in the Great Lakes Basin

into groundwater reserves or runoff to rivers.

Normally, applied phosphorus is strongly fixed in the soil. Moreover, leaching losses occur only under rare circumstances in most soils. Losses usually occur during the erosion process where phosphates are adsorbed on eroded soil particles. It is estimated that 1,000 pounds of phosphorus. Thus, when sediments enter a watercourse or body of water, they serve as a source of phosphorus, although the amount in true solution may be very small and is made available under only certain limited circumstances. There is also evidence that certain sediments may act as scavengers, actuallly removing phosphates from solution, and thereby decreasing pollution of water. However, the immense volumes of sediments which reach the lakes each year is such that the absolute contribution of phosphorus cannot be underestimated.

As previously mentioned, much emphasis has been placed on runoff, or agricultural drainage. Research on plots and small watersheds has yielded some information. Studies at Choshocton, Ohio[1] showed that over a three-year period, average annual losses of nitrate nitrogen and phosphorus from farmland runoff were 3.86 and 0.06 pounds per acre (lbs./A) respectively, as compared to 0.92 and 0.04 lbs./A for woodland.

Agricultural sub-surface drainage must also be considered. Studies

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[1]Unpublished data - Taylor, Edwards and Simpson, U.S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division.

on tile drain effluents at Tiffin, Ohio,[2] showed annual losses of nitrate nitrogen and phosphorus of 2 and less than 0.04 lbs./A respectively. Studies of large drainage areas in Wisconsin,[3] showed annual losses in base flow of total nitrogen and phosphorus to be 1.0 and 0.1 lbs./A respectively. These unit loss rates appear quite low. When multiplied by the large acreages in drainage basins, however, the absolute contribution of nutrients is significant. This is illustrated in figures 2 through 5,which show data on nitrates and orthophospate concentrations representative of those from a large watershed in the northern midwest.

Several studies have shown that phosphorus losses from cropland is associated almost entirely with erosion. Due to the sporadic character of soil composition, no precise statement can be made about the general rate of this type of phosphorus movement, but some broad estimates are possible. Experiments with cotton and corn in Virginia showed a loss of 5 tons per acre of soil containing 1,000 ppm. of phosphorus.

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[2] Schwab, Taylor, and Waldron - Ohio Report on Research and Development, page 87, July-August 1970.

[3] Minshall, Nichols and Witzel - Water Resources Research 5:706, 1969.

This represents a loss of 10 pounds of phosphorus per acre per year. Under high erosion, the loss may reach 30 to 50 pounds. Additional data on nutrient runoff from an agricultural watershed in Kansas (figures 5 and 6) further emphasizes the potential severity of the total nutrient runoff problem.

Up to 50 percent of the total phosphorus in a surface soil may be present in organic forms. Little information is available on the biological activity of organic phosphates in streams, and new analytical procedures may be necessary to reveal its true significance.

The information shown in Table 2, further amplifies the disparity found in data relating to pollution due to agricultural runoff of nutrients. But the table does show that approximate mean values for rural runoff exceed all other sources combined. What is needed is an intensive program designed to determine the actual contribution of nutrients in the Great Lakes from agricultural practices so that control measures and research needs may be promulgated.

Eutrophication

A major concern in the Great Lakes is accelerated eutrophication. This is attributable to a myriad of factors including nutrient enrichment due to vast inflows of nitrogen and phosphorus, minor nutrients, and organic carbon sources. Domestic sewage remains a major source of these elements. Drainage from rural sources may also contribute appreciably because of the vast area involved. The actual contribution on a per-acre basis, however, has not been assessed. Sources of lesser consequences would be natural sources such as mineralization of soil organic matter and decay of plant residues, contributions from wildlife, and natural shoreline erosion of the lakes.

There exists an undeniable need to survey the actual contributions of all agricultural sources of pollution in the Great Lakes to establish a basis for prescribing means to abate, prevent or control these sources.

C. Pesticides

Pesticide usage on agricultural lands and urban sites has increased tremendously in the past two decades. During this period, water pollution due to pesticides also has increased although the degree of pollution is variable between watersheds. The pollution of lakes, streams, and estuaries

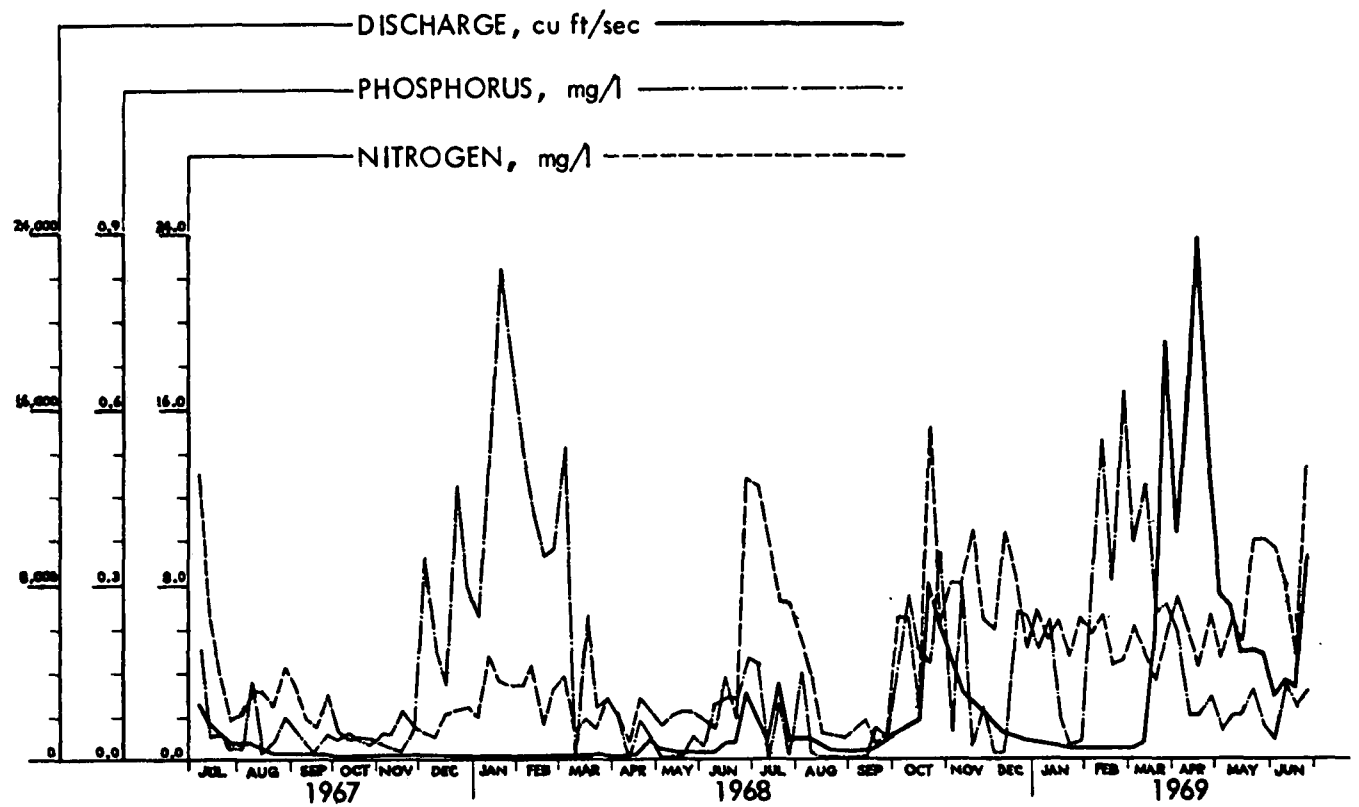

Figure 2 -- Concentration of Nutrients and Flow in the Des Moines River at Boone, Iowa

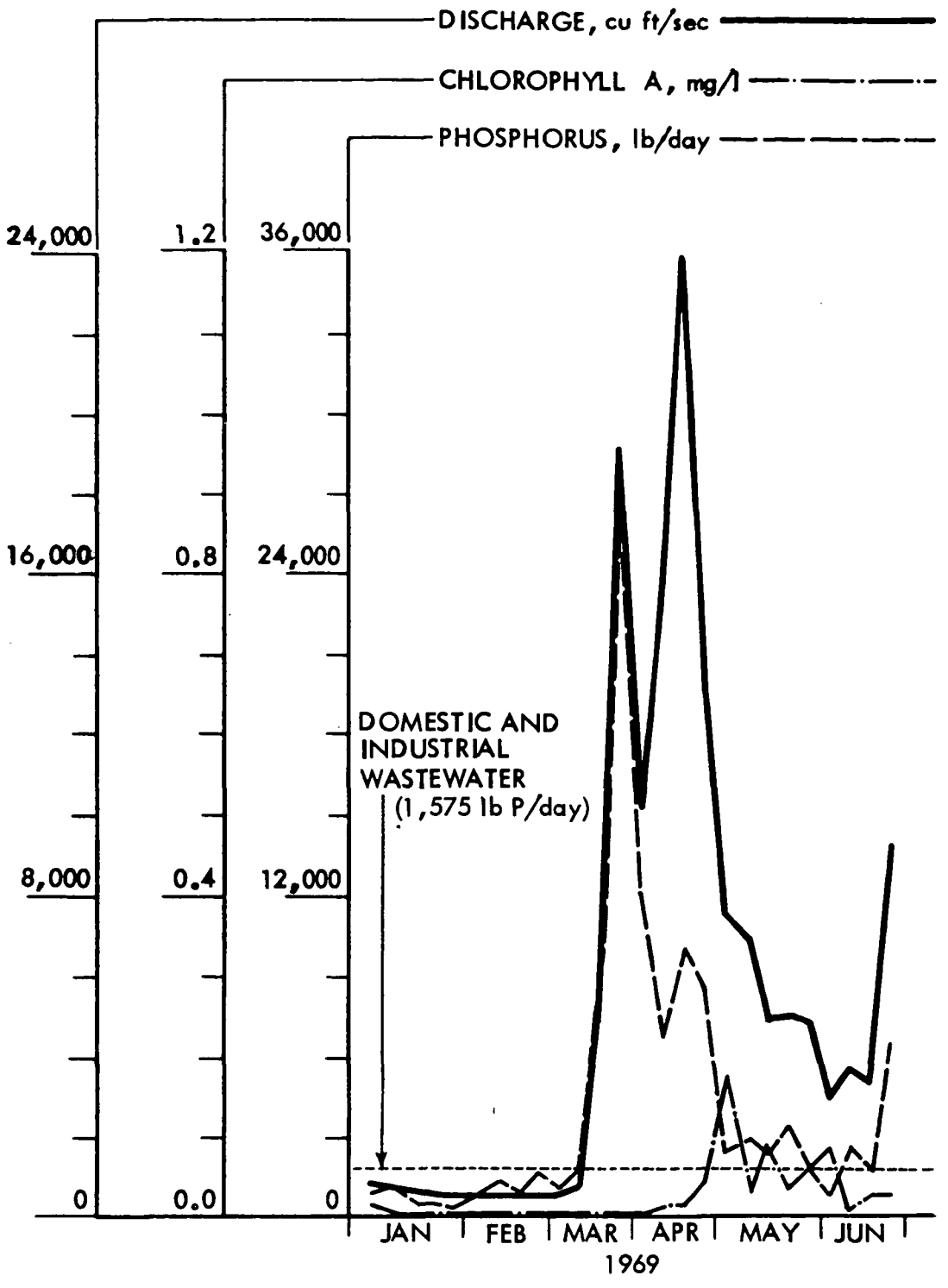

Figure 3 -- Phosphorous, Chlorophyll A and Flow in the Des Moines River During a Wet Period.

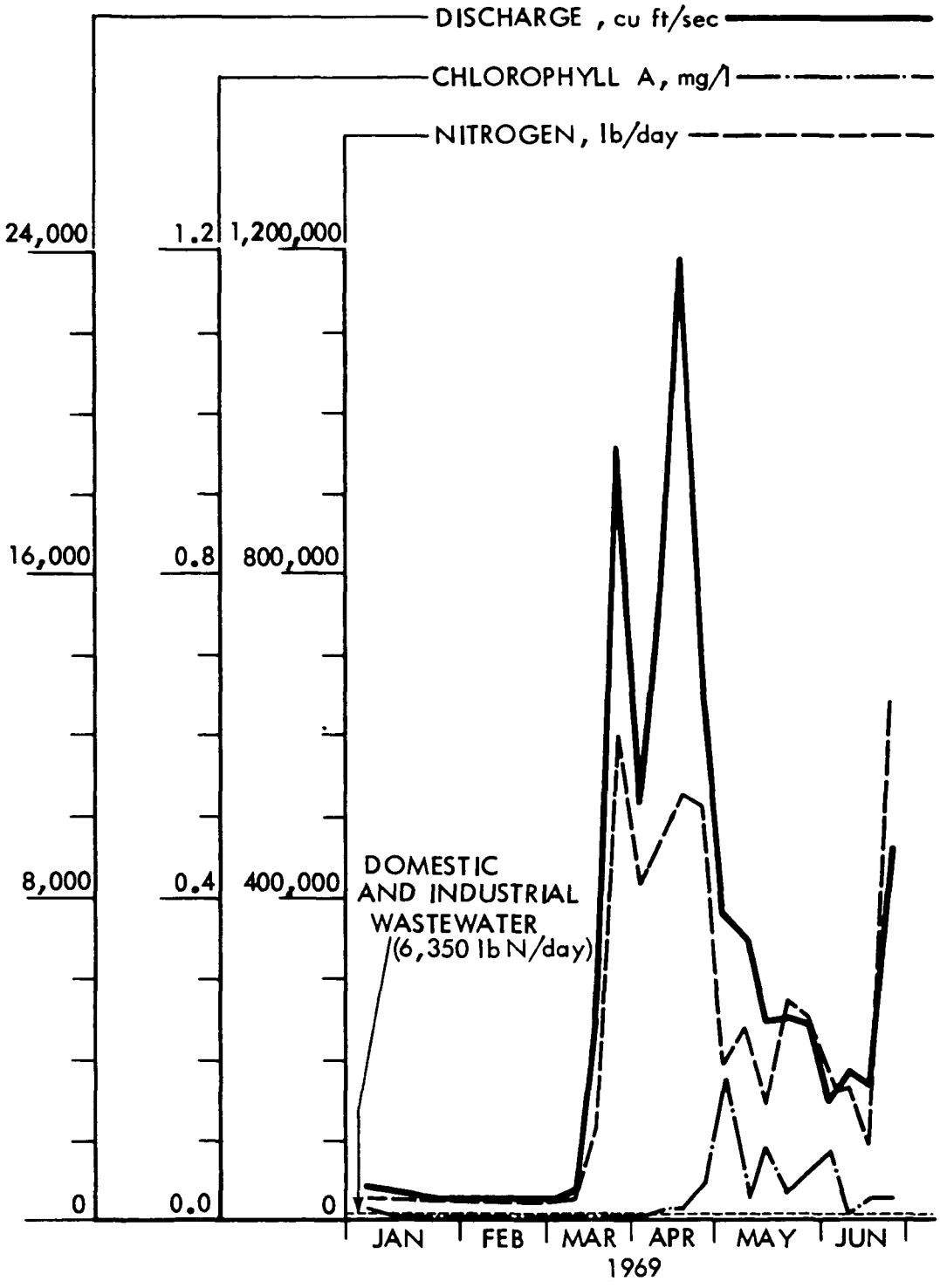

Figure 4 -- Nitrogen, Chlorophyll A, and Flow in the Des Moines River During a Wet Period.

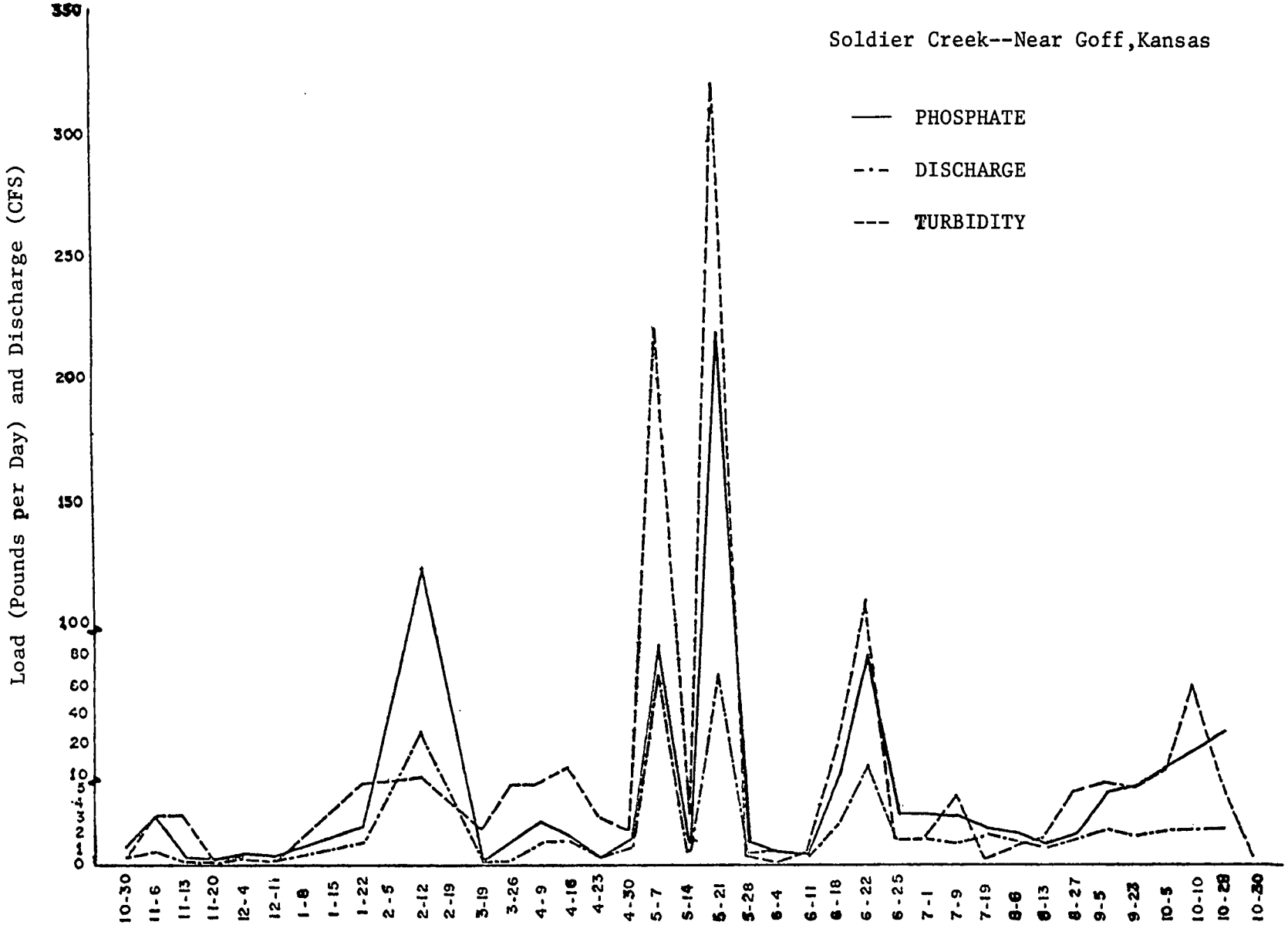

Figure 5 -- Phosphate and Turbidity in Runoff From an Agricultural Watershed

TABLE 2 -- ESTIMATE OF NUTRIENT CONTRIBUTION FROM VARIOUS SOURCES*

Source	Nitrogen 10^6 lb./yr.	Phosphorus 10^6 lb./yr.
Domestic Waste	1100-1600	200-500
Industrial Waste	1000	----
Rural Runoff - Agricultural Land	1500-15,000	120-1200
Non-Agricultural Land	400-1900	150-170
Farm Animal Waste	1000	----
Urban Runoff	110-1100	11-170
Rainfall	30-590	3-9

*Task Group 2610 P. Sources of Nitrogen and Phosphorus in Water Supplies. JAWWA 59:344-366 1967

Table 3 -- Synoptic Survey of Chlorinated Hydrocarbon Pesticides in Surface Waters, September 1966 *

Location	Concentration in micrograms per liter						
	Dieldrin	Endrin	DDT	DDE	DDD	Heptachlor	BHC
Great Lakes Region							
St. Lawrence River; Massena, N. Y.	ND	ND	ND	.002	ND	ND	ND
Lake Erie: Buffalo, N.Y.	ND	ND	ND	ND	ND	ND	ND
Detroit River: Detroit, Michigan	ND	ND	ND	ND	ND	ND	ND
St. Mary's River: Sault Ste. Marie, Michigan	ND	ND	ND	ND	P	ND	ND
Lake Superior: Duluth, Minn.	ND	.022	.026	P	.005	ND	ND
Lake Michigan: Milwaukee, Wis.	ND	ND	ND	ND	ND	ND	ND
Maumee River: Toledo, Ohio	ND	ND	ND	ND	.006	ND	ND
St. Joseph River; Benton Harbor, Mich.	P	.029	ND	ND	.013	ND	.003
Grand River: Grand Haven, Mich.	P	ND	ND	ND	.009	ND	ND
Detroit River: Grosse Isle, Mich.	ND	ND	ND	ND	.012	ND	ND
Fox River: Green Bay, W	ND	.007	ND	ND	.007	ND	ND

ND - indicates none detected.

P - indicates presumptive. Data are reported as presumptive in instances where the results of chromatography were highly indicative but meet all requirements for positive identification and quantification.

* Excerpt from Green et al. - AAAS Symposium on "Agriculture and the Quality of our Environment." December, 1966.

by pesticides may occur as the result of application of these materials to crops, soils, livestock, and in communities to control such pests as mosquitoes. The residues may contaminate water as the result of soil runoff, or through sewage from streets, homes, etc., that eventually reach natural water resources. Moreover, insecticides applied for various purposes may drift into aquatic environments.

The necessity to use insecticides for efficient crop and livestock production and to protect people in agricultural areas from attack by pests is fully understood. Alternative methods of control from most pests are still lacking and considerable work is required to develop improved pest control (and environmentally innocuous) chemicals. For the present, it is impossible to control most pests effectively in agricultural environments or in aquatic environments without chemical pesticides.

Pesticides can be classified into two broad groups: persistent and non-persistent. The latter are readily degraded, and are not considered a significent chronic pollution problem. However, spills or indiscriminate use can cause severe pollution effects. The persistent pesticides, primarily

chlorinated hydrocarbons, are of major concern. These compounds have limited solubility in water and become pollutants of water largely by (1) adsorption to clay particles in sediment; and (2) solution in water and/or organic carriers.

Of the Great Lakes, current information reveals that the greatest pesticide problem occurs in Lake Michigan. For the other lakes, there is either low usage of pesticide in the watershed or detention times are apparently too short for a problem to develop. Although no comprehensive data for the entire Lake Michigan watershed is available, some estimates are available for certain areas. For example, a total of 13,702 pounds of aldrin, 3,913 pounds of dieldrin and 127,516 pounds of DDT were estimated to have been used in the Wisconsin Lake Michigan watershed.

Definitive research data on the extent of pesticide pollution from agricultural lands are extremely limited. Studies using dieldrin at Coshocton, Ohio, show that in a 12-month period, 0.005 percent of that applied was lost in runoff.

Most studies indicated that the absolute amount of pesticide residues actually reaching water through runoff and drift is usually very small, involving quantities generally within the parts per billion range. This is illustrated in the results of a synoptic survey of chlorinated hydrocarbon pesticides in surface waters of the Ohio River Basin and Great Lakes Region (Table 3). However, the impace on organisms in water may still be substantial. Fish, shrimp, mussels and other aquatic animals concentrate the low level residues in their bodies by selective absorption of the pesticide residues, by screening out residues by gills through the intake of large quantities of water, and by the phenomenon of biological magnification of residues through food chains. Not only are pesticides toxic to fish (e.g. 0.1 ppb of dieldrin has been shown toxic to fish fry), but also are accumulated in body tissue throughout the food chain, thus affecting wildlife survival and human food supplies.

Considerable pesticide pollution arises from misuse. This includes accidental spills, careless application practices, and improper disposal of containers and wastes. Much of this can be avoided by more careful handling of these materials or legislative action to require return of spent containers, etc.

Losses on sediment may vary from 0 to 3 percent of that applied, depending upon the degree of erosion.

Since runoff losses are often small, conservation and practices to control erosion will greatly minimize water pollution hazards from pesticides.

Research has been conducted in Waynesville, North Carolina to determine runoff of herbicides from small watersheds as influenced by slope, vegetative cover, rainfall, and other edaphic factors. Similar research has also been conducted at Watkinsville, Georgia, to determine extent of herbicide runoff under simulated rainfall conditions as influenced by different soil conditions. In genreal, the herbicide runoff was directly related to the movement of soil particles by erosion. There was little or no evidence of herbicide movement independent of the movement of soil particles.

Additional research is being conducted in Athens, Georgia (EPA) to develop a mathematical model to predict the amount of runoff of any pesticide under any climatic and geologic circumstance for all areas of the United States. Field plot tests of the model are underway and it is anticipated that full scale testing will be warranted by 1972.

D. Poultry and Animal Wastes

Potential pollution from animal wastes will depend upon the number and type of livestock, size and type of operational units, and waste disposal methods used. The primary problems associated with the runoff from confined animal operations are organic waste load, nutrients, dissolved solids (salts) and pathogenic organisms.

Characteristics of animal wastes vary with the type and size of animal, the diet fed, and many other variables. As a point of reference, average pollutional characteristics of different types of animal wastes are shown in Table 4. These values will also vary considerably with storage and handling practices. Actual pollution contribution must be assessed on the basis of that fraction that finds its way into a water resource.

Feedlot runoff is high in dissolved and suspended organic compounds and has a high oxygen demand and frequently lowers the dissolved oxygen content of the water, making it hazardous to aquatic biota. Runoff from two experimental feedlots at Kansas State University showed ammonia concentrations up to 140 mg/l, COD 1,000 to 3,000 mg/l and BOD from 400-1500 mg/l.[1]

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[1] 2nd Compendium of Agricultural Feedlot pollution, FWQA, Kansas City, Missouri, 1969.

No fish kills that were attributable to feedlot runoff have been reported in the Great Lakes region; however, eighty-seven such kills were reported in 1968 across the Nation.

Furthermore, microbial decomposition of these compounds results in the production of carbon dioxide which could stimulate algal growth. Nutrient contributions, primarily nitrogen and phosphorus, could also stimulate algal growth in bodies of water where these nutrients are growth-limiting, (Figure 6). In certain areas of intensive livestock or poultry production there is some concern of possible nitrate pollution of surface or ground waters. The degree of water borne disease transmission from animal to man is not adequately documented however, high concentrations of total coliform, fecal coliform, and streptococci are found in animal feedlot runoff.

A representative graph of these noted at one test site is shows in figure 7. Salmonella organisms are usually present, but others such as leptospirosis have also been reported.

Because of the growing trend in the Lakes area and elsewhere toward intensive operations, it is important to consider waste management practices which help prevent the potential for runoff pollution. For example, animals on pasture distribute their wastes on the land and the pollution potential may be

negligible. On the other hand, in confined dairy farming operations in the Great Lakes Region, farmers frequently spread accumulated manure on the snow during the winter months, which promotes pollution of the runoff when the snow melts.

Manure disposal to the land is decreasing due to high level costs and the low price of chemical fertilizers. Manures are then being "stockpiled" where this or land spreading takes place, the practice presents a potential hazard especially when there is a Spring thaw and "slug" runoff occurs. Other practices involving application of solid or liquid animal wastes to the land could create a problem if necessary management precautions including rates and times of applications are now followed.

There are many remedial methods for preventing water pollution from animal wastes some of which may be effective for modest operations. These include use of anaerobic plue aerobic lagoons, diversion structures to prevent runoff from entering a stream, land disposal of solid and liquid wastes, and site selection to minimize surface and groundwater pollution. Optimum pollution control practices must be tailored for each situation taking into consideration soil, topographic, geologic, vegetative, climatic and other factors. Design criteria will also be determined by size and type of animal unit desired.

TABLE 4 -- Average Pollutional Characteristics of Animal Wastes Weight Units (Pounds per Day*)[1]

Animal	Total** Solids	BOD	COD	Nitrogen Total	Nitrogen Ammonia	P_2O_5
Chickens (4-5 lbs)	0.066	0.015	0.047	0.0033	0.0015	0.0026
Swine (100 lbs)	0.74	0.33	0.73	0.055	0.024	0.025
Dairy Cattle (1000 lbs)	8.2	1.20	7.1	0.41	0.23	0.12
Beef Cattle (1000 lbs)	3.6	1.02	3.26	0.26	0.11	--

* lb./day means lb./day.animal

**Dry solids

[1]Loehr, R.C. Pollution inplications of animal wastes - A Forward Oriented Review. FWQA - July 1968.

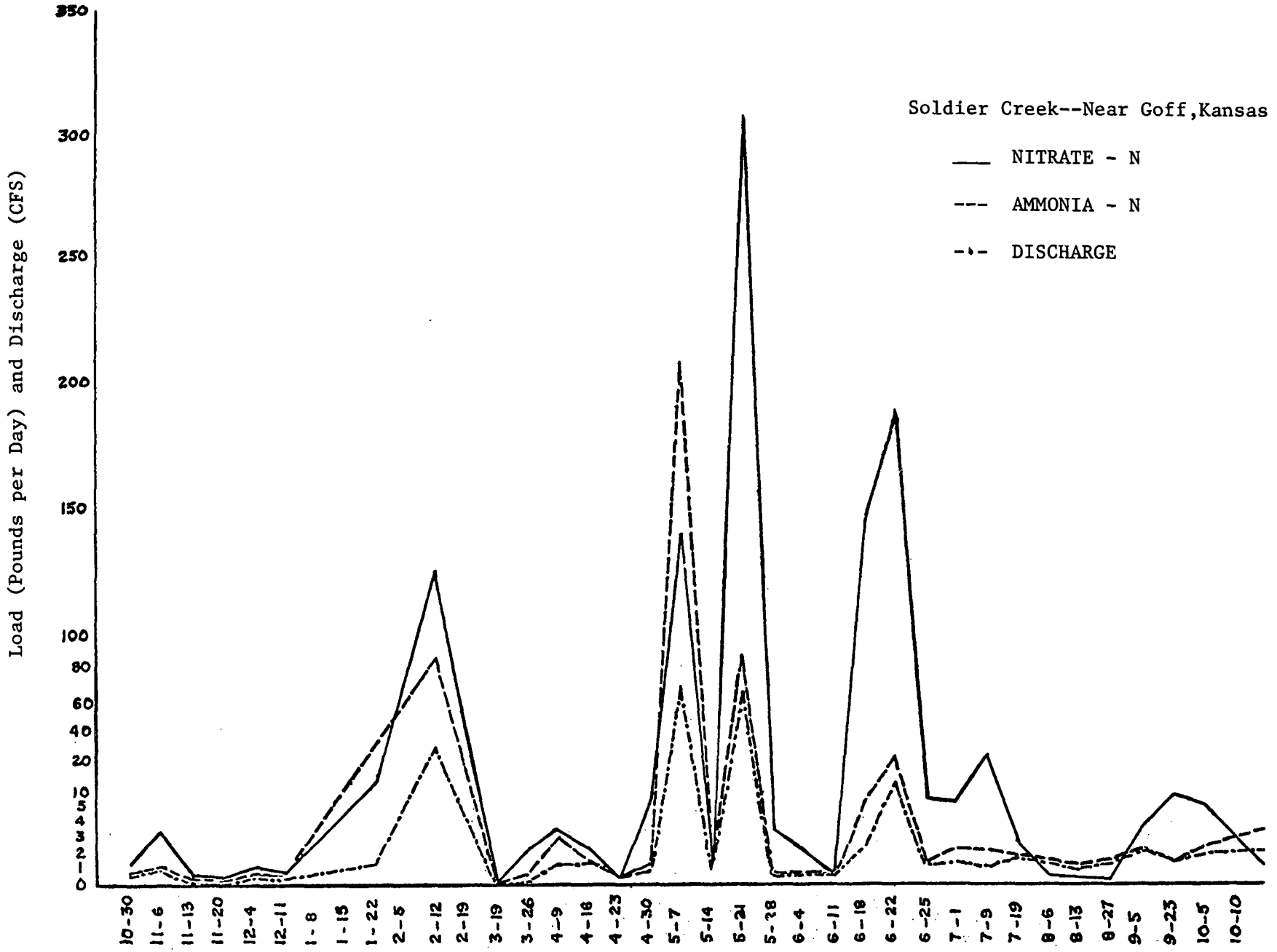

Figure 6 -- Nitrogen Runoff From An Agricultural Watershed

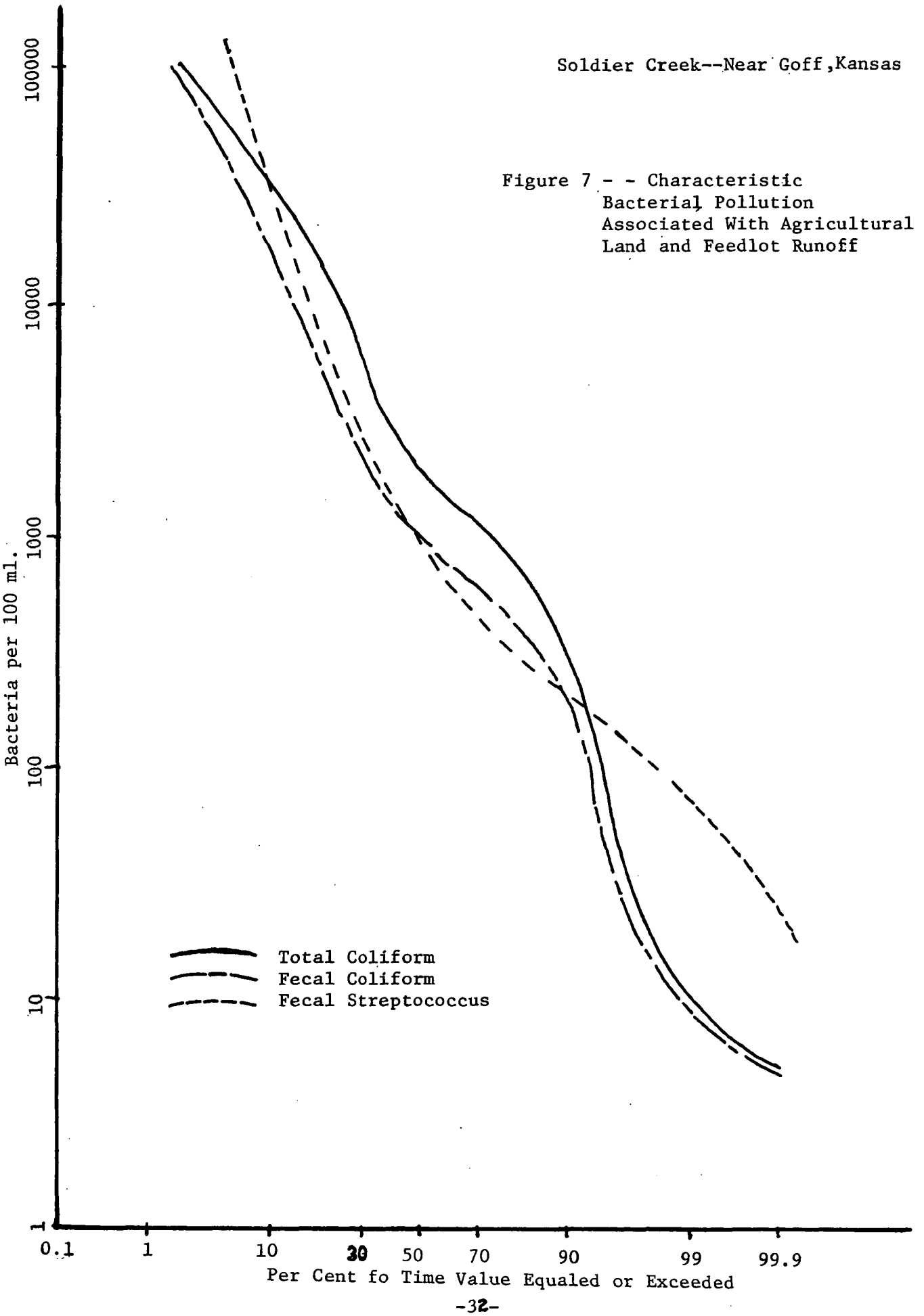

Figure 7 - - Characteristic Bacterial Pollution Associated With Agricultural Land and Feedlot Runoff

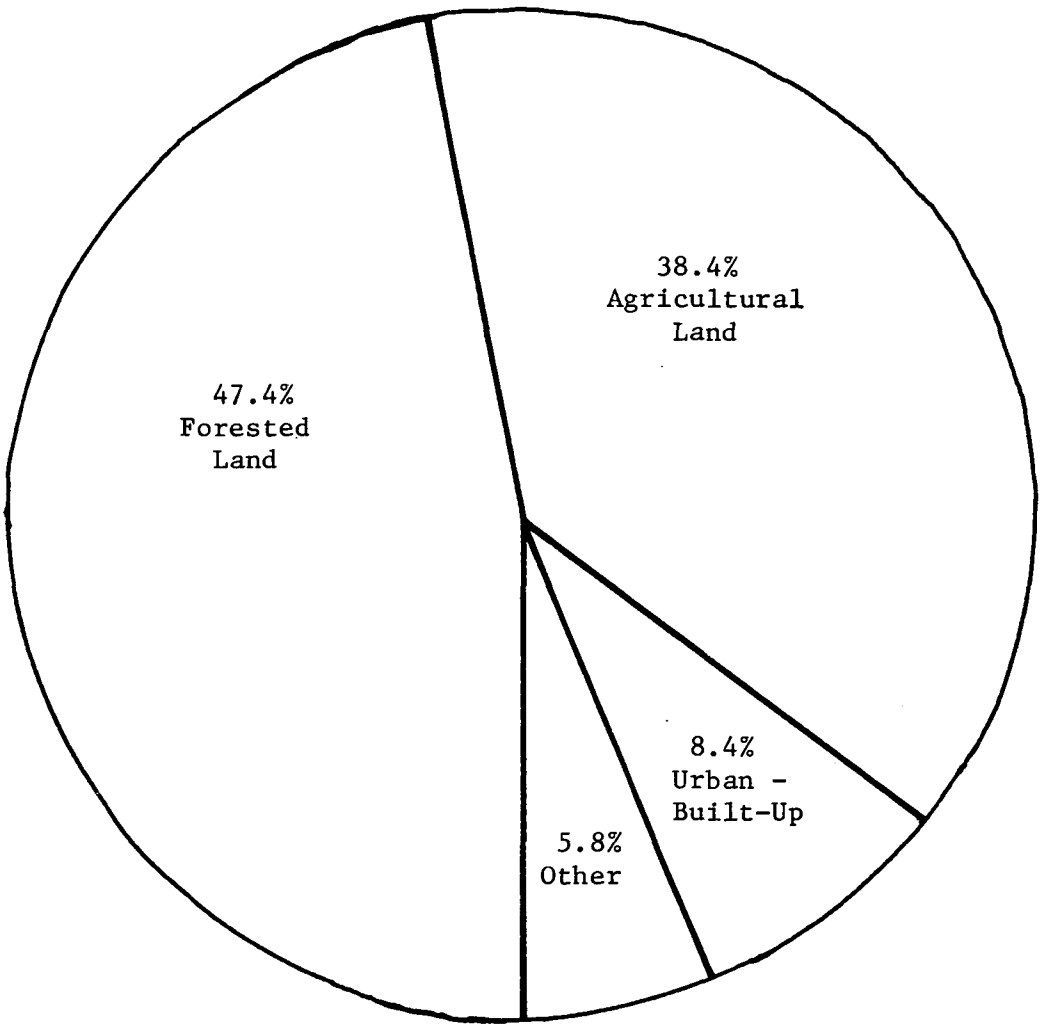

Figure 8 -- Land Use Patterns for the Great Lakes Basin,U.S. 1967

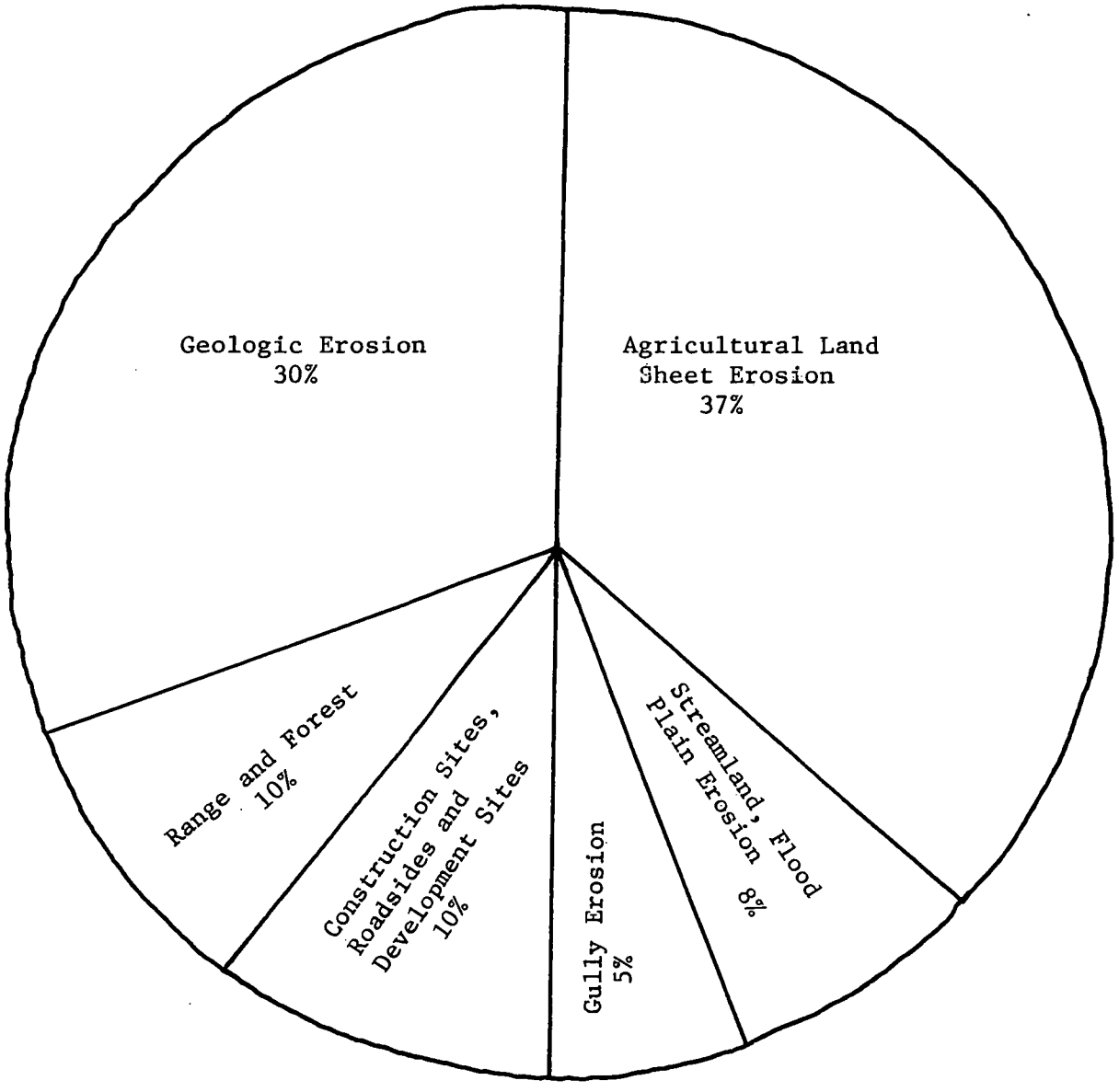

Figure 9 -- Estimated Sediment Contributions by Source;
Great Lakes Basin, U.S., 1967

TABLE 5 -- SEDIMENT DELIVERED TO LAKE ERIE[1]

Unit	Sheet (A)	Stream-bank (B)	Urban (C)	Roadside (D)	Total
Black River	32,600	1,400	-		34,000
St. Clair Complex	22,200	1,300	-		23,500
Clinton River	38,500	1,500	8,000		48,000
Rouge River	107,600	1,400	22,000		131,000
Huron River	57,400	1,600	6,000		65,000
Swan Creek Complex	58,300	700	-		59,000
Raisin River	116,200	2,800	-		119,000
Maumee River	1,159,000	7,000	13,000		*1,179,000
Toussaint-Portage Complex	111,900	2,100	-		114,000
Sandusdy River	223,700	2,300	-		* 226,000
Huron-Vermillion Complex	214,000	2,000	-		216,000
Black-Rocky Complex	119,100	1,900	9,000		130,000
Cuyahoga	183,000	1,600	16,000		* 200,600
Chagrin Complex	28,500	1,000	8,000		37,500
Ashtabula-Conneaut	15,300	700	-		16,000
Erie-Chautaugua	50,400	1,600	8,000		60,000
Chattaragus	16,700	1,300	-		18,000
Tonawanda Complex	34,800	3,200	17,000		55,000
				21,000	21.000
Basin Total	2,610,3000	36,800	107,000	21,000	2,775,100
Percent of Total	94	1.0+	4.0-	1.0-	100

* Measured USGS Data

(A) Based on an average annual rate computed from conservation needs data by soil resource areas. Delivery ratios applied based upon drainage area size averages.

(B) Based upon average erosion rate of 27 tons per square mile found in recent streambank erosion study. Delivery ratio applied.

(C) From special evaluation of urban erosion, Great Lakes Basin Framework Study. Delivery ratios applied.

(D) Based upon recent roadside erosion study in Wisconsin. Delivery ratios applied.

[1]Great Lakes Basin Framework Study - Land Use and Management Appendix 13 Aug. 1970.

TABLE 6 -- SEDIMENT DELIVERED TO LAKE MICHIGAN 1/

Hydrologic Unit	Annual Tons Delivered From:			
	Sheet Erosion	Streambank	Urban Construction	Roadside
Menominee Complex	25,000			
Menominee River	21,000			
Peshtigo River	7,000			
Oconto & Pensaukee Complex	36,000	25,000		
Saumico Complex	7,000			
Fox River	138,000		3,000	
Green Bay Complex	217,000			
Chicago-Milwaukee Complex				
Wisconsin	199,000			
Indiana	232,000		20,000	
Illinois	-			
St. Joseph River	310,000			
Black River South Haven Complex	79,000			
Kalamazoo River	144,000	17,000	26,000	
Black River-Ottawa Complex	31,000			
Grand River	217,000			
Muskegon River	43,000			
Sable Complex	97,000			
Manistee River	25,000	19,000		
Traverse Complex	85,000			
Seoul Choix-Groscap Complex	5,000			
Manistique River	3,000			
Bay De Noe Complex	4,000			
Escanaba River	4,000			
Total Lake Michigan Basin	1,929,000(A)	61,000(B)	49,000(C)	4,000(D

Grand Total Delivered to Lake Michigan: 2,043,000 Tons Per Year

(A) Based upon computed sheet erosion rates and delivery ratios applied by hydrologic units.

(B) Based upon recent streambank erosion study, mean average of 27 tons per square mile erosion, delivery ratios applied.

(C) Based upon special urban erosion study, delivery ratios applied.

(D) Based partly upon special roadside erosion study in Wisconsin. Erosion rate estimated at 20 tons per acre, delivery ratios applied.

1/ Great Lakes Basin Framework Study - Land Use and Management

Appendix 13 August 1970

TABLE 7 -- SEDIMENT DELIVERED TO LAKE SUPERIOR 1/

Unit	Erosion Source - Tons Per Year				
	Sheet	Streambank	Urban	Roadside	Total
Superior Slope Complex	24,100	5,600			
St. Louis River	6,400	3,000	15,400		59,200
Nemadji River	4,200	500			
Apostle Islands Complex	25,700	4,200			29,900
Bad River	8,500	1,000			9,500
Montreal River	2,400	400			2,800
Porcupine Mountain Complex	11,100	2,500			13,600
Ontonagon River	2,800	1,300			4,100
Kenasna Peninsula Complex	14,200	3,300			17,500
Sturgeon River	2,200	900			3,100
Huron Mountain Complex	5,900	2,300			8,200
Grand Marain Complex	7,300	2,900			10,200
Tehquanenen River	1,100	900			2,000
Sault Complex	1,700	600			2,300
				21,600	21,600
Basin Total	117,600	29,400	15,400	21,600	184,000
Percent of Total	64 A	16 B	8 C	12 D	100

A Based on an average annual rate computed from conservation needs data by soil resources areas. Delivery ratios applied based upon drainage area size averages.

B Based upon average erosion rate of 27 tons per square mile found in recent streambank erosion study. Delivery ratios applied.

C Duluth-Superior Metropolitan area. Based upon present average annual erosion from urban construction of 76,000 tons (from urban erosion evaluations in Great Lakes Basin Framework Study). Delivery ratio of 25 percent assumed.

D Based upon recent roadside erosion study in Wisconsin. Rate of 20 tons erosion per square mile. Delivery ratios applied.

1/ Great Lakes Basin Framework Study - Land Use and Management Appendix 13

August 1970

Little specific information regarding the magnitude of the animal waste pollution hazard in the Great Lakes watersheds, is available. However, from data that is available, it is estimated that 15,000 tons of phosphorus and 67,000 tons of nitrogen are produced by the cattle, chicken and hog population in the United States section of the Lake Erie basin (Federal Water Pollution Control Administration, 1968). It is estimated that 9,000 tons of phosphorus and 45,000 tons of nitrogen are produced by the cattle, chicken and hog population in the United States section of the Lake Ontario basin. Again, it must be emphasized that these are total figures, and that the actual contribution to the respective lakes from these wastes may represent only a small fraction of this total.

E. Sediment

Sediment can be a serious pollutant. Deposition of silt in lakes and reservoirs is detrimental, and rectification by dredging is very costly and creates other pollution problems. Silt, as enumerated earlier, also serves as a primary transport medium for both phosphates and pesticides. The colloidal and organic fractions are usually the most active in this respect. The degree to which sediment can adsorb and transport phosphates and pesticides depends upon its chemical and mineralogical

characteristics. Particulate organic matter can serve as a carrier until it is broken down by microorganisms. Since sediment is such an important constituent of water pollutants, it deserves special consideration. At least 4 billion tons of sediment are produced through erosion in the United States annually. Of this, about 2 billion tons are washed into streams and up to 1 billion tons reach tide-water.

The sediment contribution to the Lakes Erie, Michigan and Superior from their basins are shown in Tables 5, 6, and 7. Major contributory sources, such as sheet, streambank, urban and roadside erosion, are indicated. To further evaluate these sources, the land use distribution in the Great Lakes Basin is shown in Figure 8. The percentage contribution from each of these sources is shown in Figure 9.

Actually, the Great Lakes Basin produced only 0.4 percent of the Nation's total sediment. Less than 25 percent of the total land area in the Great Lakes Basin is rural land with an erosion hazard. Except for the Maumee River sub-basin, the concentration of sediment in streams is less than 270 ppm. In the Maumee River sub-basin concentrations range from 270 to 1900 ppm, and contributes two million tons per year of sediment to Lake Erie.

Direct measurement of the total phosphorus concentration, including that on the suspended mineral material, is not a useful measure of the amount available for plant growth. Most of the phosphorus is inert, i.e. dissolves very slowly. The reactive surface-adsorbed fraction usually comprises less than 5 or 10 percent of the whole. Thus, the amount of biologically active phosphorus is a small fraction of the total in sediment-laden stream waters. For example, water containing a sediment load of 0.1 percent by weight, with 1,000 ppm of phosphorus in the sediment, would have a total phosphorus concentration of 1.0 ppm. The amount in true solution might be 0.1 ppm or less which may still be sufficient to trigger algae growth. Settling out of the sediment will carry down considerable amounts of phosphorus that may be re-suspended in the upper water under storm conditions. In some instances, suspended sediment may actually remove phosphorus from solution, thereby lowering the concentration of soluble phosphorus. Thus, sediment may act as a sink for phosphorus rather than a source. On the other hand, it is known that phosphates will be slowly released from bottom sediments to be redissolved in the carrier streams.

Technology is currently available to minimize sediment production from various sources. Continuing implementation

of soil and water management practices is necessary to conform to changes in land management and construction patterns.

Land Disposal of Municipal Wastes

The disposal of municipal wastes and sludges for application to land for land beneficiation or for crop growth is receiving greater attention.

Several concepts are being demonstrated to obtain the necessary technological, water quality, and operational data to determine the usefulness and/or limitations of this method of waste management.

The Pennsylvania State University has demonstrated that secondary sewage effluent can be disposed of safely on agricultural land. Full scale demonstrations of sewage effluent and sludge disposal utilizing the most advanced technology and management controls are being sponsored by the Environmental Protection Agency in Muskegon, Michigan and Chicago, Illinois. In Phoenix, Arizona, it has been demonstrated

that by careful management secondary effluents can be safely used for ground water recharge.

F. Agency Descriptions

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency is the agency with direct statutory responsibility for conducting programs leading to the abatement, prevention, and control of all water quality problems. The agency's ultimate function is one of enforcement (with monitoring and surveillance), however, the total program encompasses an extensive (approximately 50 million dollars) in-house and extramural (contract and grant) program in Research and Development, and the one billion dollar Federal Construction Grant program (for municipal sewage facilities). In addition, EPA is involved with numerous Federal cooperative programs, pollution control training and education; and State cooperative program and planning grants program including basin-wide planning to incorporate agricultural water users and pollution sources.

Within the Research and Development program, agricultural pollution control is a major concern, and currently accounts for about 7 percent of the Research and Development budget. Included are research, development and demonstration projects into improved methods to alleviate or abate all agricultural sources of pollution. The improved methods are designed to help agricultural entrepreneurs obtain waste discharges the quality of which is sufficient to meet water quality standards in any locale in the country.

U.S. DEPARTMENT OF AGRICULTURE

The Federal Pollution Control Program in agriculture is abetted by programs being conducted by several USDA agencies that provide both financial and technical assistance to help private landowners apply proper land use and resource conservation practices to their land. These practices result in soil and water conservation and in many cases have the added benefit of pollution abatement particularly in sediment control. Some of the agencies direct similar resource management programs on publicly owned lands. Other agencies carry on research and provide technical information and support to these operations agencies.

The Agricultural Stabilization and Conservation Service (ASCS), through its established system of State and local elected farmer committees, administers a series of assistance programs which includes the Agricultural Conservation Program (ACP). The ACP authorizes federal cost-sharing with farmers for carrying out conservation practices relating to soil, water, wildlife, and woodland, and recently for specific pollution abatement practices. The main area of concern in the early phases of pollution abatement has been with feedlots and other sources of animal wastes. In 1969, approximately $8.5 million was used for practices that directly or indirectly help prevent or abate pollution (primarily due to sediment) in the Great Lakes and St. Lawrence watersheds.

Research to support the land and water resource programs of the Department of Agriculture is conducted by the Agricultural Research Service (ARS). Within the total ARS program, a limited amount of funds are

allocated for pollution control. Specific projects relate to pollution from land-use sources and include investigations on: hydrologic performance of agricultural watersheds; erosion and sedimentation; soil properties, processes, and management; and practices and systems for preventing or controlling contamination of soil and water resources by agricultural chemicals and farm wastes. In other research, emphasis is being placed on reducing the amount of hazardous pesticides in the environment by developing alternative measures for pest control, e.g. sterilization.

The Economic Research Service carries out a program of economic research designed to benefit farmers. Some of the major activities include research on marketing, domestic and foreign economy, farm production, and natural resources. In the latter area are included analyses of the management of land and water resources, such as the economics of water management on farms, costs and returns of water and soil conserving practices, and alternatives for improving water quality.

Another agency which is involved in research is the Cooperative State Research Service. This Service adminsters Federal grant programs for agricultural and forestry research conducted at State agricultural experiment stations and certain other State institutions. Research on water pollution as related to agriculture, forestry and rural areas is included. All of the agricultural experiment stations in the Great Lakes States are conducting research on nutrient enrichment of waters. Some are including the contribution of soil erosion and water runoff and the role of sediment-nitrogen and sediment-phosphorus interactions in

eutrophication. Additional research is being conducted on pesticide usage, transport, and degradation, animal waste management, soil and crop management to minimize soil erosion, and the disposal of sewage sludge and sewage plant effluent on agricultural and forest lands. Conservation of the soil through technical assistance to individuals, groups, cities and towns, and county and state governments is the role of the Soil Conservation Service (SCS). Specifically, the SCS develops and carries out a national soil and water conservation program through soil and water conservation districts, administers the national cooperative soil survey, develops and carries out watershed-protection, flood-prevention, and river-basin investigation projects, helps local sponsors develop and carry out multi-county resource conservation and development projects, and gives technical assistance to land owners and operators participating in the conservation-credit and cost sharing programs of the Farmers Home Administration and Agricultural Stabilization and Conservation Service. The SCS conducted a "National Conservation Needs Inventory" which outlined 1066 small watersheds in the Great Lakes St. Lawrence region. Three hundred-three of these, covering approximately 24,500,000 acres, are considered feasible for development for water and land conservation and flood control under Public Law 566 (83rd Congress, 1954). Local sponsoring organizations have made application for 74 of these, 31 have been authorized for planning, and authorization for construction has been given for 21 projects. Eight projects have now been completed with a total area of 381,000 acres. The Cooperative Extension Service conducts a continuing overall educational program to aid the public. Part of this effort is concerned

with the possible health hazards of water, air, and land pollution. Safe and effective methods for using pesticides and fertilizers which will result in maximum production advantage and minimum adverse effects on living conditions and plant and animal life forms are stressed. There are county offices in nearly all of the counties in the Great Lakes and St. Lawrence River watersheds. The staffs in the watershed area plan to devote approximately 40 man-years to education work on pollution abatement in FY 1971. Responsibliity for applying sound conservation and utilization practices to the natural resources of the National Forests and for promoting these practices among all forest landowners rests with the Forest Service. Cooperation with private landowners, and with State, local, or private organizations is the role of the State and Private Forestry Service. The programs of this division are aimed at protecting the forests and watersheds against fire, insects, and disease, encouraging better forest practices, aiding in the distribution of planting stock for forests, and stimulating the development and proper management of State, County, and Community forests. A total of $4,377,000 in FY 1971 was allocated by the Forest Service to the States in the Great Lakes area for State and Private Forestry Cooperation.

U.S. DEPARTMENT OF THE INTERIOR

The National Park Service operates a system of national parks, monuments, and similar reservations throughout the United States. In addition to providing for the public enjoyment of the parks, the Park Service is required to give the fullest possible protection to the natural resources comprising such parks. The protection program consists not only of the prevention of fires, stream pollution, and injury to natural, historic, or prehistoric features, but also of restricting uses that are incompatible with the basic purposes of the parks. Six National Park Service Areas are located in the Great Lakes Basin Area; although not all areas are fully developed nor has total land acquisition been completed, the total area of presently authorized Parks is approximately 755,000 acres.

STATE AGENCIES

Many sub-groups within the various state governments are involved in programs relative to land use, such as the Departments of Agriculture, Highways, Natural Resources and Pollution Control. The organization and responsibilities of the groups differ from state to state, but in general the Departments of Agriculture will support programs to inform the agricultural communities on subjects of farming practices, marketing, pesticides application, and livestock production and frequently will advise the legislative branch on matters of control of pesticide usage, livestock wastes and other agricultural pollutants.

The Highway Departments, responsible for state roadway construction and maintenance, apply guidelines for reducing pollution during construction and for minimizing pollution from application of chemicals for soil conditioning, pest control along right-of-ways, and surface treatment during winter conditions. The State Highway Departments advise the county and municipal highway departments on recommended procedures but do not have any direct control over their practices.

The organization of the pollution control agencies differs widely from state to state; the agencies have varying degrees of responsibility dependent upon the particular environmental control laws of the state. All states have water quality standards which describe the quality of water to be maintained on the various interstate watercourses and most states in addition have adopted criteria for their intrastate waters. It would be on the basis of the limits on pollutants, detailed in the water quality standards, that most pollution control agencies would have some degree of control over agricultural operations.

On the other hand, in states where a particular potential problem may exist, such as from livestock feedlots, special regulations have been proposed and in some instances enacted into law (excerpts for the State of Kansas Agricultural Waste Control Law are given in the appendix). None of the states within the Great Lakes Region now have feedlot pollution regulations although several states have drafted proposed controls which are in various stages of approval and adoption.

Similarly, pesticide regulations have been adopted or are being considered in several states. These regulations range from the banning of certain long - lasting chemicals from all use in the environment to the licensing of professional application firms and distributors of chemicals on restricted lists.

To consider some problems of widespread occurrence, regional committees are sometimes established. Once such group is the 5-State Governors' Interdisciplinary Pesticide Committee. Authorized on September 2, 1969, representatives from various areas or disciplines in Michigan, Indiana, Illinois, Minnesota, and Wisconsin were formed into the Committee and charged with considering the pesticide problems that are unique to the Lake Michigan Basin. A survey, detailing the general farm use of pesticides, has been make for the five states through the cooperation of the State-Federal Statistical Reporting Services in each of the states.

III. PROBLEMS OF MANAGEMENT AND LAND USE ACTIVITIES

Although there are large numbers of agencies, Federal, State, and local, that have programs relating to land use activities, many are ineffective in significantly abating pollution from agriculture or other land use operations. Chiefly this is due to limitations imposed by the working of the basic law, charter, or order that has established the agency and which delineates the areas in which the body is empowered to operate. For example, the Soil Conservation Service (SCS) activities in the Great Lakes Region are limited to the technical assistance and advisory programs detailed elsewhere in this report. The SCS programs have been established for the purpose of conserving soil and establishing optimum agricultural conditions. The emphasis has not been on retarding erosion because of its pollutional properties. Therefore, in areas of the region where there is little local agricultural interest in the SCS programs nothing has been or can be done to abate soil erosion even though it may be extensive. These same comments generally apply to the Agricultural Conservation Program of the Agricultural Stabilization and Conservation Service. While it is true that some pollution has been abated by past programs of these agencies, it has not been and still is not their main emphasis.

The lack of local interest in utilizing the existing soil conservation programs of the SCS and ASCS may be the product of several factors. Primarily, there is a lack of understanding and appreciation of the pollutional effects of soil erosion in the majority of the agricultural community. This exists

in spite of an extensive and commendable educational program conducted by the U.S. Department of Agriculture through the Extension Service and other agencies and through some State advisory services. Because of economic pressures, many farms are currently financially marginal operations and their operators cannot afford to take pollution abatement steps even with the help of certain cost-sharing programs. Other individuals are reluctant to spend any money unless it will bring them some monetary return. And lastly, there is a feeling of distrust among many operators for becoming involved in any way with governmental programs.

At the present time the agricultural advisory agencies must rely upon local initiative to install their practices. They have no provisions whereby their assistance is mandatory or even that if their planning design assistance is requested, that it must be followed. The Soil Conservation Service's recently completed National Conservation Needs Inventory clearly outlines areas where erosion control practices could effectively be installed; however, there is no law or regulation which will direct Federal, State, or local efforts in implement programs on these priority areas.

The Soil Conservation Service, through Congressional action has been empowered to cost share with farmers in the Great Plains region for the installation of extensive land conservation practices. This program allows up to $25,000 for a broad program of conservation practices to be installed on a farm and establishes a total land management scheme on the property of the cooperating landowner. Such a comprehensive program is lacking in the Great Lakes Region.

While public ownership of the land makes possible the implementation of standardized conservation and pollution control programs, it by no means is the optimum condition and often is not totally effective except in the case of involved and informed citizenry. For example, in most cases federal and state highway departments are doing a good job of applying erosion control measures to highway rights-of-way over which they have jurisdiction. This cannot be said for many of the country and township highways. Frequently, unprotected highways roadbanks are major sources of sediment accumulating in streams. Responsible units of government recognize the problem; however, funds are usually limited so that funds are used primarily to provide a transportation facility for vehicles.

Problems may develop in local areas for which there is no adequate means of coping with the situation. The National Forests in the Great Lakes watershed received a total of 7,001,800 visitor days of recreation use during calandar year 1969. Studies indicate this use is increasing by 5% - 7% per year. While this indicates a real potential for pollution of the environment, the current pollution abatement program will result in Forest Service facilities which are adequate to meet sanitation needs in most areas. However, there are local situtations which are potentially serious pollution threats. An example is along the rivers in the Manistee National Forest in Michigan which are visited by thousands of salmon fishermen each fall. Most of the land along these streams is privately owned and consequently has no recreational developments and few public sanitation facilities. The Forest Service is striving to meet this problem, but

public ownership of land adjacent to these rivers appears to be essential to solving it.

The problem of land management for pollution control on the National Forests is complicated by intermingled ownerships. Farm ponds, stream impoundments, stream side pastures, and faulty septic systems on private holdings make watershed improvement and protection difficult. Warm water, nutrient enrichment of the water, and sedimentation downstream are problems given to the whole watershed. Cooperative ventures of all landowners are needed under such programs as Public Law 566.

IV. Adequacy of Current Land Use Practices

Total land area of the region is 84.3 million acres.[1] Of this acreage 70.7 million acres are non-federal rural land, 7 million acres are classified urban and built-up, 6.2 million acres are Federally owned, and 0.4 million acres are in water areas less than 40 acres in size.

Nonfederal Rural Land

The conservation needs inventory compiled by the U.S. Department of agriculture covers the 70.7 million acres of rural land, which is 84 percent of the total area. By land uses this acreage is:

Cropland - 28.5 million acres (40%)
Pasture - 3.5 million acres (5%)
Forest - 34.2 million acres (48%)
Other - 5.5 million acres (7%)

Because treatments for cropland and other land are primarily for conserving the soil resource, the needs are based largely on land capability class and subclass. Pastureland and forest needs are based on the condition of the plant cover in relation to the potential of the soil to produce such vegetation as well as for soil conservation. Treatment was considered adequate on 31.9 million acres (45%) of the land in inventory. By land uses the adequately treated acreage is:

12.2 million acres (43%) of the cropland
1.1 million acres (31%) of the pastureland
15.3 million acres (45%) of the forest land
3.3 million acres (74%) of the other land

The inventory shows that 88 percent of all cropland is in capability classes I, II, and III. This large percentage represents cropland which is of a type which safely lends itself to use for crop production

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[1] 1967 land use and treatment needs inventory for the Great Lakes Water Resource Region adjusted and projected to include Herkimer, Oneida, and St. Lawrence Counties in New York, and Menominee County, Wisconsin; and to exclude Franklin County, New York.

provided supporting conservation practices are applied and the proper choice of plants is made. Another 9 percent of the cropland is in class IV which is useable as cropland provided it is very carefully managed. The remaining 3 percent is in classes V, VI, VII, and VIII and is generally unsuitable for cultivation without major treatment. Land in these last four classes, however, lends itself to such uses as grazing, woodland, recreation or wildlife food and cover. Of all the nonfederal rural land in the region, 67 percent is in classes V through VIII.

Erosion is the dominant soil limitation on 35 percent of the cropland and 32 percent of all land. Treatment is considered adequate on 42 percent of the 8.9 million acres of cropland in tillage rotation which has erosion as the dominant limitation. The remaining 58% (5.2 million acres) needs the following conservation treatment to control erosion and to prevent soil runoff (and the resultant movement of fertilizers, pesticides, and other pollutants as they are carried by sediment):

	Percent	Acres (1,000K)
Residue Management and annual cover	21.0	1.1
Sod in rotation	24.0	1.2
Contouring only	11.0	.6
Stripcropping, terraces and diversions	33.0	1.7
Change in land use to permanent cover	6.0	.3
Drainage Systems	5.0	.3
	100.0	5.2

The question of sediment as a carrier of potential pollutants is covered more fully in the section of this report which discusses the pollution problems in the region.

Pastures and privately owned forest land contribute to erosion and sediment problems, but the contribution is small in comparison to that from other agricultural and open lands. Erosion is caused by grazing of forest land, forest fires, and improper logging practices. These problems may be attributed to small ownerships, absentee ownerships, lack of interest and lack of knowledge of technical assistance available. Private recreation developments with inadequate sanitary facilities may be contributing to pollution.

National Forests

Current land use practices on the National Forests are not now contributing to pollution to any great extent. As the intensity of use increases with more people using the lands, the level of protection will have to be increased. Nutrient enrichment now so evident on some lakes in the Superior National Forest will quite possibly be the most important area of concern on all National Forests of this area.

Because sedimentation is one natural source of nutrients that can be controlled, soil and mantel management is imperative. The high fertility level of soils on the Superior National Forest indicates that soils adjacent to the lakes can make a significant contribution of nutrients.

At present, there are approximately 400 miles of eroding streambank and lakeshore on National Forest land in the Great Lakes Basin. The total miles from non-Federal holdings is proportionately much greater. This type of erosion has resulted in the filling with sediment of Stronach Reservoir on the Pine River on the Manistee National Forest. Over a 40-year period, sediment filled the 640-acre feet storage capacity of Stronach, a rate of 16 acre feet per year from the 290

square mile watershed. The use of the dam for power was discontinued in the early 1950's because of sediment, with the sediment now beginning to fill Tippy Dam a few miles downstream. Eroding banks along the Pine River in Michigan are as high as 150 feet.

Sediments from eroding streambanks are detrimental by 1) affecting fisheries; 2) loss of valuable land; 3) filling reservoirs; and 4) filling harbors.

The problem of land management for pollution control on the National Forests is complicated by intermingled ownerships. Farm ponds, stream impoundments, stream side pastures, and faulty septic systems on private holdings make watershed improvement and protection difficult. Warm water, nutrient enrichment of the water, and sedimentation downstream are problems given to the whole watershed. Cooperative ventures of all landowners are needed under such programs as Public Law 566.

Surface-Mined Areas

Accelerated erosion is often particularly acute in areas of strip mining operations. A number of states have enacted legislation regulating surface mining operations and establishing requirements for the restoration of disturbed lands. Such legislation and resulting programs have been directed only at operations carried out subsequent to enactment of this legislation and do nothing to restore past "workings" which have been left as sources of sediment and other land and water pollutants.

The enforcement of restoration regulations will result in increased costs of operation which mining operators will pass on to society

in the way of increased costs for the products mined. For those areas previously mined where restoration was not required it can be said that society received the mined products at a subsidized rate (in the amount of the restoration costs that would be required) and therefore should contribute to the restoration of such lands. The solution to the problem of reducing pollution that is and can continue to arise from such sources include:

(1) Enactment and enforcement of suitable strip mine restoration laws in or applicable to all States.

(2) programs to assist the restoration of areas that have undergone surface mine operations prior to enactment of suitable regulatory legislation. Such programs would need to provide for technical as well as financial assistance to units of government and landowners in planning and carrying out the necessary restoration work.

The restoration of such lands is not feasible from the standpoint of a return to agricultural productivity. Their restoration must largely be justified on environmental and aesthetic bases. The establishment of satisfactory cover on most areas requires two or more years depending upon the nature of the mine spoils. To be effective it is essential that efforts to deal with surface mined land be programmed over a period of time and provide for long term contracts between the Federal government and State or local agencies, or private landowners, as appropriate, to assure

the establishment and maintenance of needed work.

Erosion in Urban Areas

One of the greatest opportunities to reduce the volume of sediment reaching surface waters lies in the adoption of development practices and in the planning and installation of soil water conservation measures that will effectively reduce soil erosion and sediment production in expanding urban areas. Land denuded of plant cover during long construction periods has rates of erosion as high as 89,000 tons per square mile annually. Such sediment contributes to the filling of stream channels, and causes damage and economic loss to the public and private sector. Much of this can be prevented with timely planning and action, including the adoption of needed regulatory measures on the part of local governmental agencies.

The following table summarizes the current estimate of average annual erosion from urban development activity in the metropolitan complexes of the Great Lakes Basin. These areas do not cover all of the economic growth areas of the Basin, so an additional 10 to 20% should be added to properly reflect all urban development activity in the basin.

Table 8

ESTIMATED POTENTIAL TOTAL EROSION FROM URBAN DEVELOPMENT ACTIVITY

PRESENT THROUGH THE YEAR 2020

Metropolitan Complex	Average Annual Tons Per Year (1000's)						
	Present	1970	1980	1990	2000	2010	2020
Duluth-Superior	76.8	74.5	77.6	82.2	87.6	93.0	98.5
Green Bay-Oskosh	68.4	74.6	81.4	91.0	100.5	112.9	127.9
Milwaukee	314.0	376.8	439.6	518.1	590.3	678.2	781.9
Chicago	2642.8	3065.6	3409.2	3805.6	4202.0	4625.0	5179.9
South Bend-Elkhart	167.4	187.5	204.2	226.0	246.0	272.8	303.0
Kalamazoo-Battle Crk.	135.8	165.7	194.2	226.8	263.4	302.8	350.4
Grand Rapids	147.0	166.1	185.2	207.3	232.3	260.2	295.5
Lansing-Jackson	136.0	165.9	194.5	227.1	263.8	303.3	350.9
Bay City-Sag.-Flint	164.0	190.2	214.8	246.0	301.8	342.8	346.0
Detroit	1600.0	1904.0	2192.0	2528.0	2800.0	3168.0	3600.0
Toledo	86.6	91.1	106.5	119.5	132.5	148.0	166.3
Fort Wayne	102.0	122.4	142.8	168.3	195.8	228.5	267.2
Loraine-Elyria	90.0	99.0	108.9	122.4	135.9	151.2	169.2
Cleveland-Akron	817.0	898.7	988.6	1102.9	1233.7	1372.6	1536.0
Erie	79.0	81.4	89.3	98.0	106.7	116.9	130.4
Buffalo	163.5	171.7	188.0	207.6	227.3	248.5	274.7
Rochester	112.6	129.5	145.2	163.3	185.8	209.4	236.5
Syracuse-Rome	161.5	177.7	197.0	221.3	247.1	274.6	306.9
GREAT LAKES BASIN	7064.4	8147.4	9159.0	10361.4	11552.5	12808.7	14521.0

Roadside Erosion

In most cases federal and state highway departments are doing a good job of applying erosion control measures to highway rights-of-way over which they have juriodiction. This cannot be said for many of the county and township highways. Frequently, unprotected highway roadbanks are major sources of sediment accumulating in streams. Responsible units of government recognize the problems; however, funds are usually limited so that funds are used primarily to provide a transportation facility for vehicles.

National Park Service

All plans for sanitary and water systems are submitted to the Environmental Protection Agency and state and local authorities for review. The more stringent set of standards are used for design purposes.

In addition, Public Health personnel inspect the parks and we make an effort to correct as soon as possible any defects or adverse situations which are uncovered in these inspections.

The only fully developed parks in the Great Lakes Basin are Perry's Victory in Put-in-Bay, Ohio and Lake Royale National Park in Lake Superior. The former is small and contributes to pollution.

On the other hand, Isle Royale has contributed to both water and atmospheric pollution. Thus in the tentative 1972 Fiscal Year construction program NPS has items for the construction of three incinerators, two can crusher units, and two boat service dock and sewage systems. The dock units will enable boat owners to discharge their waste materials into holding tanks which are inturn connected to septic tanks and leeching fields.

V. CURRENT PLANNING, ADVISORY, AND REGULATORY STANDARDS

Water Quality Standards

The Water Quality Act of 1965 provided that the Fifty States would develop Water Quality Standards for interstate waters and continguous waters in the United States, subject to the approval of the Federal Government. The Fifty States, to date, have promulgated these Standards and have received approval for all except for some special cases.

Pollution problems associated with agricultural are characteristically non-point source in origin and are more insidious thatn those normally exemplified by municipal or industrial point discharges. Moreover, the primary water pollution problems have heretofore been associated almost entirely with these point sources of waste discharges. As the National effort to cope with water pollution has increased however, the technology to control a major portion of these wastes has become available, and much of the legislation required to implement the use of the technology has been enacted or promulgated. The principal vehicle for implementation is the system of water quality standards that have been enacted by the States. These standards are designed to effect control of water quality in a manner to protect all beneficial uses of water including agriculture. However, the standards emphasized bacterial, chemical, and dissolved oxygen specification and generalized in development

to have impact on all pollution sources. Yet, some pollution sources were very partially considered (or not at all) since the criteria necessary to develop specific standards was not available for all sources. Among the sources which received little specific attention was agricultural runoff.

The gradual control of point sources, coupled with the refinement of their treatment control systems, has necessitated a re-direction of the National effort to encompass a major program to develop criteria, standards, and methods to abate, prevent, or control all sources of agricultural runoff pollution.

The vast diversity which characterizes the agricultural industry dictates that an extensive research and development effort be undertaken to develop and demonstrate a complete array of means to control the many pollution sources. Coincident with the development of the control measures will be the development of water quality criteria (based upon the effluent quality required) and water quality standards which relate specifically to runoff of agricultural chemicals, sediments, salinity and feedlot wastes.

Impact on Agriculture

The key to relating the impace of water quality standards upon agricultural operation lies in the recognition of the fact that farming operations (and operators) just like "heavy" industry and municipalities are liable to meet existing water quality standards. Since agricultural

sources were not explicitly considered in the promulgation of the Water Quality Standards, two problems arise: (1) a farmer must meet a standard which may have little direct relation to his operation; and (2) the control measures a farmer now has available are often remedial and may cause as many problems as they solve. In addition to these problems, farmers have yet to reap the benefit of an effective, concerted education program which fully describes their responsibilities in water quality control, the current, best types of pollution control measures, improved operation and management ideas, and other information requiried for efficient waste management systems.

Water quality standards for agricultural wastes will be designed to achieve water pollution control in a context which reflects: (1) the need "to protect public health and welfare," and the need to eliminate the discharge of matter into interstate waters which reduces the quality of such waters below (established) water quality standards";[1] and (2) a defined associative relationship between the standards to be met and the type of farm production enterprise, the product needs (e.g. pest controls) of the enterprise, and national food and fiber production requirements. Therefore, agricultural operations not only will be capable of succeeding in their primary mission, but also capable of effectively implementing their (already existing) responsibility to protect the Nation's water resources by utilizing any one of an array of treatment, control, or management systems that are now being developed and refined.

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[1]Federal Water Pollution Control Act, As Amended, Section 10, FWQA June 1970.

Design Standards

1. Soil Conservation Service

a) There are minimum conservation treatment standards that must be met in contributing watershed areas before retarding structures may be installed with assistance either under the Watershed Protection and Flood Prevention, or Resource Convervation and Development Programs. The requirements are that:

(1) The owners of 50 percent of the lands in the drainage areas must agree to carry out recommended soil conservation measures and proper farm plans, and

(2) Seventy-five percent of the critical sediment source areas must be treated on undergoing treatment.

b) Conservation planning standards, used in working with land users in planning for adequate soil and water conservation programs, are based on the reduction of erosion losses to acceptable minimums.

c) Guidelines have been issued outlining SCS policy for minimizing soil erosion and water and air pollution that may be a result of construction carried out by or with the assistance of SCS.

d) Watershed Protection and Flood Prevention and Resource Conservation and Development Project assistance may be provided for fish and wildlife and recreational developments, including needed basic facilities. State and local requirements relating to public health and to the prevention, control and abatement of water pollution must be complied with. This also is true for the installation of measures

designed to control certain agricultural related pollutants, e.g., wastes from feedlots.

e) The Soil Conservation Service provides assistance in the installation of about 120 different soil and water conservation practices or measures. Standards and specifications have been established for each, based on research and observed results, to assure their installation in a manner that will be effective in achieving the objectives for their installation.

f) The Soil Conservation Service has issued an environmental memorandum stating its policy concerning the use of pesticides in all its programs.

2. Forest Service

a) Advanced waste treatment methods used to protect water quality at installations in national forests include:

(1) Lagoons to improve effluent quality such as polishing ponds.

(2) Filter beds to remove suspended solids.

(3) Seepage lagoons to provide subsurface disposal.

(4) Aerated lagoons to increase dissolved oxygen.

(5) Detention ponds or chlorination chambers for disinfection of fecal effluent.

(6) Agricultural utilization of sewage effluents by spray irrigation or surface application by use of gravity lines in forested areas and vegetated fields.

In summary nearly all wastes from sewage treatment facilities are disposed of by either subsurface or soil renovation methods. There are only three locations from which there

is a total discharge of less than 40,000 gallons to surface water, after treatment, within the Great Lakes Basin.

All waste treatment methods have been approved by the states and the Environmental Protection Agency.

b) Roads: Pollution Control Practices

Bank stabilization and other soil retention methods are used to reduce erosion and stream sedimentation.

Ditch checks, diversion channels, riprap, rubble masonry and other devices are also used extensively to check runoff and reduce siltation of surface water.

Provisions for stabilization of slopes during road constuction are included in contracts. Seed, lime, and fertilizer are applied after a reasonable footage of slipes are completed. In many cases a good catch of turf has developed after 2-3 months.

The fertilizers are used in limited applications. The total available nutrients are either used by the plants and grass or retained in the soil. The total contribution to stream pollution would be very minor.

Calcium chloride is used in roadbed stabilization but is essentially retained in the surfacing material. There is no detectable contribution to pollution as a result of the limited application.

Sodium chloride is used on only a few forest roads in limited amounts for road surface stabilization. The pollution potential is therefore very remote.

Sodium chloride is also used to some extent on roads within the forest boundaries for ice removal. This is recognized as being a potential pollution problem that is created by state, county, and township road crews.

The use of salt can be minimized by mixing with sand before application. Some highway departments are using this method to correct winter driving hazards and also reduce the amount of salt used.

The use of herbicides for controlling brush and tree growth within right-of-ways has been reduced to a minimum inside the forest boundaries in recent years. The selective hand spray and control methods presently used limits the amount of herbicides used and thereby the pollution potential.

The Forest Service cooperates with the Environmental Protection Agency , Bureau of Public Roads, Soil Conservation Service, state health departments, and state and local highway departments in all engineering activities.

APPENDIX

Data On Pesticide Use And Animal Production

In The U.S. Great Lakes Basin

Table A1

Quantities of pesticides used by farmers on crops, livestock, and for other purposes, Great Lakes Basin, United States, 1966[1].

Major use	Pounds active ingredients[2] 1,000 pounds
Crops[3]	23,545
Livestock[4]	3,285
Other[5]	548
Total	27,378

[1]Estimated based on use shown by the ERS Pesticide and General Farm Survey, 1966.
[2]Includes sulfur and petroleum
[3]Includes all crops, pasture, and rangeland.
[4]Includes livestock buildings.
[5]Includes pesticides for all other noncrop and nonlivestock uses.

Table A2

Quantities used and acres treated with selected fungicides, all crops, Great Lakes Basin, United States, 1966[1].

Type of fungicide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Inorganic fungicides:		
Copper sulfates	25.2	11.0
Other coppers	126.2	35.6
Mercury compounds	5.8	28.8
Other inorganics	88.2	14.4
Total inorganics (not including sulfur)	245.4	
Organic fungicides:		
Dithiocarbamates:		
Maneb	613.2	88.6
Zineb	841.6	215.4
Ferbam	153.6	45.8
Others	128.4	22.4
Total dithiocarbamates	1,736.8	
Phthalimides:		
Captan	870.6	148.0
Others	47.0	9.6
Total phthalimides	917.6	
Karathane, Dodine, Quinones	172.8	82.0
Phenols	15.4	6.0
Other organics	30.4	17.2
Total organics	2,873.0	
Total fungicides (not including sulfur)	3,118.4	
Sulfur	1,104.8	65.0
Total fungicides	4,223.2	

[1]Estimates based on use shown by the ERS Pesticide and General Farm Survey, 1966.

[2]May include use for purposes other than as fungicides.

[3]Not additive since one or more ingredients or different commercial preparations of a single ingredient may be applied on same acres.

Table A3

Quantities used and acres treated with selected herbicides, all crops, Great Lakes Basin, United States, 1966.[1]

Type of herbicide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Inorganic herbicides	242.6	48.4
Organic herbicides:		
Arsenicals	3.4	6.0
Phenoxy:		
2,4-D	2,649.6	4,152.8
2,4,5-T	46.6	111.2
MCPA	99.6	221.8
Other phenoxy	4.4	23.8
Total phenoxy	2,800.2	
Phenyl urea:		
Diuron	22.6	20.8
Linuron	256.4	192.8
Other phenyl urea	11.4	12.4
Total phenyl urea	290.4	
Amides:		
Propachlor	442.6	308.6
Propanil	---	---
NPA	149.0	118.6
Total amides	591.6	
Carbamates:		
CIPC and IPC	77.2	80.2
CDAA	953.2	725.4
Other carbamates	277.6	93.4
Total carbamates	1,308.0	
Dinitro group	251.8	87.6

See footnotes at end of table

Table A3

Quantities used and acres treated with selected herbicides, all crops, Great Lakes Basin, United States, 1966[1]--continued.

Type of herbicide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Triazines:		
Atrazine	3,397.8	2,135.8
Propazine	---	---
Other triazines	36.0	20.0
Total triazines	3,433.8	
Benzoic:		
2,3,6-TBA	549.0	292.0
Amiben	712.8	763.4
Dicamba	8.4	27.0
Total benzoics	1,270.2	
Other organics:		
Trifluralin	237.2	262.2
Others	226.4	155.6
Total other organics	463.6	
Total organic herbicides (not including petroleum)	10,413.0	
Total herbicides (not including petroleum)	10,655.6	
Petroleum	1,263.8	61.4
Total herbicides (including petroleum)	11,919.4	

[1]Estimates based on use shown by the ERS Pesticide and General Farm Survey, 1966.

[2]May include use for purposes other than as herbicides.

[3]Not additive since one or more ingredients or different commercial preparations of a single ingredient may be applied on same acres.

Table A4

Quantities used and acres treated with selected insecticides, all crops, Great Lakes Basin, United States, 1966[1].

Type of insecticide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Inorganic insecticides	790.0	54.6
Botanicals and biologicals	.6	6.8
Synthetic organic insecticides:		
Organochlorines:		
Lindane	24.2	82.4
Strobane	---	---
TDE (DDD)	99.0	29.2
DDT	305.0	179.6
Methoxychlor	86.8	90.0
Endrin	1.0	2.4
Heptachlor	292.2	377.8
Dieldrin	35.8	51.0
Aldrin	2,744.0	2,552.4
Chlordane	57.2	46.6
Endosulfan	30.8	27.8
Toxaphene	103.6	64.4
Others	.8	3.8
Total organochlorines	3,780.4	
Organophosphorus:		
Disulfoton	148.6	116.6
Bidrin	---	---
Methyl parathion	15.0	2.0
Parathion	242.4	317.2
Malathion	111.0	89.8
Diazinon	507.4	533.0
Trichlorfon	.4	.2
Azinphosmethyl	159.8	123.6
Ethion	72.0	34.8
Others	66.6	68.4
Total organophosphorus	1,323.2	

See footnotes at end of table

Table A4

Quantities used and acres treated with selected insecticides, all crops, Great Lakes Basin, United States, 1966[1]--continued.

Type of insecticide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Carbamates:		
Carbaryl	674.4	203.4
Others	35.4	61.4
Total carbamates	709.8	
Other synthetic organics	2.4	
Total synthetic organics	5,815.8	
Total insecticides (not including petroleum)	6,606.4	
Petroleum	390.2	18.4
Total insecticides	6,996.6	

[1]Estimates based on use shown by the ERS Pesticide and General Farm Survey, 1966.

[2]May include use for purposes other than as insecticides.

[3]Not additive since one or more ingredients or different commercial preparations of a single ingredient may be applied on same acres.

Table A5

Quantities used and acres treated with selected miscellaneous pesticides, all crops, Great Lakes Basin, United States, 1966[1]

Type of pesticide product[2]	Pounds active ingredients 1,000 pounds	Acres treated[3] 1,000 acres
Miticides:		
Dicofol	47.0	29.4
Chlorobenzilate	2.0	1.6
Aramite	---	---
Tetradifon	35.0	30.0
Others	13.6	19.0
Total miticides	97.6	
Fumigants:		
Nemagon	22.0	.2
D-D misture	24.2	.2
Sulfur Dioxide	95.6	9.6
Others	110.0	66.8
Total fumigants	251.8	
Defoliants and desiccants:		
Arsenic acid	---	---
Magnesium chlorate	---	---
DEF and Folex	16.6	12.0
Others	---	---
Total defoliants and desiccants	16.6	
Rodenticides	1.8	7.4
Plant growth regulators:		
Maleic hydrazide	32.0	4.4
Others	.2	1.2
Total plant growth regulators	32.2	
Repellents	6.2	2.6
Total miscellaneous pesticides	406.2	

[1]Estimates based on use shown by the ERS Pesticide and General Farm Survey, 1966.

[2]May include use for purposes other than those indicated.

[3]Not additive since one or more ingredients or different commercial preparations of a single ingredient may be applied on same acres.

TABLE A6

NUMBER OF LIVESTOCK AND POULTRY IN THE GREAT LAKES BASIN - 1970

	Cattle on feed	Other Dairy	Milk Cows	Other Cattle	Hogs	Sheep	Chickens	Bros.
Ohio	564,038	155,640	121,808	377,798	686,889	203,354	4,539,913	1,250,634
New York	1,824,850	658,377	527,313	518,544	75,550	73,842	4,455,405	495,030
Minnesota	63,815	18,537	14,300	27,016	2,748	3,838	89,578	-------
Michigan	2,035,449	536,226	447,365	927,651	751,855	254,990	7,696,138	733,295
Pennsylvania	69,587	23,379	17,729	21,582	3,538	1,268	181,831	8,526
Wisconsin	1,484,636	629,173	603,486	627,273	381,667	35,575	2,054,427	1,921,464
Illinois	283,677	58,886	43,409	133,505	161,588	11,153	685,770	46,217
Indiana	436,509	93,914	65,779	201,235	455,749	68,130	3,949,004	4,396,777
	6,762,561	2,169,132	1,841,189	2,834,604	2,519,575	652,150	23,652,066	8,851,943

Chapter 28. State Board of Health Regulations

Article 18. Agricultural and Related Wastes Control

28-18-1. Definitions

For purposes of the regulations in this article, the following words, terms, and phrases are hereby defined as follows:

(a) The Words "confined feeding" shall mean the confined feeding of animals for food, fur, or pleasure purposes in lots, pens, pools or ponds which are not normally used for raising crops and in which no vegetation, intended for animal food, is growing. This will not include a wintering operation for cows in lots or on farming ground unless the operation causes a pollution problem.

(b) The words "confined feeding operation" shall mean (1) any confined feeding of 300 or more cattle, swine, sheep, or horses at any one time, or (2) any animal feeding operation of less than 300 head using a lagoon, or (3) any other animal feeding operation having a water pollution potential or (4) any other animal feeding operation whose operator elects to come under these regulations.

(c) The term "operator" shall mean an individual, a corporation, a group of individuals, joint venturers, a partnership, or any other business entity having charge or control of one or more confined feeding installations.

(d) "Food animals" shall mean fish, fowl, cattle, swine, and sheep.

(e) "Fur animals" shall mean any animal raised for its pelt.

(f) "Pleasure animals" shall mean dogs and horses.

(g) The words "waste retention lagoon" or "retention ponds" shall mean excavated or diked structures, or natural depressions

provided for or used for the purpose of containing or detaining animal wastes consisting of body excrements, feed losses, litter, cooling waters, wash waters, whether separately or collectively, or any other associated materials detrimental to water quality or to public health, or to beneficial uses of the waters of the state. A water retention structure shall not be construed to be a treatment facility and discharges of waste water therefrom shall not be allowed except as authorized by regulations 28-18-3 and 28-18-4.

(h) The words "waste treatment facilities" shall mean structures and/or devices which stabilize, or otherwise control pollutants so that after discharge of treated wastes, water pollution does not occur and the public health and the beneficial uses of the waters of the state are adequately protected.

(i) The words "water pollution control facilities" shall mean waste retention lagoons, retention ponds, or waste treatment facilities.

28-18-2. Registration and Water Pollution Control Facilities Permits.

(a) Effective July 1, 1967, the operator of any newly proposed confined feeding operation as defined in regulation 28-18-1(b) must register with the Kansas State Department of Health prior to construction and operation of the lot pen, pool or pond The operator of any existing confined feeding operation as defined in regulation 28-18-1(b) must register by January 1, 1968. Application for registration shall be made on a form supplied by the department .

(b) Applicants shall submit the completed application form to the department together with supplemental information regarding general features of topography, drainage course and identification of ultimate primary receiving streams. Additional information which may be deemed necessary

for satisfactory evaluation of the application may be required by and shall be submitted to the department.

(c) If in the judgment of the department, a proposed or existing confined feeding operation does not constitute a potential water pollution problem because of location, topography, or other reasons, provision of water pollution control facilities will not be required.

(d) If in the opinion of the department a confined feeding operation does constitute a water pollution potential, or if water pollution occurs as a result of any confined feeding operation, the operator shall provide water pollution control facilities which shall be constructed in accordance with plans and specifications approved by the department.

(e) Water pollution control facilities shall not be placed in use until a permit has been issued. Permits for water pollution control facilities will be issued by the executive secretary of the Kansas State Board of Health upon satisfactory completion of construction in accordance with plans and specifications approved by the department. Water pollution control facilities permits shall be revocable for cause on thirty days' written notice. If a water pollution control facilities permit is revoked, the owner or operator of the confined feeding operation involved shall be allowed to finish feeding existing animals in the lot, pen, pool or pond at the time of revocation but shall not place or allow to be placed in the lot, pen, pool or pond any other animals until the minimum requirements for water pollution control as set forth in regulations 28-18-3 and 28-18-4

have been met and a new water pollution control facilities permit has been issued.

28-18-3. Requirements for Facilities

Water pollution control facilities required shall be kept at the minimum requirements stated in the following paragraphs; provided that when site topography, operating procedures, and other available information indicate that adequate water pollution control can be effected with less than the minimum requirements, the minimum requirements may be waived; provided further that if site topography, operating procedures, experience, and other available information indicate that more than the minimum requirements will be necessary to effect adequate water pollution control, additional control provisions may be required.

(a) CATTLE: The minimum water pollution control facilities for the confined feeding of cattle shall be retention ponds capable of containing three inches of surface runoff from the feedlot area, waste storage areas, and all other waste contributing areas. Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Waste retained in detention ponds shall be disposed of as soon as practicable to insure adequate retention capacity for future needs.

(b) SWINE: Waste retention lagoons for swine feeding operations may be allowed in lieu of waste treatment facilities. Waste retention lagoons must be capable of retaining all animal excreta, litter, feed losses, cooling waters, wash waters, and any other associated materials and shall additionally be capable of retaining three inches of rainfall runoff from all contributing drainage areas.

Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Provision must be made for periodic removal of waste material from retention lagoons.

(c) SHEEP: The minimum water pollution control facilities for the confined feeding of sheep shall be retention ponds capable of containing three inches of surface runoff from the confined feeding area, waste storage areas, and all other waste contributing areas. Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Waste retained in detention ponds shall be disposed of as soon as practicable to insure adequate retention capacity for future needs.

(d) OTHER ANIMALS: Each confined feeding operation registered involving other animals shall be evaluated on its own merits with regard to the water pollution control facilities required, if any. The confined feeding of other animals shall not cause or lead to the pollution of the waters of the state by runoff water from confined feeding areas, release or escape of water from pools or ponds, improper storage or disposal of waste materials removed from the confined feeding area, or by any other means.

(e) Waste treatment facilities shall be designed, constructed, and operated in conformance with the provisions of regulation 28-18-4. If waste treatment facilities consist only of pond or lagoon type structures, there shall be a minimum of two such structures for series operation.

(f) Other methods of water pollution control shall be permitted where in the judgment of the department effective results will be obtained.

28-18-4. Operation of Facilities.

(a) The water pollution control facilities shall be operated and maintained so as to prevent water pollution and to protect the public health and the beneficial uses of the waters of the state.

(b) Waste discharges from retention ponds, lagoons, or waste treatment facilities into any watercourse shall be in conformance with the water quality requirements of the appropriate river basin criteria as set forth in chapter 28, article 16 of regulations adopted by the Kansas State Board of Health and regulation 28-18-3.

(c) Waste materials removed from retention ponds, waste treatment facilities, and/or confined feeding areas shall be disposed of or stockpiled in a manner which will not contribute to water pollution. Wastes may be used for irrigation or spread on land surface and mixed with the soil in a manner which will prevent runoff of wastes. Other methods of disposal of wastes from retention ponds, retention lagoons, waste treatment facilities, and/or confined feeding areas shall be evaluated and permitted if in the judgment of the department effective water pollution control will be accomplished.

PART B

CANADIAN SECTION

CHAPTER I: 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 nitrogren 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" cammonly 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. Attemptswill 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 in 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. 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. Absorbed by plants or microorganisms and subsequently reverted 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 absorbed 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 microorganisms 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 not 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 1.1.

Table 1.1.— Yield of Corn and NO_3-N Content of Top four Feet of Soil as Affected by Rate of Nitrogen Addition. a/

Rate of N lb./ac./yr.	Yield of grain (1967-1969) bu./ac.	NO_3-N content of soil, Fall 1970 lb./ac. 4 ft.
0	78	52
100	102	104
200	107	260

a/ J.W. Ketcheson, Unpublished data, Department of Soil Science, University of Guelph.

Even where no nitrogen has been applied since 1964, nitrates were present following harvest 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 of 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 1.2— 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)

	ppm NO_3 in solution at 5-6 foot depth			
	lb. of N/ac. supplied annually			
Rotation	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 n nitrogen availability have proven reliable. Hence, the recommendations for nitrogen fertilizer made in the Ontario Soil Testing Service operated by the Department of Soil Science, University of Guelph, for the Ontario Department of Agriculture and Food are based on 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 ploughed 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 1.3 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 1.3.— Nitrogan Recommendations for Corn by Ontario Soil Testing Service (July 1, 1969-June 30, 1970)

County[a] 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	107
Haldimand	258	95	92
Huron	305	97	96
Kent	597	100	119
Lambton	238	99	106
Middlesex	338	98	104
Norfolk	488	99	109
Northumberland	321	95	91
Ontario	560	98	100
Oxford	651	100	105
Perth	198	94	89
Peterboro	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 Ont.	10,345	97	95

[a] Only those counties or districts with more than 150 samples included.

Care must be used in interpreting the data in Table 1.3 because of the relatively small proportion 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 1.3 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 who 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 descrepancy.

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 estimated 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 1.4 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 1.1.

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 singificant 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, 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 cropland 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.

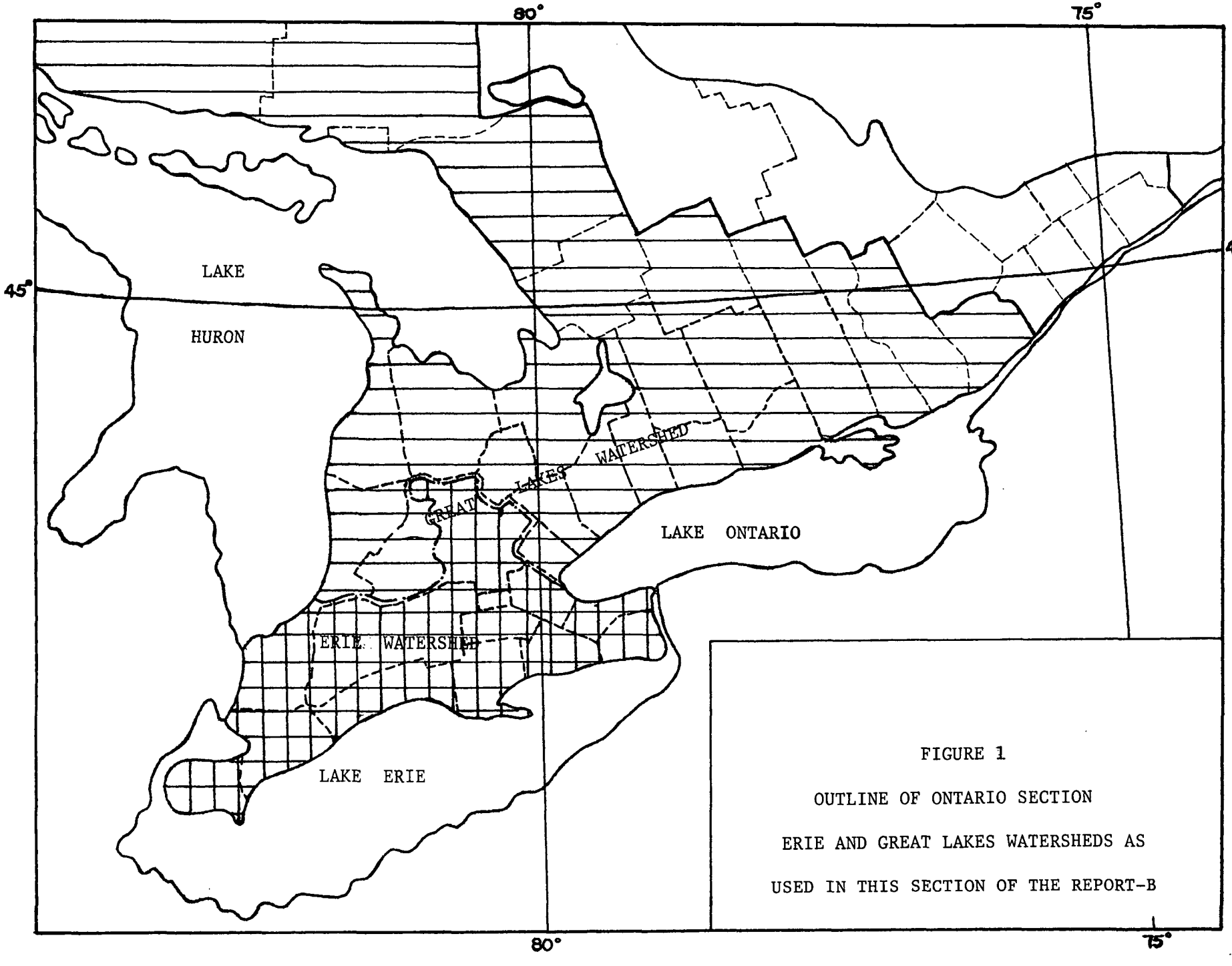


FIGURE 1

OUTLINE OF ONTARIO SECTION

ERIE AND GREAT LAKES WATERSHEDS AS

USED IN THIS SECTION OF THE REPORT-B

Table 1.4.— Nitrogen Balance Sheet for Land Under Crops in Ontario Section of Erie and Great Lakes Watersheds

ERIE WATERSHED

Nitrogen Additions	Tons
Symbiotic fixation[a]	43,950
Non-symbiotic fixation[b]	16,560
Rainfall[c]	11,590
Fertilizer[d]	77,419
Animal waste[e]	43,335
TOTAL	192,854
Nitrogen Removal	
Harvested crops[f]	140,876
ADDITION LESS REMOVAL	51,978

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.

[a] Based on fixation of 100 lb. N/ac. by hay and 60 lb. N/ac. by soybeans.

[b] Assuming an addition of 10 lb./ac of land under crops.

[c] Assuming an addition of 7 lb./ac. of land under crops.

[d] See Appendix Table A.1 for basis of estimation.

[e] Obtained from calculation of animal population as shown in Table 3.12 in section on animal waste.

[f] See Appendix Table A.2 for basis of estimation.

The question of dividing the rural source 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 1.5). 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 1.5.— The Average Annual Losses of Nitrogen Through Tile Drains on Brookston Clay, 1961-1967

Crop	N (lb./ac./yr.)	
	No fertilizer	Fertilizer
Corn	5.0	13.5
Oats — Alfalfa	3.8	5.1
Alfalfa 1st year	4.3	3.5
Alfalfa 2nd year	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 1.2. 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 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.

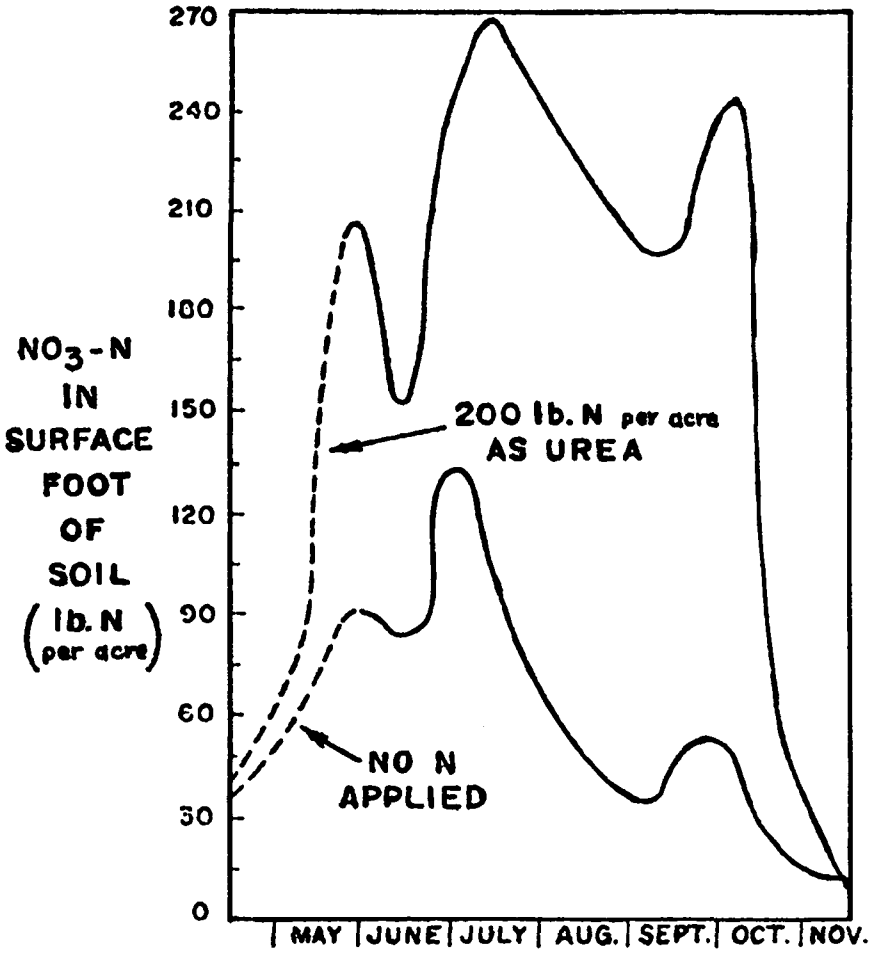


Figure 1.2.— Nitrate-Nitrogen Content of Surface Foot of Soil on Fertilized and Unfertilized Plots

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 October 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 October 5, 1969 (Table 1.6). The percentage of the addition recovered appeared to be the same for each amount of N added.

Table 1.6.— Nitrogen Balance from Manure-Treated Lysimeters Guelph Loam Soil

	Treatment			
	A (check)	B	C	D
Nitrogen Added (lb. N/ac.) 1968 + 1969	0	890	1,780	2,670
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	1,010	1,177
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 lysimeter after the 1969 growing season, 10.5 inches of water were added to each lysimeter in 1-inch increments between October 6 and November 26. With some 15 inches of percolate collected, the nitrogen removed still tends to be a constant percentage of that added (Table 1.6). 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 1,000 to 2,000 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 occurs 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 0.1 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 several 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 per cent of samples indicating a need for fertilizer phosphorus addition and the average amount of fertilizer phosphorus required are indicated in Table 1.7, 1.8, and 1.9 for corn, hay-pasture and potatoes, respectively. From these tables it can be noted that the phosphorus level of the samples submitted for corn was H- or higher for all but one of the counties included in Table 1.7. 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 1.7.— Average Phosphorus Soil Test Values of Samples From Corn Fields (July 1, 1969 — June 30, 1970)

County or district[a]	No. of samples	Ave. test	Rating for corn[b]	%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	238	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-	78	39
Peterboro	202	18	H	64	34
Simcoe N.	217	15	H-	75	36
Simcoe S.	351	15	H-	78	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

[a] Only counties or districts with 150 or more samples included.

[b] 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 1.8.— Average Phosphorus Soil Test Values of Samples From Hay-Pasture of Half or More Legume (July 1, 1969 — June 30, 1970)

County or district [a]	No. of samples	Ave. test	Rating [b] 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	58	6	L+	98	80
Wellington	235	9	M-	95	60
Southern Ontario	1,606	14	H-	66	47

[a] Only counties with 50 or more samples included.

[b] 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 1.9.— Average Phosphorus Soil Test Values of Samples From Potato Fields (July 1, 1969 — June 30, 1970)

County or district [a]	No. of samples	Ave. test	Rating [b] 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	205	63	H+	76	91
Southern Ontario	541	52	H	76	79

[a] Only those counties or districts with 25 or more samples included.

[b] 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 1.8). 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 1.9),the potato crop has a much higher requirement. Therefore, the average rating for the various counties tends to be similar to that for corn 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 1.10) 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 1.11 show the effect of phosphorus fertilization on the available phosphorus content of a sandy soil at various depths.

Table 1.10.— Phosphorus Balance Sheet for Land Under Crops in Ontario Section of Erie and Great Lakes Watershed

ERIE WATERSHED	Tons
Phosphorus Additions	(as P)
Fertilizer[a]	33,269
Animal waste[b]	14,199
TOTAL	47,468
Phosphorus Removal	
Harvested crops[c]	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 [a]	48,153
Animal waste [b]	32,352
TOTAL	80,505
Phosphorus Removal	
Harvested crops [c]	39,594
ADDITION LESS REMOVAL	40,911 tons
Equivalent to 11.6 lb. P (27 lb. P_2O_5) per acre of land under crops.	

[a] See appendix Table A.1 for basis of calculation.

[b] Obtained from calculation of animal population as shown in section on animal waste.

[c] See appendix Table A.2 for basis of calculation.

Table 1.11.— 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 per acre were applied over a seven-year period is shown in Figure 1.3. 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.

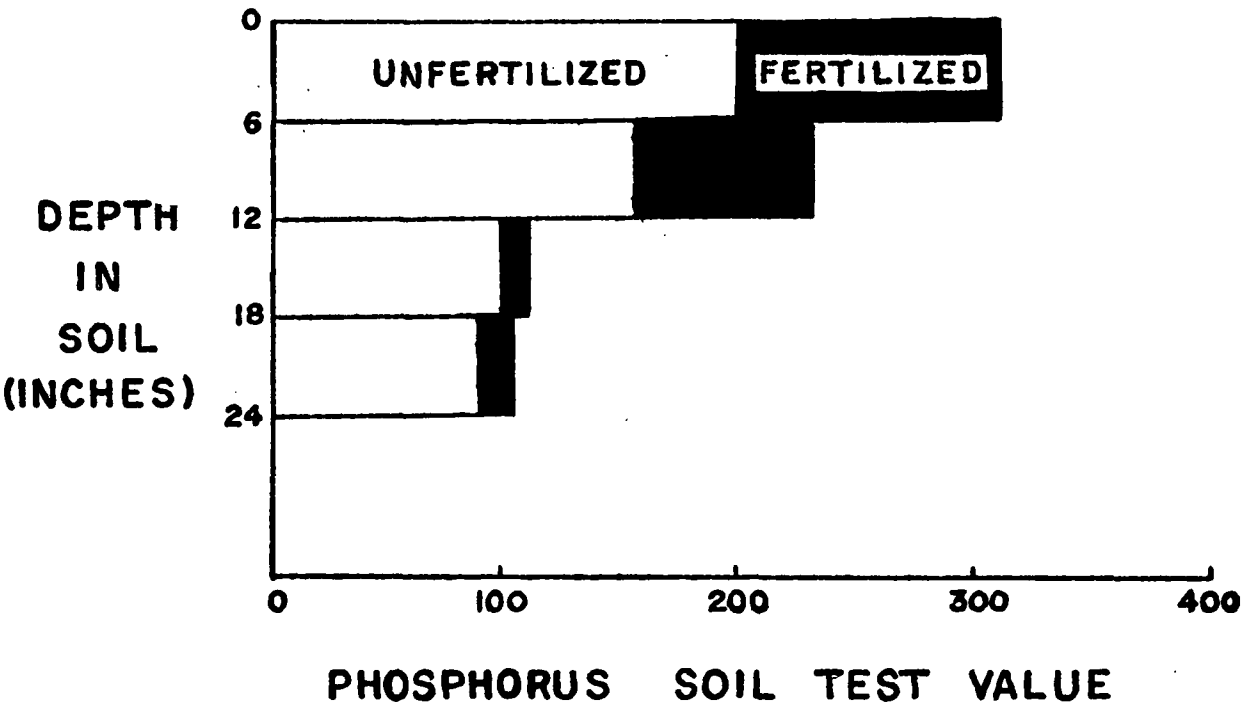


Figure 1.3 Distribution of fertilizer phosphorus in a Burford loam to which 300 lb. P/ac. were applied over a seven-year period. (From 1966 Progress Report, Dept. of Soil Science, Univ. of Guelph).

The phosphorus content of tile drainage waters has been measured at Woodslee, Ontario (Table 1.12). 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 1.12— The Average Annual Loss of Phosphorus Through Tile Drains on Bookston Clay (1961-1967) at Woodslee, Ontario

Crop	P in Drainage Water	
	No fertilizer	Fertilized
	(lb./ac./yr.)	
Corn	0.12	0.21
Oats — alfalfa	0.12	0.12
Alfalfa — 1st year	0.12	0.13
Alfalfa — 2nd year	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 1.13. The poultry manure was added in two applications, in the spring of 1968 and 1969. In the fall of 1969 approximately 10 inches 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 1.13.— 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 fields will be higher in phosphorus than that from 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 phsophorus 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 land in contemporary agriculture. Acutally 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[1/] presents estimations of the source of phosphorus in Lake Erie and Lake Ontario. This data is summarized in Table 1.14.

1/ Prepared by the International Lake Erie Water Pollution Board and the International Lake Ontario — St. Lawrence River Water Pollution Board, 1969.

Table 1.14. — Annual Input of Phosphorus to Lake Erie and Lake Ontario

	Tons per Year	% of Total
LAKE ERIE (excluding that from Lake Huron)		
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
TOTAL	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
TOTAL	36,500	100.0

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."[1/]

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 (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.

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

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 metorpolitan area and an overall average erosion rate of 2.6 tons per acre per year for southeast 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 1,000 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 parctice, 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 12.5 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: 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%).

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.

Table 1.15 and Table 1.16 show effect of crops on soil loss and runoff. The data in Table 1.15 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 1.16 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 1.15.— The Effect of Different Cropping Systems on Runoff and 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 1.16.— 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

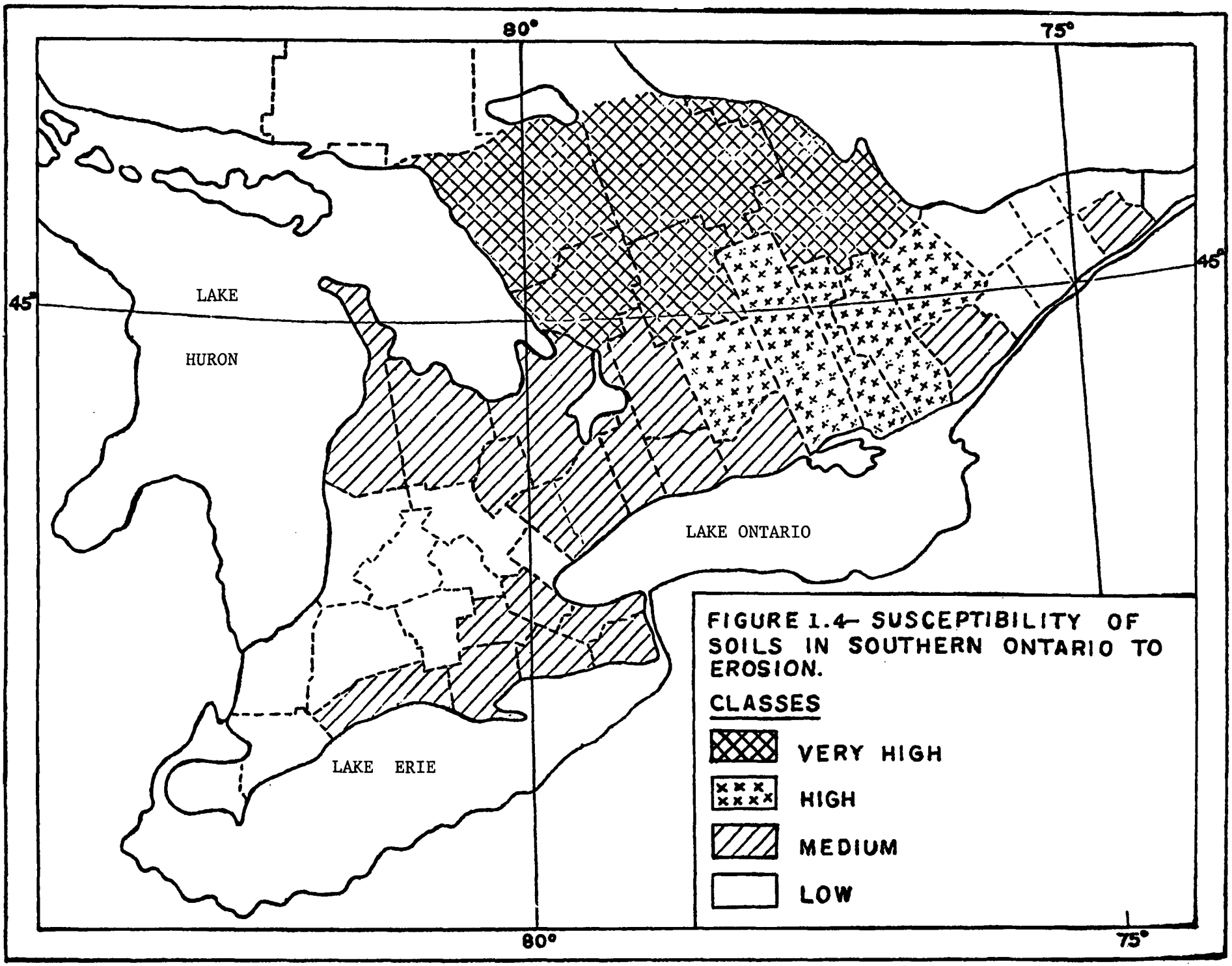
The data show the necessity in establishing crops rapidly. Increasing the amount and density of a crop also decreases erosion because it enhances raindrop interception. The addition of fertilizer accomplishes both these goals. High yields and erosion control go hand in hand.

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 1/3 during a nine year period over unfertilized corn land. 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 1/2 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 seven 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 1.4. This map was prepared 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.


80°
75°
45°
45°
LAKE
HURON
LAKE ONTARIO
LAKE ERIE
80°
75°
FIGURE 1.4- SUSCEPTIBILITY OF SOILS IN SOUTHERN ONTARIO TO EROSION.
CLASSES
VERY HIGH
HIGH
MEDIUM
LOW

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./yr. 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 2½% 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.

CHAPTER II: PESTICIDE USE AND POLLUTION

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 Ontario Department of Agriculture spray calendar recommendation for DDT, 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 to control the 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 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 2.1). The sudden drop in sales reflects the restrictions on uses described in Section 4.

Table 2.1— Total Sales of Chlorinated Hydrocarbons in Ontario

Material	Actual toxicant sold (lbs.)		
	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 2.2). 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. Some 93% of the sediments contained measurable residues — with an average of .084 ppm. (Table 2.2). 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 2.3). 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, 0.6% 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 milkfats 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 metabilites). 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 2.4).

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 2.5). 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, and soils are often thin thus making surface movement 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, reservior 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 that 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 apples 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 bloom-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 2.1. In Ontario, all sales amounts (in any concentration) of 4 lbs. or more of dusts, powders or granule and 160 fluid ozs. 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 2.2.— Pesticide Residues in Water and Sediments — Ontario, 1968-69

Sample	Number Analyses	Content in water (ppb) and sediment (ppm) DDE,DDD,DDT	Dieldrin	Other chlorinated hydrocarbons	Measurable residue	Non Measurable residue
					%	%
Well water	14	Trace	--	--	7	93
Potable water	11	.015	.009	--	73	27
Raw river water	40	.019	.006	--	45	55
Average	65	.014[a]	.004	--	42	58
River sediment (dry)	84	.080[b]	.004	--	93	7

[a] The .014 ppb consisted of .007 ppb DDE (50%), .002 ppb DDD (14%) and .005 ppb of DDT (36%).

[b] The .080 ppm consisted of .020 ppm DDE (25%), .049 ppm DDD (61%) and .011 ppm of DDT (14%).

Table 2.3— 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 crip 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 2.4.— Pesticide Residues in Animal Milk and Meats

Sample	Number analyses	Content in whole tissue: DDT and metabolites (ppm)	Content in whole tissue: DDT %	Content in whole tissue: Cyclodienes (ppm)	Fat[a] %	Content in fat: DDT and metabilites (ppm)	Content in fat: Cyclodienes (ppm)	Content in fat: Lindane (ppm)
Bovine — Milk	1,651	.005	26	.001	4.0	.134	.032	.005
— Fat	132		30		100.0	.263	.031	.017

[a] Based on extractable fat.

Table 2.5.— Pesticide residues in fish — Ontario, 1968-69

Location	Number analyses	In muscle tissue(ppm) DDT,DDD,DDE	In muscle tissue(ppm) Dieldrin	Fat[a] %	In fat[a] (ppm) DDT,DDD,DDE	In fat[a] (ppm) Dieldrin	DDT %
Trent River — Bay of Quinte	329	.507	.004	1.75	29.0	0.23	32
Holland Marsh and Lake Simcoe	312	.682	.023	2.77	24.6	0.83	27
Muskoka Lakes and Rivers	519	7.97	.030	3.60	221.4	0.83	63
Great Lakes	404	.750	.025	4.25	17.6	0.59	44
Ottawa River	57	.118	.009	3.22	3.66	0.28	36

[a] Based on extractable fat.

CHAPTER III: 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 per cent 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 3.1 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 Tables 3.2 and 3.3 for the Lake Erie Watershed (refer to Figure 1.1, section on Fertilizer Use and Pollution) and in Tables 3.4 and 3.5 for the Great Lakes Basin.

Table 3.1.—Production Quantities and Characteristics of Livestock Manures

	Total Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
			- lb/day/animal -			
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	0.08	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) Turkeys (broiler)	0.16	0.013	0.011	0.0015	0.0008	0.00018
Chickens (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

Table 3.2. — Components of Animal Manures Produced on Farms in the Lake Erie Watershed

	Numbers	Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
		lb/day	lb/day	lb/day	lb/day	lb/day	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	15,880,000	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 and Ponies	22,200	1,221,000	31,080	42,180	5,772	1,998	222
Total Animals		75,054,800	1,934,181	2,359,099	304,696	164,005	27,003

Table 3.3. — Components of Poultry Manures Produced on Farms in the Lake Erie Watershed

	Numbers	Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
		lb/day	lb/day	lb/day	lb/day	lb/day	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	30,887	6,154
Total Poultry and 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 3.4.— Components of Animal Manures Produced on Farms in the Great Lakes Basin

	Numbers	Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
		lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
Bulls	24,400						
Cows (milk)	668,700						
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	53,455,000	1,763,685	2,191,245	171,024	106,890	10,689
Calves	578,000	14,450,000	208,080	300,560	46,240	17,340	5,780
Pigs (feeders)	3,039,200	30,392,000	1,154,896	1,033,328	182,352	121,568	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	23,188	11,594	3,162	2,108	105
Horses and 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 3.5. — Components of Poultry Manures Produced on Farms in the Great Lakes Basin

	Numbers	Manure	BOD	SS	Nitrogen	P_2O_5	Sodium
		lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
Hens (layers)	7,386,556						
Chickens (hatchery)	1,296,755						
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	20,938	12,689	6,344
Turkeys (hatchery)	299,966	92,989	9,000	6,000	1,380	1,230	120
Total Poultry		11,188,508	1,055,584	773,626	86,539	56,062	11,319
Total Poultry and Animals -							
	lbs/day	211,817,408	5,953,285	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 3.6 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 to maturity.

Table 3.7 gives the animal unit equivalent of the various classes of farm animals and poultry.

Tables 3.8 and 3.9 show the animal units in the Great Lakes Basin broken down by county. The Lake Erie Watershed (refer to Figure 1.1 in section on Fertilizer Use and Pollution) because of its special significance, is given as a percentage for the total of the Basin in Table 3.9. 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 Figures 3.1 and 3.2 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 3.8 and 3.9.

Table 3.6.—The Nitrogen and Phosphorus Excreted by Different Kinds of Livestock

Kind of Livestock	N lb.	P lb.
1,000 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 1,100 lb.)	140	29
1 dairy cow (365 days) (1,200 lb.)	140	29

Table 3.7.—Animal Unit Equivalents of Various Classes of Livestock

1 dairy cow	1 animal unit (365 days)
2 heifers (for milk purposes)	1 animal unit (365 days)
4 calves (under one year)	1 animal unit (365 days)
1 beef cow	1 animal unit (365 days)
2 beef steers (400-1,100 lb.)	1 animal unit (365 days)
2 beef heifers (400-1,000 lb.)	1 animal unit (365 days)
1 bull	1 animal unit (365 days)
1 horse (includes ponies)	3/4 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 rams)	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)
1,000 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 3.8. — Livestock Populations (Animal Units) by Counties in the Great Lakes Watershed (not Including Lake Erie Watershed in Ontario)

County or District	Poultry	Pigs	Dairy	Beef	Sheep	Horses	Animal Units Total	Commercial Farms (acreage)	Animal Units (per 100 acres)
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	22.8
Haliburton	--	90	575	1,150	30	150	1,995	4,741	42.0
Hastings	3,984	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	15,050	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	21,391	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	81,272	12.4

Table 3.9. — 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	18,700	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	5,983	6,900	32,250	8,150	1,250	750	46,283	209,260	22.1
Kent	5,539	17,525	5,850	24,820	792	675	55,201	527,041	10.5
Lambton	10,240	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	118,136	29.4
Middlesex	16,553	22,650	47,800	51,170	2,283	1,875	142,336	591,420	24.1
Norfolk	6,060	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	21,689	79,483	27.3
Wentworth	8,752	7,075	17,300	5,900	375	825	40,227	133,653	30.1
Waterloo	12,708	33,350	31,100	18,850	875	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**	

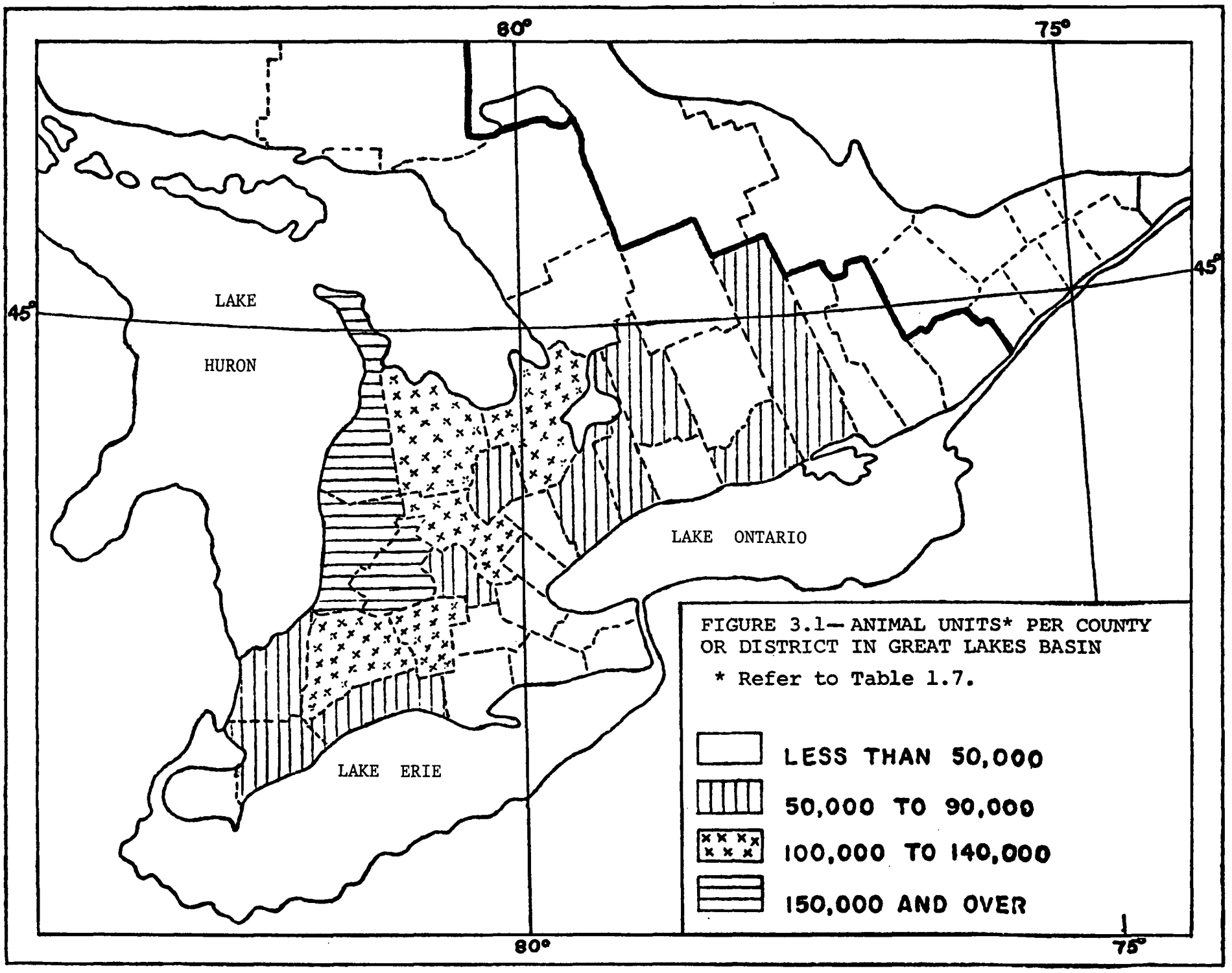


FIGURE 3.1— ANIMAL UNITS* PER COUNTY OR DISTRICT IN GREAT LAKES BASIN

* Refer to Table 1.7.

- LESS THAN 50,000
- 50,000 TO 90,000
- 100,000 TO 140,000
- 150,000 AND OVER

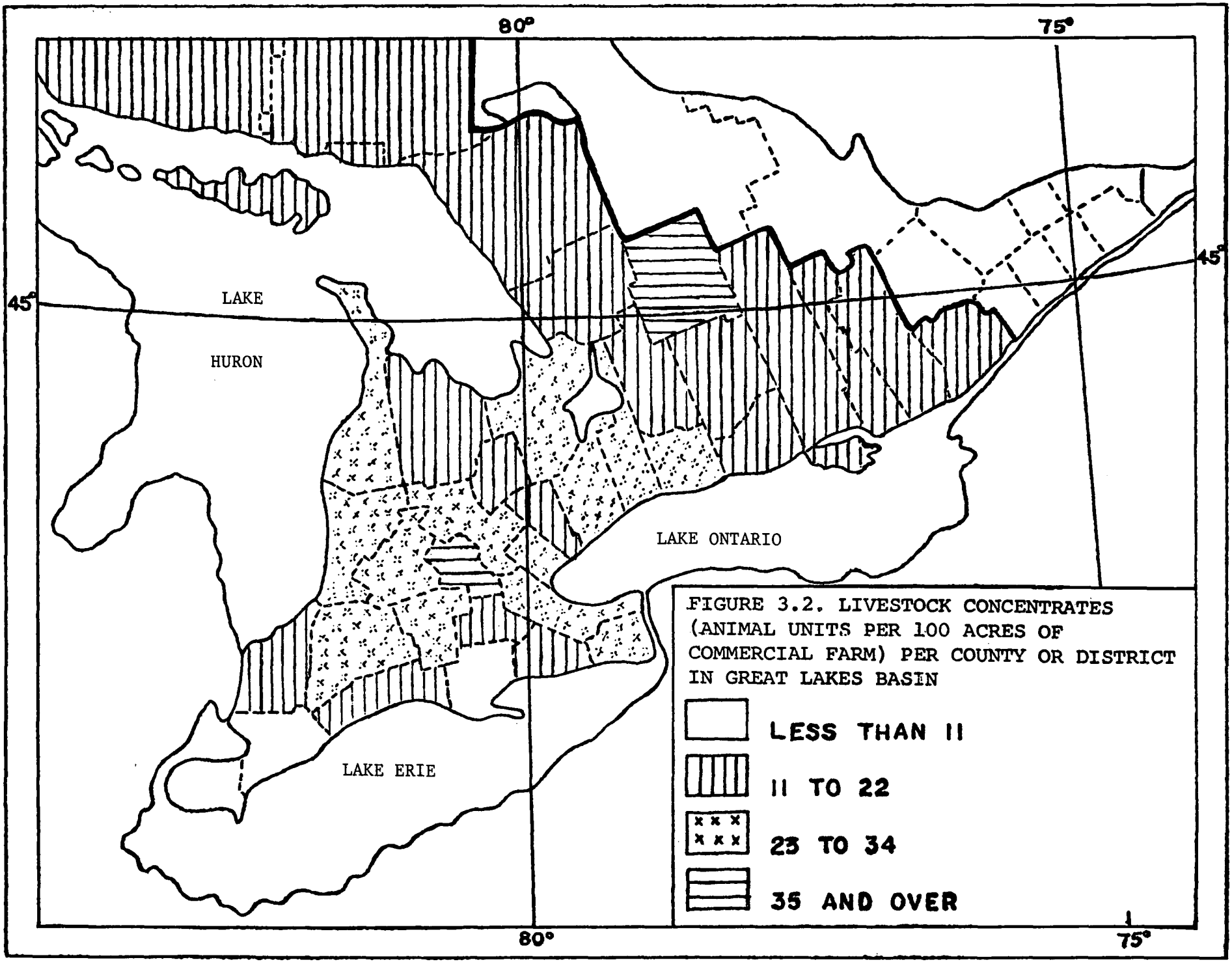


FIGURE 3.2. LIVESTOCK CONCENTRATES (ANIMAL UNITS PER 100 ACRES OF COMMERCIAL FARM) PER COUNTY OR DISTRICT IN GREAT LAKES BASIN

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 in manure is presented in the following table.

Table 3.10.— 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 six months of each year, a considerable portion of the nitrogen and phosphorus produced from their manure would not be available for crop acres and would, 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 3.11.— 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	10,588
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 3.12 show the quantities of nitrogen and phosphorus produced in the Great Lakes Basin discounted as described above.

Table 3.12— 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 preceeding 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, and 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 so that 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 nitrates 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 salmonellsis, 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 by 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 runoff 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 runoff 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 ground water.

So far as the authors are aware, few establishments follow the pratice 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.

1. (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 groundwater.

   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. suggests that the storage provide 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, 1,000 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 runoff 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 runoff 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 4,500 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 in them and a number of mechanical devices are in service on farms in the Great Lakes Basin.

Manure drying, 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 is 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 runoff 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 runoff 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 in 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 co-ordinate research on animal wastes in the Province.

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

CHAPTER IV

II 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 per cent 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

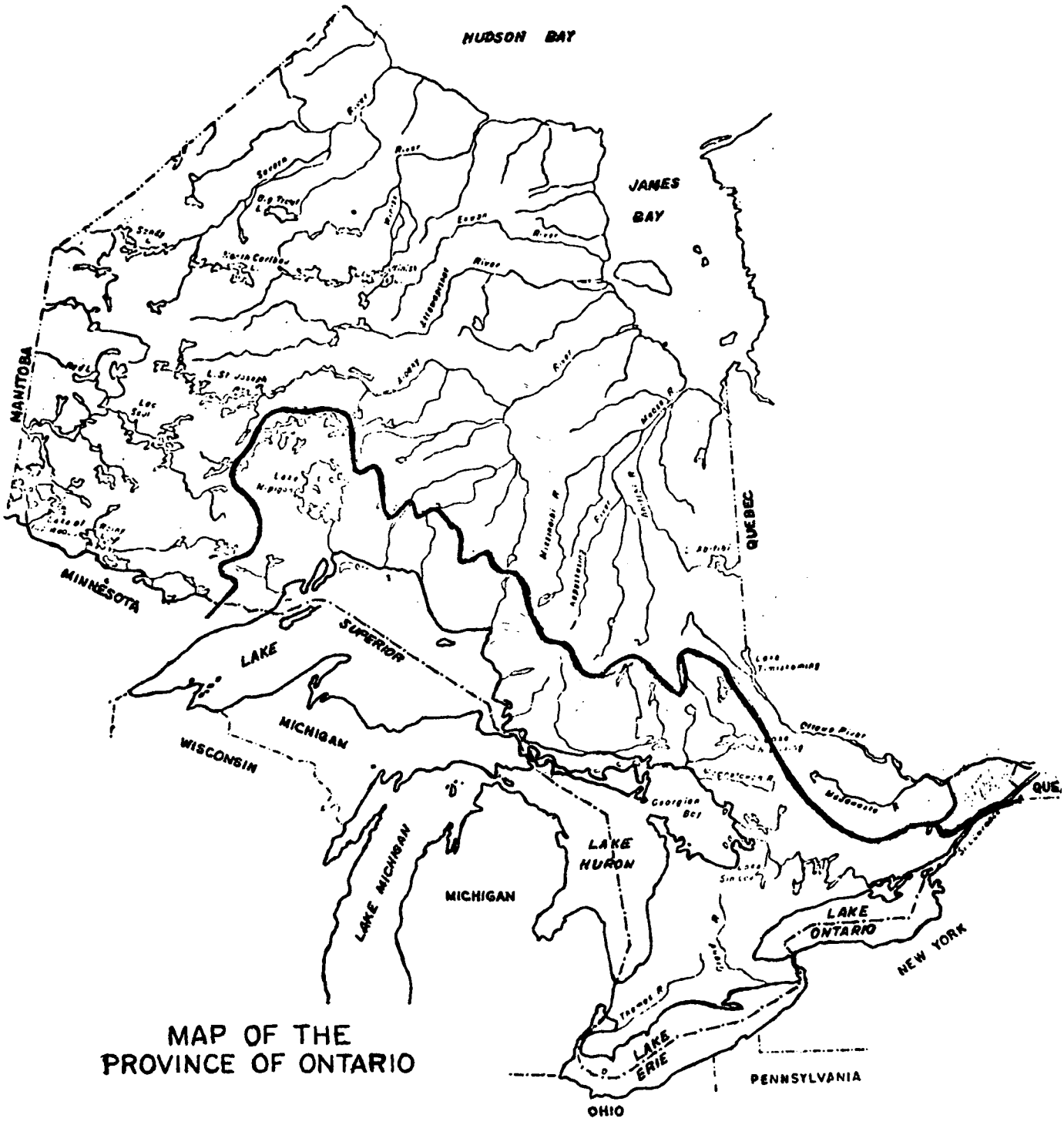
(a) Insecticides: In protecting the forests within the Great Lakes drainage, including the parks, the current average acreage sprayed each year is about 15,000. This is 0.04% of the forested area. DDT has not been used since the 1967 field season, and the short-lived insecticides now being used to control 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	
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
	- 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 populations. 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 (i) land surface erosion and (ii) 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 pheonomena. 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 Table A3) 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 developments, 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 it 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 co-operation 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 yeild 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 Survey Section.

In addition, the co-operation of the provincial departments of the 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.

CHAPTER V

III 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. 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 will 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 where the animal wastes are 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) that less than 2.5 per cent 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 to the lower Great Lakes. The contribution of nutrients from each tributary can be expected to vary significantly depending upon local land use patterns. Terry and Salbach (1970) 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 altoghther, 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 Cirteria 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 co-operation 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 and industrial waste effluents to 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 licencees 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.

CHAPTER VI
SUMMARY AND CONCLUSIONS

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 a Study-Group to deal with pollution of the Great Lakes from Agriculture, Forestry and Conservation sources (excluding processing).

The study-group 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, it 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 to the land.

The Study-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 study-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. Adherance 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 1968-69. 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 DDE 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 severely 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 undersirable 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 phsophorus in soil, fertilization increases the phosphorus content of the surface soil. Therefore, soil carred by surface runoff or erosion from fertilizer fields will be higher in phosphorus than that from unfertilized fields. If fertilizer use is contributing to build-up 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 2½ 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 reserviors. 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 & 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 and 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 need for control and abatement of their impact.

In response to this development, the Federal Government is soon to have a Department of the Environment, the duties and powers of which will extend to and include all matters over which the Parliament of Canada has jurisdiction, not by law assigned to any other department, branch or agency of the Government of Canada, relating to amongst other things:

a) sea cost and inland fisheries,

b) renewable resources including,
   i) the forest resources of Canada,
   ii) migratory birds, and
   iii) other non-domestic flora and fauna,

c) water,

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

e) the enforcement of any rules or regulations made by the IJC, promulgated pursuant to the treaty between the U.S. and the Crown (1909), relating to boundary waters and questions arising between the U.S. and Canada as far as the same relate to pollution control.

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.

APPENDICES

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

	Tons
Erie Watershed	
Fertilizer sold[1] (excluding Norfolk County)	462,781
Nitrogen content (ave. of 16% N)[2]	74,045
Phosphorus content (ave. of 6.5% P)[2]	29,618
Fertilizer sold in Norfolk County	61,357
Nitrogen content[3]	3,374
Phosphorus content[3]	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), and 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]	Average 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	8.4	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	2.90 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 -

$$121{,}153 \times \frac{3{,}312{,}951}{2{,}841{,}500} = 140{,}876 \text{ tons.}$$

Total phosphorus contained in crops - 19,269 tons.

GREAT LAKES WATERSHED

Crop	Acres[1]	Average Yield per Acre	N Content		P Content	
			lb./ac.	tons	lb./ac.	tons
Wheat	357.300	39.8 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	2.70 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 -

$$271{,}557 \times \frac{7{,}052{,}196}{6{,}433{,}720} = 297{,}752 \text{ tons.}$$

Total phosphorus contained in crops - 39,600 tons

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

APPENDIX
Table A3.

Section 27(1)
Ontario Water Resources Commission Act

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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 or any well, lake, river, pond, spring, stream, reservoir or other water or watercourse 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.

Discharge of polluting material prohibited.

APPENDIX
TABLE 4
JOINT RECOMMENDATIONS OF CANADIAN AND U.S. SECTIONS

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 interjurisdictional 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.

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