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International Reference Group on Great Lakes Pollution from Land Use Activities

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

**INTERNATIONAL
JOINT
COMMISSION**

AGRICULTURAL WATERSHED STUDIES IN THE CANADIAN GREAT LAKES DRAINAGE BASIN

AGRICULTURAL WATERSHED STUDIES

GREAT LAKES DRAINAGE BASIN

CANADA

FINAL SUMMARY REPORT

CO-OPERATING AGENCIES

Agriculture Canada

Ontario Ministry of Agriculture & Food

Ontario Ministry of Environment

TASK GROUP C (CANADIAN SECTION) ACTIVITY 1
INTERNATIONAL REFERENCE GROUP ON GREAT
LAKES POLLUTION FROM LAND USE ACTIVITIES

May 1, 1978

3. DISCLAIMER

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

Certain data presented in this report have been developed using loading calculation procedures which are still in the process of review. Modifications in these procedures may result in the amendment of certain loading values presented in this report.

4. ACKNOWLEDGEMENTS

Editing of the material available and drafting of this summary report was the responsibility of the following:

- D. R. Coote, Soil Research Institute, Agriculture Canada
- E. M. MacDonald, Soil Research Institute, Agriculture Canada
- W. T. Dickinson, School of Engineering, University of Guelph

Responsibility for the technical information contained in this summary report was distributed as follows:

Phosphorus	- M. H. Miller and A. C. Spires, Dept. of Land Resource Science, University of Guelph
Nitrogen	- G. H. Neilsen and J. L. Culley, Soil Research Institute, Agriculture Canada
Sediments	- G. J. Wall and L. P. J. van Vliet, Ontario Soil Survey, Agriculture Canada
Heavy Metals	- L. M. Whitby, Soil Research Institute, Agriculture Canada
Pesticides	- R. Frank, Pesticide Residue Testing Laboratory, Ontario Ministry of Agriculture and Food
Livestock Sources	- J. B. Robinson and D. W. Draper, Dept. of Environmental Boilogy, University of Guelph

The above individuals ("Integrators") compiled information related to each of the indicated subject categories from all of the Agricultural Watershed Studies in which that subject was considered. References to contributing projects and to the literature at large will be found in each Integrator's report, - they have been omitted here in the interests of brevity. The cooperation of each of the project leaders with the integration of the results of their projects is gratefully acknowledged.

Technical reports on each aspect of the PLUARG Agricultural Watershed Studies (Canada) will be available as part of the PLUARG Technical Report Series, with each Integrator, and each individual Project Leader, responsible for a technical report.

The Editors wish to acknowledge the contribution to this work of the Ontario Ministry of the Environment, Water Resources Branch and Laboratories Branch, by way of water quality monitoring and flow data collection, and laboratory analyses, respectively.

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8. SUMMARY

This Summary Report contains information prepared by scientists who have interpreted the results obtained by all of the projects conducted within the Canadian PLUARG Task C Agricultural Watershed study. The study approach is presented, along with summaries and discussion of data, and possible remedial measures for all of the major water quality parameters investigated. Extrapolation to unmonitored areas and remedial measures alternatives are discussed for total phosphorus and sediment. The reader is referred to the many reports of the investigators and "Information Integrators" who have participated in the Agricultural Watershed Studies for supporting methodology, data presentation and analysis, and discussion of results.

The Agricultural Watershed Studies consisted of a variety of investigations into the relationships between agricultural land and water quality in the Great Lakes Basin. Monitoring of water quality and quantity at eleven small (19 to 73 km^2) watersheds, selected to be representative of major agricultural regions of the Canadian Great Lakes Basin, was carried out for two years. Detailed studies on sediment, nutrients and heavy metals were carried out in some of the watersheds. All watersheds were characterized in detail.

In terms of the water quality parameters of greatest concern to PLUARG - total phosphorus and sediment - the higher the degree of intensive cultivation and/or the greater the area of fine-textured soils, the greater were the unit-area loads. These watershed characteristics accounted for most of the differences observed in the loads of total phosphorus and sediment among the study watersheds. The reasons for this were determined to be the effect of these factors on soil erosion rates, fertilizer and manure use, and transport of the clay-sized particles which contain and carry phosphorus. The unit-area loads of total phosphorus ranged from 0.2 to 1.5 kg/ha/yr, while those of suspended solids (sediment) ranged from 60 to 960 kg/ha/yr. It was estimated that the total contribution of Canadian agricultural land to streams in the Great Lakes Basin in 1976 was about 3000 tonnes of total phosphorus, and about 1,084,000 tonnes of sediment.

Consideration was given to remedial measures programs to reduce the contributions of pollutants from agricultural activities. Although several possible measures were identified, it is emphasized that localized variations in pollution sources, soil properties and landscapes, cropping systems and active pollutant contributing areas make general application of remedial measures impracticable. To illustrate the site-specific nature of, and demonstrate an approach to, remedial measures, programs were developed for four watersheds and phosphorus and sediment loading reductions and costs were estimated. These examples are presented in the report.

Monitoring and detailed studies were also carried out to determine the role of agricultural land as a source of other water quality parameters. It was concluded that applications of fertilizer and manure, and livestock operations adjacent to streams, were contributing to the observed levels of the dissolved fractions of phosphorus (ortho-P) and nitrogen ($NO_2^- + NO_3^-$) in streams. Loads of these fractions ranged from 0.02 to 0.46 kg/ha/yr, and from 2.4 to 25.9 kg/ha/yr respectively. Soil incorporation of phosphorus fertilizers and manure, used according to soil test recommendations, and better management and timing of nitrogen applications, were suggested as measures which would reduce these dissolved nutrient loadings.

It was determined that agricultural activities were not influencing the quantities of heavy metals in streams, - other than by way of increases in stream sediment loads, which resulted in increases in those fractions of the metal loads that were naturally associated with the sediment. The pesticide materials now in use were found to be of sufficiently low persistence that they were seldom detected in stream water. Accidental spills were the suspected causes of the occasional presence of these materials. Only the herbicide atrazine was commonly found in stream water, but it has no known deleterious water quality impact. Residues of the past use of the organochlorine pesticides such as DDT were routinely observed in stream water.

Agricultural activities could not be entirely separated from other possible sources. Indicator bacteria were found in relatively high numbers in the agricultural watersheds. They could not be related to potential livestock sources, and may well have also been derived from wildlife, human population and natural stream conditions. Other observed non-agricultural influences on water quality in the agricultural watersheds were: the contribution of rural housing to dissolved phosphorus levels; the presence in streams of herbicides from spraying of highway rights-of-way; and the almost constant presence of the industrial organic toxicant PCB - believed to be primarily the result of atmospheric deposition.

9. INTRODUCTION

9.1. Study Objectives

In February, 1974, the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) prepared a "Detailed Study Plan to Assess Great Lakes Pollution From Land Use Activities". This study plan outlined four main tasks including assessment of the problem (Task A), inventory of land use activities (Task B), watershed studies (Task C) and lake studies (Task D).

Task C was described as, "Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes Basin, and to relate contamination of water quality, which may be found at river mouths on the Great Lakes to specific land uses and practices".

The objective of Activity 1 (Canada) of Task C, "Pilot Watershed Surveys", was "to obtain data on the inputs of pollutants into the Great Lakes Drainage System which have their origin in the complex land use activities known as agriculture".

The Agricultural Watershed Studies (Task C - Activity 1 (Canada)) developed into a three-phase program with objectives as follows:

Phase I (Monitoring):

To measure the ambient concentration and loading rates for various potential pollutants that occur with agricultural land use.

Phase II (Detailed Studies):

1) To determine the effects of the soil, land use and associated practices on ambient concentrations and loading rates of selected pollutants from agriculture.

2) To derive information on the mechanics of transport and storage of these pollutants within the selected agricultural watersheds.

3) To develop relationships so that the information derived can be utilized in a predictive sense and extrapolated to other areas.

Phase III (Remedial Measures):

To develop remedial measures where significant problems are identified.

9.2. Study Approach

The Agricultural Watershed Studies in Canada consisted of the monitoring of 11 small (20-70 km^2) agricultural basins selected to represent major agricultural regions in Southern Ontario, and included a number of detailed studies in six of these (Table 9.2.). The agricultural regions (determined by soil type, climatic zone, and combination of crops grown with or without livestock) were identified and representative watersheds selected during the preliminary phase of the study (April 1974 - April 1975). These regions and watersheds are shown in Figure 9.2. Field activities of the study were initiated in April 1975 and continued until May 1977.

The monitoring program covered precipitation quantity (Project 6A, University of Windsor), stream flow quantity and stream quality (Projects 2 and 3, Ontario Ministry of the Environment, Agriculture Canada; Project 4, Ontario Ministry of Agriculture and Food). An inventory of land use practices was carried out on the 11 watersheds (Project 5, Ontario Ministry of Agriculture and Food).

For the six watersheds included in the Phase II Detailed Studies, precipitation quality has been determined (Project 6B, University of Windsor). A detailed soil survey has been made of these watersheds (Project 7, Ontario Soil Survey) and a study of the nature and enrichment of sediments which involved mineralogical, physical, organic, trace elemental and nutrient characterizations (Projects 8 and 9, Agriculture Canada, Guelph-Ottawa). These programs were co-ordinated to allow assessment of the relationship of pollutants in sediments and in soils, and contributed to an integrated program on agricultural sources, transport and storage mechanisms of metals (Project 9, Agriculture Canada, Harrow and Ottawa). A one-year program was added to identify sources of high levels of metals in one watershed (Project 23, Brock University).

The study of livestock operations has included the study of pollutant transport to sub-surface and surface waters in an integrated farm operation on the Greenbelt farm of the Animal Research Institute (Project 22, Agriculture Canada); and the study of runoff and groundwater pollution from cattle feedlots and cattle manure storage areas (Project 21, Agriculture Canada). Another study on surface transport of nutrients with emphasis on livestock operation areas has been conducted by BEAK Consultants Ltd. (Project 20).

An integrated program on two watersheds has included the study of sources of nutrients and heavy metals (Project 10, Agriculture Canada, Harrow); the study of transformations and transport of nitrogen and water in agricultural soils (Projects 11, 12 and 13 Agriculture Canada, Ottawa); and the study of the role of the groundwater flow regime in the transport of nitrates to streams (Project 14, University of Waterloo).

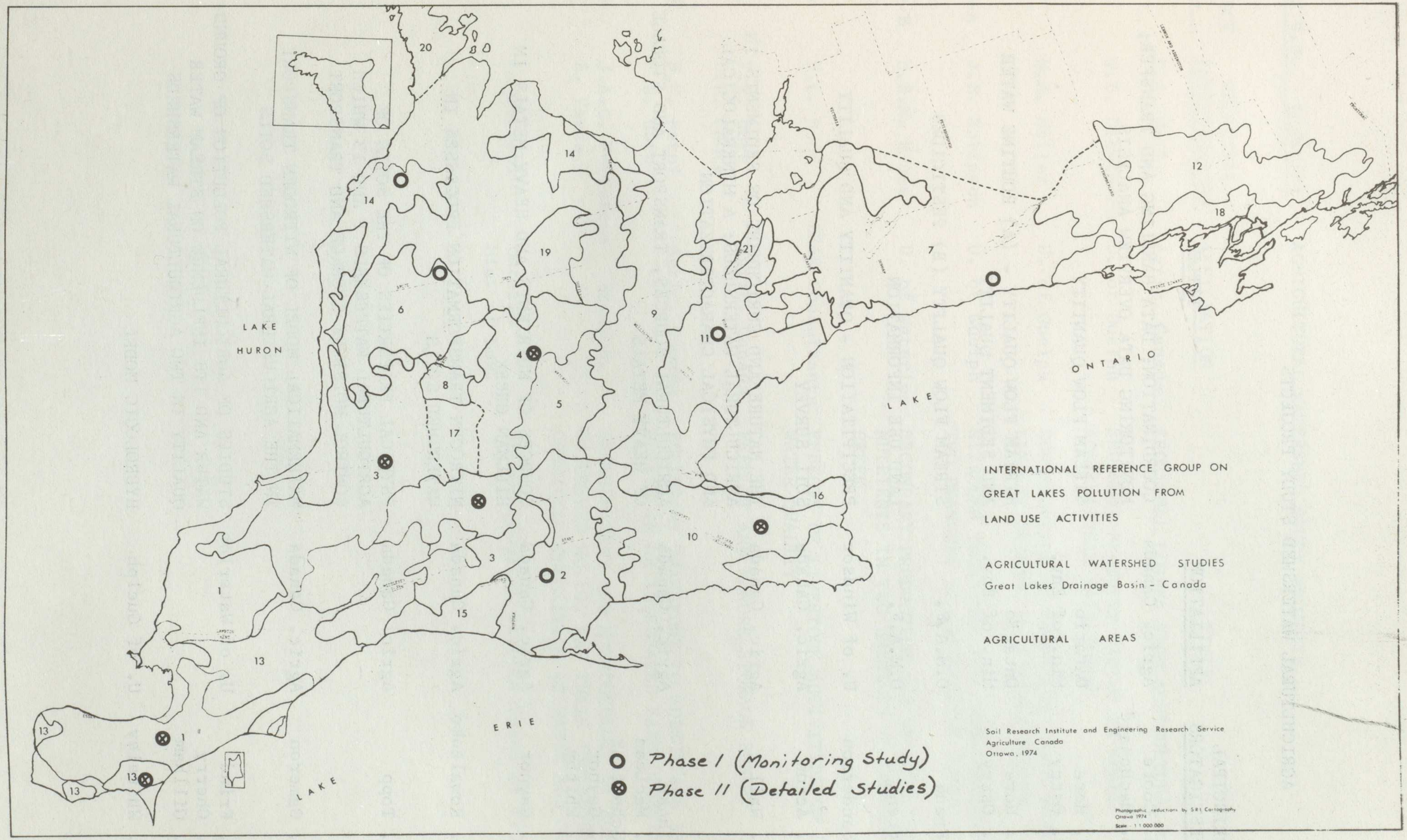


Figure 9.2: Agricultural Regions of Southern Ontario and PLUARG representative watersheds

TABLE 9.2. AGRICULTURAL WATERSHED STUDY PROJECTS

PROJECT NO.	PRINCIPAL INVESTIGATORS	AFFILIATION	TITLE
1	D.R. Coote E.M. MacDonald	Agric. Canada	COORDINATION; DATA HANDLING AND TRANSFER; MONITORING DATA OVERVIEW ANALYSIS
2	R.C. Hore R.C. Ostry	Ontario Min. of Env.	STREAM FLOW QUANTITY
3	R.C. Hore R.C. Ostry	Ontario Min. of Env.	STREAM FLOW QUALITY - (A) ROUTINE WATER AND SEDIMENT QUALITY
4	R. Frank	O.M.A.F.	STREAM FLOW QUALITY (B) PESTICIDES
5	R. Frank	O.M.A.F.	LAND USE INFORMATION
6	M. Sanderson	U. of Windsor	PRECIPITATION - QUANTITY AND QUALITY
7	C.J. Acton	Agric. Canada	SOIL SURVEY
8	G.J. Wall	Agric. Canada	THE NATURE AND ENRICHMENT OF SEDIMENTS IN AGRICULTURAL WATERSHEDS: A MINERALOGICAL AND PHYSICAL CHARACTERIZATION
9	M. Ihnat A.J. MacLean M. Schnitzer J.D. Gaynor L.M. Whitby	Agric. Canada	AGRICULTURAL SOURCES, TRANSPORT AND STORAGE OF HEAVY METALS
10	J.D. Gaynor	Agric. Canada	SOURCES OF NUTRIENTS AND HEAVY METALS IN HILLMAN CREEK
11	C.G. Kowalenko	Agric. Canada	NITROGEN TRANSFORMATION PROCESSES IN WATERSHED SOILS
12	G.C. Topp	Agric. Canada	PHYSICAL PROPERTIES OF THE SOILS OF AGRICULTURAL WATERSHEDS 1 AND 13 WHICH CONTROL MOISTURE STORAGE AND TRANSPORT
13	D.R. Cameron	Agric. Canada	MATHEMATICAL MODEL OF NITROGEN TRANSPORT IN THE AGRICULTURAL WATERSHED SOILS
14	E.O. Frind J.A. Cherry R.W. Gillham	U. of Waterloo	STUDIES OF AGRICULTURAL POLLUTION OF GROUNDWATER AND ITS INFLUENCE ON STREAM WATER QUALITY IN TWO AGRICULTURAL WATERSHEDS
15	H.R. Whiteley	U. of Guelph	HYDROLOGIC MODEL

TABLE 9.2. (cont'd) AGRICULTURAL WATERSHED STUDY PROJECTS

PROJECT NO.	PRINCIPAL INVESTIGATORS	AFFILIATION	TITLE
16	G.J. Wall	Agric. Canada	EROSIONAL LOSSES FROM AGRICULTURAL LAND
17	W.T. Dickinson	U. of Guelph	SEDIMENT DELIVERY RATIOS IN SMALL AGRICULTURAL WATERSHEDS
18	M.H. Miller	U. of Guelph	CONTRIBUTION OF PHOSPHORUS FROM AGRICULTURAL LAND TO STREAMS BY SURFACE RUNOFF
19-A	J.B. Robinson	U. of Guelph	NITROGEN TRANSPORT AND TRANSFORMATIONS IN TWO BRANCHES OF CANAGAGIGUE CREEK
19-B	H.B.N. Hynes	U. of Waterloo	SECONDARY PRODUCTION AND ORGANIC DRIFT OF NUTRIENTS IN TWO BRANCHES OF CANAGAGIGUE CREEK
20	S.L. Hodd	BEAK Consultants	EFFECTS OF LIVESTOCK ACTIVITIES ON SURFACE WATER QUALITY
21	F.R. Hore D.R. Coote	Agric. Canada	FEEDLOT AND MANURE STORAGE RUNOFF
22	N.K. Patni F.R. Hore	Agric. Canada	POLLUTANT TRANSPORT TO SUBSURFACE AND SURFACE WATERS IN AN INTEGRATED FARM OPERATION
23	J.A.C. Fortescue E. Veska	Brock U.	GEOCHEMISTRY AND HYDROGEOLOGY OF AGRICULTURAL WATERSHED NO.10, AND THEIR INFLUENCE ON THE CHEMICAL COMPOSITION OF WATER AND SEDIMENTS
	A. Qureshi	Ontario Min. of Env.	MICROBIOLOGICAL STUDIES (part of Project 3)

Surface runoff from small agricultural watersheds (Project 15, University of Guelph), erosional losses from agricultural land (Project 16, University of Guelph, Agriculture Canada), transport of fluvial suspended sediments from agricultural land (Project 17, University of Guelph), and the contribution of phosphorus from agricultural land to streams by surface runoff (Project 18, University of Guelph) were combined into a co-operative program on surface sources and flow paths from agricultural land.

A comparison of the nutrient budget of an agricultural stream and a relatively undeveloped stream has been made, including nutrient transport and transformation (Project 19A, University of Guelph) and a 1975 field season study of secondary production and organic drift (Project 19B, University of Waterloo).

Descriptions of the studies referred to above may be found in the Detailed Study Plan, Agricultural Watershed Studies, Task C Activity 1, Canada, October 1975, with update in October 1976. The final reports from these detailed studies will be included in the PLUARG Technical Report Series and will be available in 1978.

In December, 1976, individuals from within the diverse activities of the Agricultural Watershed Studies were identified as "integrators" responsible for compiling information related to each major parameter group (i.e. phosphorus, nitrogen, sediments, heavy metals and pesticides) from all the detailed studies in which these parameters were considered. Livestock were given special consideration by the appointment of an integrator specifically for these sources. The integration activity included development and evaluation of remedial programs utilizing the combined expertise and experience of the PLUARG study researchers and field technicians to recommend suitable options.

Coordination and implementation of this program has been a joint Ontario Ministry of Agriculture and Food, Agriculture Canada, and Ontario Ministry of the Environment endeavour.

9.3. Methods

Referring to the division of the objectives listed under Section 9.1, the methods can be divided into three groups - monitoring, detailed studies and remedial measures.

9.3.1. Monitoring

The Ontario Ministry of the Environment (OMOE) has made available all water quality data collected at the 11 agricultural watersheds. Standard and PLUARG approved methods have been used for sample collection, treatment and laboratory analyses. Automatic samplers with time and stage height activitated suction pumps were used at 6 sites to improve event sampling. The data have been stored in the Environment Canada National Water Quality Data Bank (NAQUADAT) as well as in OMOE's data system. Flow data have been compiled and analysed by the OMOE and Water Survey of Canada (Environment Canada) from continuous recording flow stage gauges. These have also been filed in NAQUADAT, as have the results of the pesticide monitoring at each of the 11 agricultural watersheds. Precipitation has been measured by gauges located in each of the watersheds. From NAQUADAT, concentration data and monthly loadings as well as plots of parameter values have been furnished to agricultural study participants. The OMOE has calculated annual loadings according to the Beale Ratio Estimator method.

Each agricultural watershed has been surveyed by the Ontario Ministry of Agriculture and Food (OMAF) by visiting each farm in each watershed, and by gathering non-farm information from municipal offices and field observation.

Statistical analyses have been made of the 2-year monitoring data and models developed to explain variability between watersheds in terms of physical characteristics, the use of the land and agricultural management practices.

9.3.2. Detailed Studies

The methods utilized by the researchers involved in the detailed studies were numerous and varied. All conformed to standard routines for laboratory analysis, with the exception of the Plasma Source Emmission Spectrometer used by Project 23 for elemental analysis of stream waters and sediments. This machine is somewhat experimental and certain problems were encountered with laboratory procedures. Field sampling involved the use of the most appropriate equipment available which included, among others, a deep well hollow auger drill for groundwater and core sampling; inovative traps for floating and suspended organic debris; bulk and wet only precipitation samplers; and an experimental soil permeability measuring device.

Mathematical models have been developed and/or utilized to assist in the understanding of the movement of nutrients through soils; the movement of soil nutrients into groundwater and then into streams; rainfall and snowmelt runoff from various field situations (especially contributing areas) and its delivering to streams of sediments eroded from soils under different conditions; the enrichment of soil sediments by nutrients from field applications; and the effect of livestock operations on water quality.

Data gathered in the detailed studies have, for the most part, been retained in storage and retrieval systems operated by the researcher's institution or company. Methods of statistical analysis and loading calculations have been used which are most appropriate to the particular data set, and standardization has been restricted to watershed mouth data collected in the monitoring phase of the study. This flexible approach allows for specialized data manipulation, while maintaining bounds on extrapolation outside the detailed study areas.

The evaluation and integration of the results of each of the detailed studies, in terms of the overall objectives of the Agricultural Watershed Studies, have been achieved through the use of "Parameter Integrators". These individuals have communicated in detail with each investigator having data or information relevant to one of the five major parameter groups: i) phosphorus; ii) sediments; iii) pesticides; iv) heavy metals; and v) nitrogen. A sixth "Integrator" has also been identified to compile the results of any studies in which livestock sources were considered.

Analyses of the results of the detailed studies and of the monitoring program and the conclusions regarding the effect of agricultural activities within the 11 agricultural watersheds, as well as within the agricultural regions represented by these watersheds have been made by the integrators in concert with the study coordinators. This report, therefore, represents the conclusions of a large group of researchers of differing backgrounds and interests.

9.3.3. Alternative Preventative and Remedial Measures

Although the Agricultural Watershed Studies were not designed to directly test or quantify the impact of specific remedial measures, they have provided researchers the opportunity to observe many unique situations. This information has been utilized in the integration activity for the development and evaluation of alternatives for remedial measures.

9.4. Key Parameters Studied

The parameters studied in the Detailed Studies have been mainly those known to exist in the agricultural environment. The presence of many other materials has been regularly looked for, and sources identified where they have been found. The major parameters discussed in this summary report are as follows:

i) Nutrients - phosphorus, nitrogen

ii) Sediments - suspended

iii) Heavy metals - Pb, Cu, Zn

iv) Toxics - insecticides: DDT, endosulfan
- herbicides: atrazine
- PCB

Many additional water quality parameters have been monitored, and are discussed in the detailed final reports. The materials listed above are those common to all PLUARG studies, and those for which explanations of their sources and fate in the system are considered to be essential or which are known to be indicators of trends in other similar materials.

10. TABULATED RESULTS OF DATA COLLECTION

10.1. Land Uses and Practices:

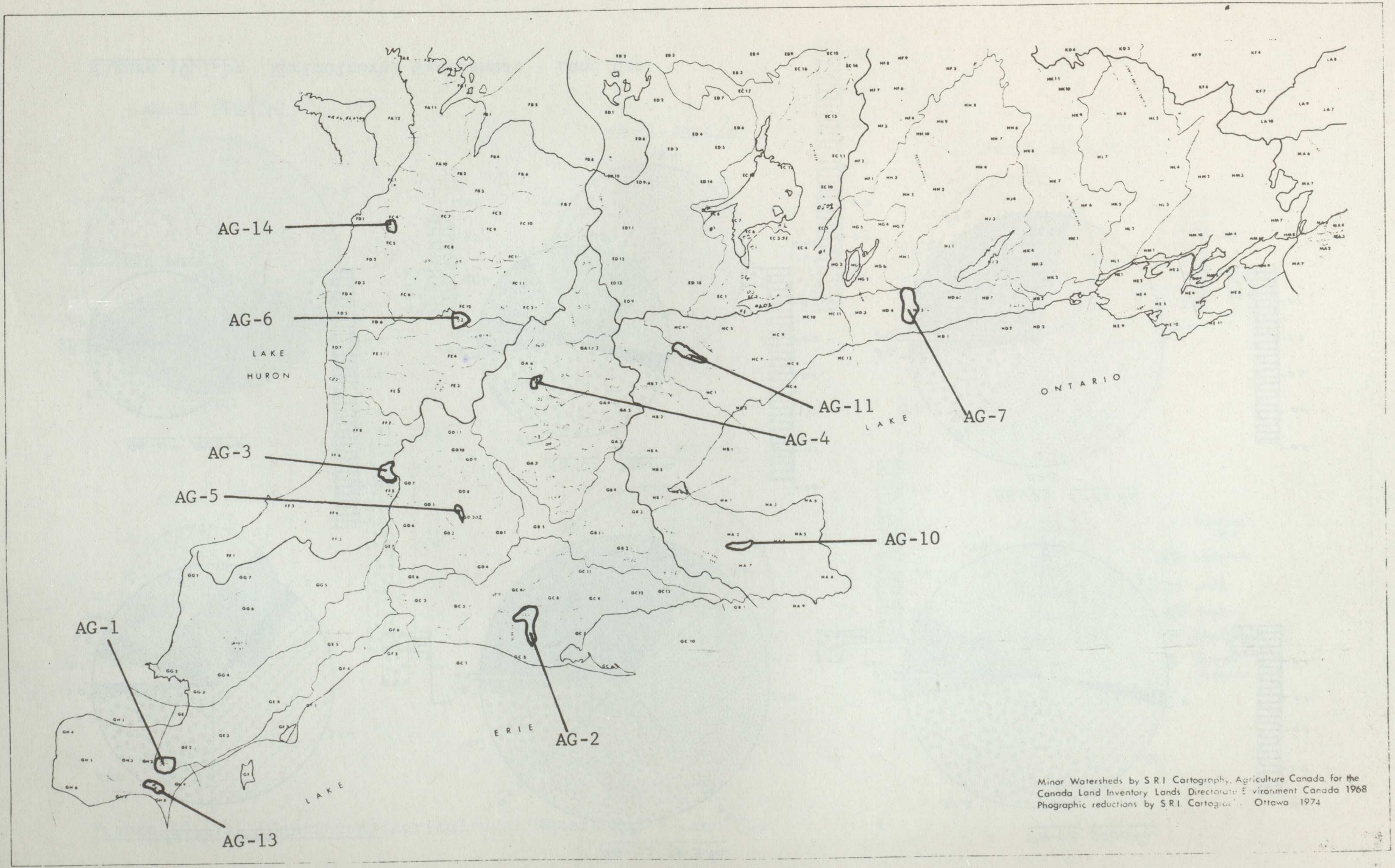
The locations of the eleven PLUARG Agricultural Watersheds (Canada) are shown in Figure 10.1.a. The diagrams which follow (Figure 10.1.b.) indicate the areas of the watersheds and the relationship between land uses of each of the watersheds. Note that there is no significant urban land use or wet-land in any of these watersheds. Livestock and human populations are presented in the histograms accompanying the land use distribution diagrams.

10.2. Loads

Tables 10.2.a-h present the fluvial loads which have been calculated for each of the Agricultural Watersheds using the Beale Ratio Estimator method and the NAQUADAT method. Seasonal loads have been determined with the NAQUADAT approach for the periods: I. "dormant, cold - warming" - to include the latter part of winter and the spring thaw i.e. approximately January through April in Southern Ontario; II. "active growing" - to include the active growth period from May through August; and III, "dormant, cooling - cold" - to include that time when little growth and rather little runoff occurs.

Unit-area load refers to the total load divided by the area of the watershed. This is a general average unit-area load for the particular agricultural "landscape" which is represented by each of the agricultural watersheds. It reflects the net effect of soil type, climatic zone, combination of crops grown with or without associated livestock enterprises, etc., and gives an approximation of the average agricultural contribution. These unit-area loadings also include such non-agricultural interferences as private waste disposal, highways, forestry, etc., which occur within agricultural areas but which cannot be readily separated as to pollutant loads.

Since the Beale and NAQUADAT methods when applied to the estimation of suspended sediment loads produced quite different results, further analysis was conducted in this regard. 1976 sediment loads computed by four different methods, including the Beale and NAQUADAT methods, are presented in Figure 10.2.a, along with long-term predicted loads. (The latter are discussed in a later section.) Detailed analysis has revealed that the hydrograph integration method and the NAQUADAT method best reflect the observed suspended sediment load conditions, and present the most reliable relative rankings of the watersheds. When the watersheds are classified into three sediment load categories (according to the integration and NAQUADAT approaches), AG-1 has an average annual unit-area loading of 900 kg/ha; AG-3, 4, 5, 10 and 13 have averages in the order of 350 kg/ha; and AG-2, 6, 7, 11 and 14 have averages of about 80 kg/ha for 1976.



Minor Watersheds by S.R.I. Cartography, Agriculture Canada for the Canada Land Inventory Lands Directorate Environment Canada 1968
Phographic reductions by S.R.I. Cartogra... Ottawa 1974

Figure 10.1.a: Locations of PLUARG Agricultural Watersheds (Canada)

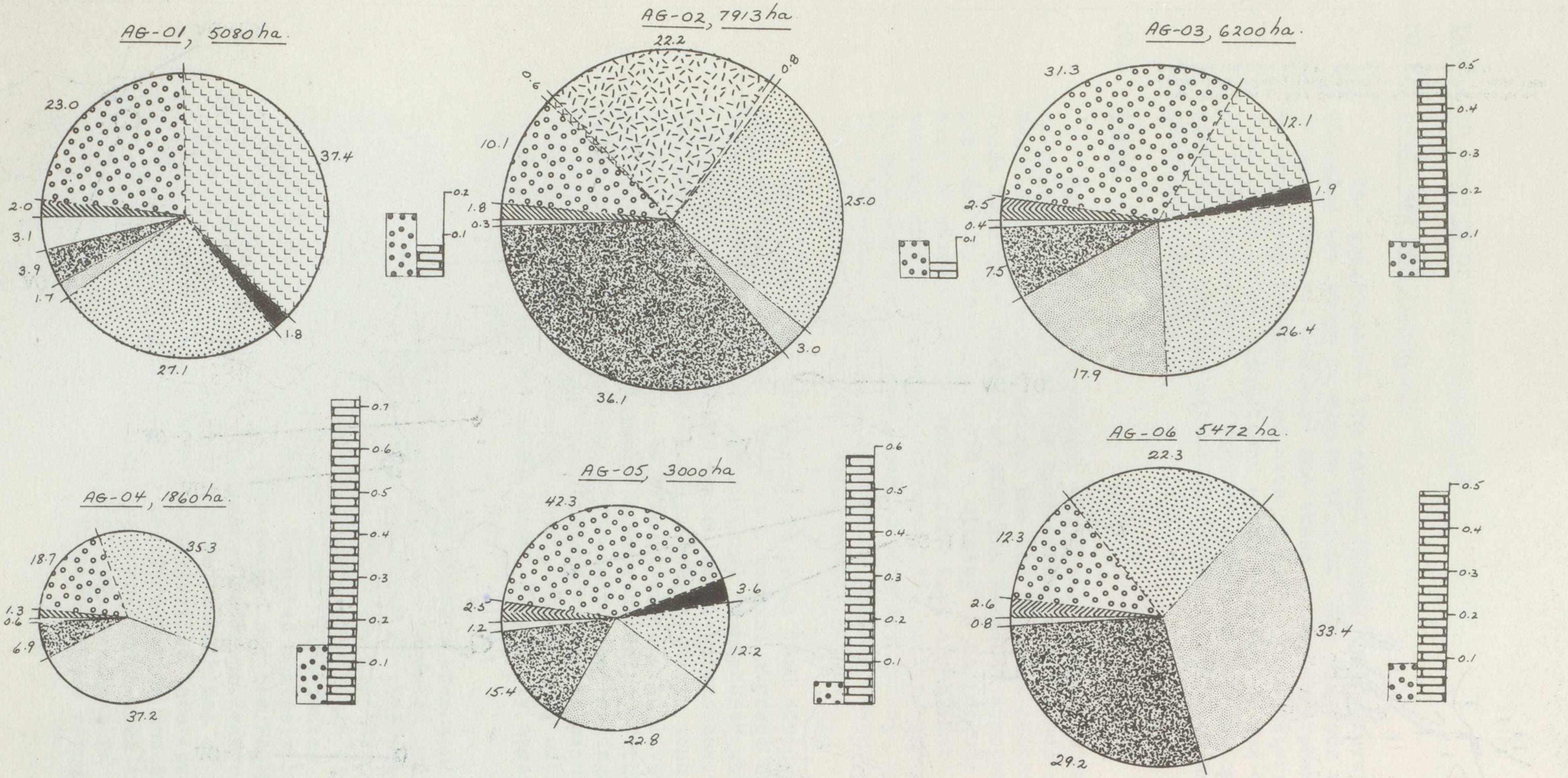


Figure 10.1.b: Agricultural Watersheds - Land Use.

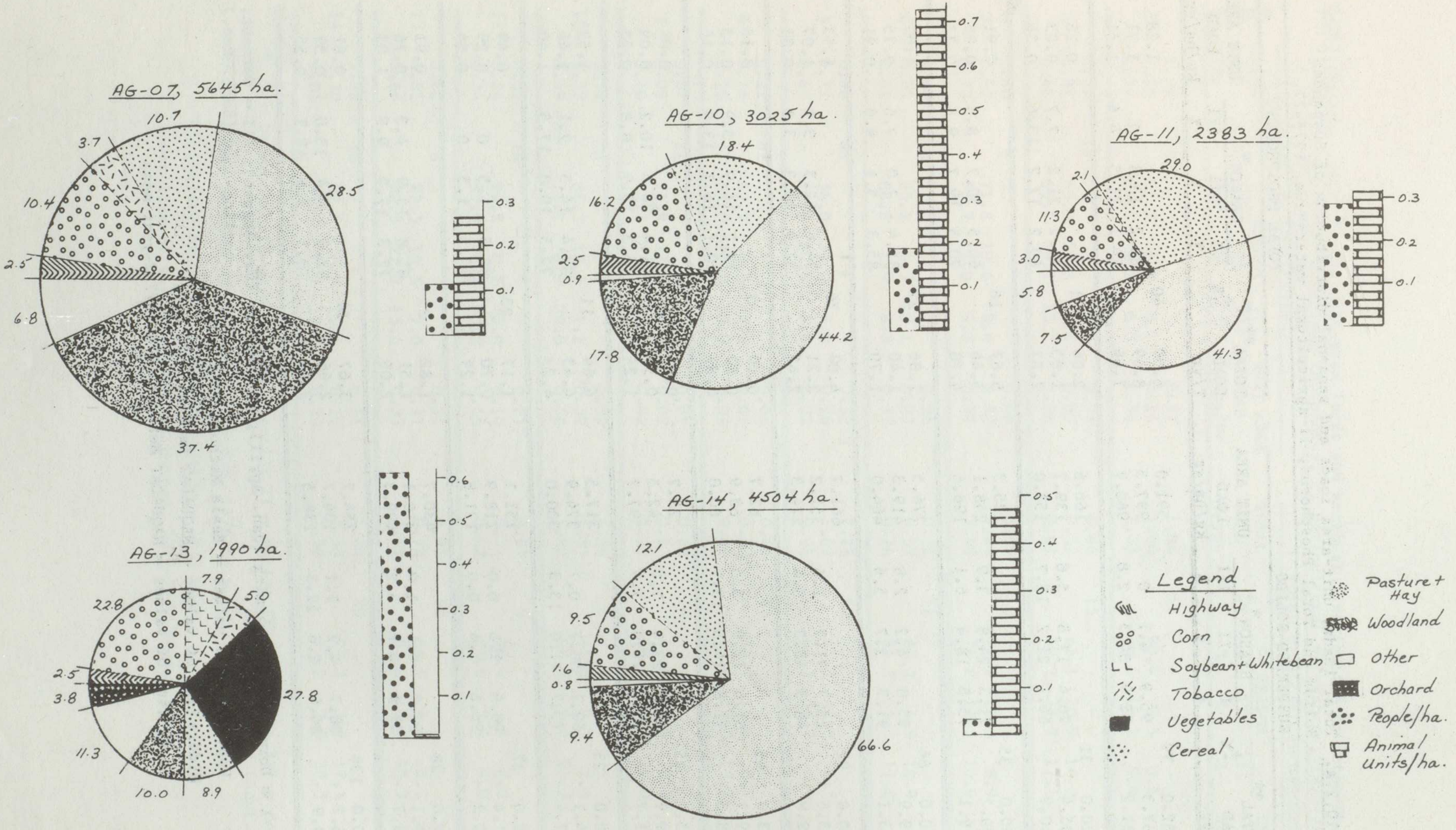


Figure 10.1.b. (Continued):Agricultural Watersheds - Land Use

TABLE 10.2.a. Total loads, unit-area loads and seasonal distribution of Suspended Solids and Total Phosphorus, 11 agricultural watersheds, 1975-77.

W/SHED	SUSPENDED SOLIDS						TOTAL PHOSPHORUS					
	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr
1	3002.0	79				591.0	6.50	40				1.28
	5067.3		95.9	4.1	0	997.5	8.69		86.2	13.8	0	1.71
	4881.2		62.9	34.3	2.8	960.9	7.66		74.1	21.5	4.4	1.51
2	1320.0	31				166.6	2.06	21				0.26
	1105.4		76.6	17.8	5.6	139.7	1.85		71.2	21.2	7.7	0.23
	1210.9		66.1	21.2	12.7	153.0	2.87		69.2	17.2	13.6	0.36
3	1400.0	35				225.3	5.67	16				0.91
	1600.2		71.3	24.8	3.9	258.1	5.46		60.5	30.7	8.8	0.88
	1219.1		75.5	18.4	6.1	196.6	4.78		70.5	19.7	9.8	0.77
4	1440.0	84				776.5	1.86	27				1.00
	779.9		93.0	4.2	2.8	419.3	1.40		85.4	7.0	7.6	0.75
	863.1		91.7	2.7	5.6	464.0	1.70		85.3	5.1	9.6	0.91
5	1990.0	92				661.7	4.60	76				1.53
	1053.6		25.7	71.7	2.6	351.2	3.21		34.6	62.3	3.2	1.07
	822.9		48.3	48.3	3.4	274.3	2.42		52.9	43.3	3.8	0.81
6	343.0	45				62.7	0.90	37				0.16
	349.7		81.6	12.9	5.5	63.9	0.80		77.2	16.9	5.9	0.15
	328.5		71.8	14.5	13.7	60.0	0.87		70.1	16.1	13.8	0.16
7	145.2	25				25.7	0.43	12				0.08
	239.9		69.4	22.9	7.7	42.5	0.53		61.4	28.4	10.2	0.09
	551.7		78.1	14.0	7.9	97.7	1.24		75.3	15.9	8.8	0.22
10	960.0	23				317.5	4.64	11				1.53
	1134.1		69.1	30.2	0.7	374.9	4.43		83.4	14.5	2.1	1.46
	907.4		75.7	11.0	13.3	300.0	4.23		72.5	10.0	17.5	1.40
11	360.0	37				151.1	1.17	23				0.49
	521.6		98.4	1.6	0.0	218.9	0.70		98.5	1.5	0	0.29
	290.2		98.6	1.4	0.0	121.8	1.29		98.5	1.5	0	0.54
13	857.0	28				430.7	1.82	23				0.91
	617.1		92.9	6.1	1.0	310.1	1.51		81.8	13.9	4.3	0.76
	993.7		81.6	15.2	3.2	499.3	2.06		72.3	17.9	9.8	1.03
14	1140.0	134				254.2	3.67	51				0.81
	606.7		88.7	4.2	7.1	134.7	2.66		82.6	4.4	13.0	0.59
	623.9		84.6	2.6	12.8	138.5	2.49		78.3	3.6	18.1	0.55

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III = dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = Beale Method, 1976 only
Middle line of values = NAQUADAT Method, 1976 only
Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

TABLE 10.2.b. Total loads, unit-area loads and seasonal distribution of Ortho-Phosphorus and Total Dissolved Phosphorus, 11 agricultural watersheds, 1975-77.

W/SHED	ORTHO PHOSPHORUS						TOTAL DISSOLVED PHOSPHORUS					
	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr
	1.88	15				0.37	1.06	52				0.21
1	1.31		85.3	14.6	0.1	0.26	1.66		90.4	9.5	0.1	0.33
	1.82		84.6	9.2	6.2	0.36	1.33		74.4	16.2	9.4	0.26
	0.37	16				0.05	0.46	15				0.06
2	0.41		63.0	25.3	11.8	0.05	0.53		65.1	20.9	14.0	0.07
	0.46		65.1	19.7	15.2	0.06	0.61		59.2	23.7	17.1	0.08
	2.86	6				0.46	3.09	5				0.50
3	2.60		71.8	19.6	8.6	0.42	2.84		72.9	19.0	8.9	0.46
	2.25		78.7	12.0	9.3	0.36	2.48		76 6	12.5	10.9	0.40
	0.49	10				0.26	0.62	11				0.33
4	0.43		85.2	4.7	10 1	0.23	0.57		84.2	4.9	10.9	0.31
	0.62		88.8	2.9	8.3	0.33	0.74		84.7	4.3	11.0	0.40
	0.96	48				0.32	1.28	42				0.43
5	0.72		54.0	39.0	6.9	0.24	1.02		44.7	48.8	6.5	0.34
	0.69		72.9	20.9	6.4	0.23	0.91		63.3	30.3	6.4	0.30
	0.21	52				0.04	0.40	33				0.07
6	0.16		82.7	9.5	7.8	0.03	0.35		78.7	14.6	6.7	0.06
	0.20		80.0	10.0	10.0	0.04	0.41		63.4	19.5	17.1	0.07
	0.07	22				0.01	0.18	14				0.03
7	0.09		71.9	17.6	10.6	0.02	0.15		47.8	28.4	10.2	0.03
	0.10		72.1	16.4	11.5	0.02	0.21		58.4	26.6	15.0	0.04
	1.79	8				0.59	1.54	6				0.51
10	1.57		86.3	12.5	1.1	0.52	1.57		91.2	7.3	1.5	0.52
	1.39		71.1	8.9	20.0	0.46	1.92		69.5	9.0	21.5	0.63
	0.50	14				0.21	0.47	6				0.20
11	0.24		99.8	0.2	0.0	0.10	0.31		98.4	1.6	0.0	0.13
	0.34		99.9	0.1	0.0	0.14	0.42		94.6	5.4	0.0	0.18
	0.62	8				0.31	0.71	18				0.36
13	0.61		82.5	10.5	7.0	0.31	0.73		84.6	9.3	6.1	0.37
	0.66		62.5	21.9	15.6	0.33	0.67		67.0	16.7	16.3	0.34
	1.38	18				0.31	1.64	20				0.36
14	1.20		82.5	0.9	16.6	0.27	1.58		79.2	3.2	17.5	0.35
	1.05		81.7	0.9	17.4	0.23	1.38		77.0	2.5	20.5	0.31

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III = dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = Beale Method, 1976 only
Middle line of values = NAQUADAT Method, 1976 only
Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

TABLE 10.2.c. Total loads, unit-area loads and seasonal distribution of Total Nitrogen and Nitrate + Nitrite, 11 agricultural watersheds, 1975-77.

W/SHED	TOTAL NITROGEN						NITRATE + NITRITE NITROGEN					
	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr
1	81.7	35				16.1	54.6	38				10.7
	84.3		75.3	22.3	2.4	16.6	50.8		71.0	27.0	2.0	10.0
	111.7		70.8	20.6	8.6	22.0	77.7		70.9	19.7	9.4	15.3
2	50.8	15				6.4	33.8	19				4.3
	58.6		51.4	27.0	21.6	7.4	40.4		47.1	29.4	23.5	5.1
	66.1		65.4	18.2	16.4	8.4	50.5		67.9	15.6	16.5	6.4
3	257.5	6				41.5	231.6	6				37.4
	249.2		68.2	21.3	10.5	40.2	223.2		68.8	20.4	10.8	36.0
	181.4		65.6	18.3	16.1	29.2	160.9		65.3	18.0	16.7	25.9
4	37.8	16				20.3	27.8	10				14.9
	37.0		80.4	9.5	10.1	19.9	28.1		80.8	9.3	9.9	15.1
	35.3		80.0	6.3	13.7	19.0	26.1		80.2	5.1	14.0	14.0
5	93.3	31				31.1	72.2	25				24.1
	100.5		67.4	20.4	12.2	33.5	83.1		72.6	14.4	13.0	27.7
	81.4		70.5	14.9	14.6	27.2	68.3		73.2	11.1	15.7	22.8
6	78.1	10				14.3	62.0	11				11.3
	86.5		68.4	18.4	13.2	15.8	70.6		69.0	17.8	13.2	12.9
	84.9		58.5	20.3	21.2	17.5	67.5		59.8	19.2	21.0	12.3
7	17.9	9				3.2	11.8	10				2.1
	21.4		65.7	22.9	11.4	3.8	14.7		63.0	18.5	18.5	2.6
	20.0		59.8	22.3	17.9	3.5	13.7		63.9	18.4	17.6	2.4
10	46.9	9				15.5	21.3	12				7.0
	43.0		84.4	12.8	2.8	14.2	16.9		82.1	14.3	3.6	5.6
	37.0		74.0	9.9	16.1	12.2	15.7		76.4	8.6	15.0	5.2
11	26.5	12				11.1	19.9	11				8.3
	17.8		98.4	1.6	0.0	7.5	13.1		99.8	0.2	0.0	5.5
	15.4		99.1	0.9	0.0	6.5	9.5		99.9	0.1	0.0	4.0
13	50.2	13				25.2	41.8	13				21.0
	47.4		86.1	10.5	3.4	23.8	39.0		86.3	10.2	3.5	19.0
	46.9		72.2	11.0	16.8	23.5	38.7		71.9	10.1	18.0	19.4
14	42.5	34				9.4	24.2	40				5.4
	45.0		72.6	5.3	22.1	10.0	26.1		72.4	3.4	24.2	5.8
	35.9		70.1	3.4	26.5	8.0	21.7		69.9	1.1	28.9	4.8

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III = dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = Beale Method, 1976 only

Middle line of values = NAQUADAT Method, 1976 only

Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

TABLE 10.2.d. Total loads, unit-area loads and seasonal distribution of Total Kjeldahl Nitrogen and Lead, 11 agricultural watersheds, 1975-77.

W/SHED	TOTAL KJELDAHL NITROGEN						LEAD***					
	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr	TOTAL** LOAD T/yr	±%	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD kg/ha/yr
							0.023	20				0.005
1	27.1		83.1	16.6	0.3	5.3	0.015		86.9	13.1	0.0	0.003
	34.0		70.7	22.7	6.6	6.7	0.101		70.1	25.6	4.3	0.020
							0.060	267				0.008
2	17.1		66.6	23.9	9.5	2.2	0.079		73.0	18.2	8.8	0.010
	15.7		57.2	26.4	16.4	2.0	0.120		56.6	27.4	16.0	0.015
							0.039	56				0.007
3	26.0		62.8	27.8	9.4	4.2	0.087		86.1	11.1	2.8	0.014
	20.5		68.0	20.4	11.6	3.3	0.106		80.9	13.3	5.8	0.017
							0.011	50				0.006
4	10.1		79.5	12.0	8.5	5.4	0.006		94.4	2.8	2.8	0.003
	9.2		79.0	9.8	11.2	5.0	0.017		89.2	6.7	4.1	0.009
							0.017	17				0.006
5	21.1		42.4	49.6	8.0	7.1	0.039		70.0	26.0	4.0	0.004
	13.1		56.5	34.9	8.6	4.4	0.022		69.8	26.0	4.2	0.007
							0.082	91				0.015
6	16.1		66.2	22.2	11.6	2.9	0.066		86.7	8.3	5.0	0.012
	17.3		53.2	24.5	22.3	3.2	0.104		68.1	18.4	13.4	0.019
							0.022	10				0.004
7	6.0		57.1	28.9	14.0	1.1	0.028		61.0	18.0	21.0	0.005
	6.3		50.9	30.8	18.3	1.1	0.083		24.9	64.9	10.2	0.015
							0.033	86				0.011
10	25.6		86.0	12.2	1.8	8.5	0.073		95.1	4.9	0.0	0.024
	21.3		72.2	10.8	17.0	7.0	0.047		76.3	11.1	12.6	0.016
							0.008	25				0.004
11	4.7		94.4	5.3	0.3	2.0	0.005		96.8	3.2	0.0	0.002
	5.9		97.8	2.1	0.1	2.5	0.010		97.7	2.3	0.0	0.004
							0.009	50				0.005
13	8.4		86.1	9.7	4.2	4.2	0.008		96.4	3.6	0.0	0.004
	8.2		73.5	15.5	11.0	4.1	0.024		83.8	13.3	2.9	0.012
							0.066	73				0.015
14	18.2		74.9	9.6	15.5	4.1	0.036		89.8	2.8	7.3	0.008
	14.2		70.3	7.0	22.6	3.2	0.056		83.1	4.6	13.3	0.012

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III = dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = Beale Method, 1976 only
Middle line of values = NAQUADAT method. 1976 only
Lower line of values = NAQUADAT method, 1975-1977 2-year mean

*** Estimates only - most concentrations below detection limit

TABLE 10.2.e. Total loads, unit-area loads and seasonal distribution of Copper and Zinc 11 agricultural watersheds, 1975-77.

W/SHED	COPPER***						ZINC					
	TOTAL** LOAD T/yr	±%	SEASON* I %	II %	III %	UNIT AREA LOAD kg/ha/yr	TOTAL** LOAD T/yr	±%	SEASON* I %	II %	III %	UNIT AREA LOAD kg/ha/yr
1	0.239	29				0.047	0.421	17				0.083
	0.213		88.6	11.4	0.0	0.042	0.422		90.9	9.0	0.1	0.083
	0.703		70.3	23.1	6.6	0.138	0.682		70.0	23.5	6.5	0.134
2	0.107	190				0.013	0.186	189				0.024
	0.253		84.6	9.6	5.8	0.032	0.213		49.2	33.3	17.5	0.027
	0.205		43.2	22.9	33.9	0.026	0.303		55.4	19.8	21.0	0.038
3	0.185	53				0.030	0.354	106				0.057
	0.062		86.5	11.1	2.4	0.010	0.341		87.5	9.7	2.8	0.055
	0.143		76.1	17.6	6.3	0.023	0.289		85.7	7.5	6.8	0.047
4	0.052	70				0.028	0.352	151				0.189
	0.091		96.3	2.9	0.8	0.049	0.214		97.6	1.9	0.5	0.115
	0.085		77.7	10.9	11.4	0.046	0.206		96.7	1.9	1.4	0.111
5	0.043	38				0.014	0.079	50				0.026
	0.090		70.4	26.5	3.1	0.030	0.060		77.8	16.3	5.9	0.020
	0.068		69.2	26.2	4.6	0.023	0.081		84.6	8.7	6.7	0.027
6	0.134	42				0.024	0.307	82				0.056
	0.060		88.5	8.6	2.9	0.011	0.164		81.2	14.6	4.2	0.030
	0.131		45.8	34.8	19.4	0.024	0.147		69.5	17.8	17.7	0.027
7	0.120	120				0.021	0.109	35				0.019
	0.085		12.8	82.0	5.2	0.015	0.102		73.8	20.7	5.5	0.018
	0.095		13.4	75.1	11.5	0.017	0.188		27.0	68.9	4.1	0.033
10	0.113	36				0.037	0.519	41				0.172
	0.178		95.2	4.2	0.6	0.059	0.436		90.6	8.8	0.6	0.144
	0.112		75.5	6.3	18.2	0.037	0.297		72.1	8.7	19.2	0.098
11	0.046	10				0.020	0.113	32				0.047
	0.024		97.6	2.4	0.0	0.010	0.050		94.4	5.6	0.0	0.021
	0.025		98.2	1.8	0.0	0.010	0.044		96.4	3.6	0.0	0.018
13	0.128	115				0.064	0.144	39				0.072
	0.094		96.6	2.9	0.5	0.047	0.109		97.0	1.7	1.3	0.055
	0 075		78.4	14.3	7.3	0.038	0.119		83.2	10.1	6.7	0.060
14	0.169	76				0.038	0.370	62				0.082
	0.054		91.3	3.8	4.9	0.012	0.270		85.6	2.2	12.2	0.060
	0.083		82.2	6.6	11.2	0.018	0.215		84.2	1.9	13.9	0.048

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III = dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = Beale Method, 1976 only
Middle line of values= NAQUADAT Method, 1976 only
Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

*** Includes estimates - some watersheds had most concentrations below detection limit.

TABLE 10.2.f. Total loads, unit-area loads and seasonal distribution of 2,4-D and Atrazine + Desethyl Atrazine, 11 agricultural watersheds, 1975-77.

W/SHED	2,4-D***						Atrazine + Desethyl Atrazine***					
	TOTAL** LOAD kg/yr	± %	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD g/ha/yr	TOTAL** LOAD kg/yr	± %	SEASON* I %	SEASON* II %	SEASON* III %	UNIT AREA LOAD g/ha/yr
1	0.074		0.0	100.0	0.0	0.015	8.59		8.8	90.2	1.0	1.69
	3.562		0.1	97.4	2.5	0.701	15.66		18.5	75.8	5.7	3.08
2	0.619		0.0	86.6	13.4	0.078	0.93		40.9	40.8	18.3	0.12
	0.475		8.1	83.2	8.7	0.060	4.34		31.5	64.8	3.7	0.55
3	0.315		0.0	100.0	0.0	0.051	39.83		52.3	34.5	12.9	6.42
	0.284		3.4	96.6	0.0	0.046	27.69		39.1	51.8	9.1	4.47
4	0.230		0.0	100.0	0.0	0.124	4.03		36.5	59.3	4.2	2.17
	0.145		2.8	79.6	17.6	0.078	3.15		35.2	54.5	10.3	1.69
5	0.030		0.0	80.0	20.0	0.010	8.68		53.8	40.9	5.3	2.89
	0.053		13.8	80.2	6.0	0.018	5.21		62.8	31.7	5.5	1.74
6	0.625		0.0	100.0	0.0	0.114	1.79		85.5	11.7	2.8	0.33
	1.331		0.9	77.2	21.9	0.243	2.67		59.0	52.4	8.6	0.49
7	0.284		0.0	50.4	49.6	0.050	0.00		0.0	0.0	0.0	0.0
	0.348		0.0	79.8	20.2	0.062	0.116		0.0	87.3	12.7	0.02
10	0.000		0.0	0.0	0.0	0.000	8.21		44.8	45.1	10.1	2.71
	0.052		47.2	52.8	0.0	0.017	9.39		34.1	35.8	30.1	3.10
11	0.000		0.0	0.0	0.0	0.000	2.45		94.7	5.3	0.0	1.03
	0.000		0.0	0.0	0.0	0.000	1.08		93.8	6.1	0.1	0.45
13	0.016		0 0	0.0	100.0	0.008	0.89		24.7	28.1	47.2	0.45
	0.043		72.0	12.7	15.3	0.022	1.16		36.2	39.4	24.4	0.58
14	0.027		0.0	0.0	100.0	0.006	9.91		61.5	7.1	31.4	2.20
	0.020		33.7	1.1	65.2	0.004	8.40		48.3	16.0	35.7	1.87

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III - dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = NAQUADAT Method, 1976 only

Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

*** Estimates only - many concentrations below detection limit

TABLE 10.2.g. Total loads, unit-area loads and seasonal distribution of DDT and Dieldrin, 11 agricultural watersheds, 1975-77.

	1976 ΣDDT						DIELDRIN***					
			SEASON*						SEASON*			
	TOTAL** LOAD kg/yr	±%	I %	II %	III %	UNIT AREA LOAD g/ha/yr	TOTAL** LOAD kg/yr	±%	I %	II %	III %	UNIT AREA LOAD g/ha/yr
1	0.113		95.6	4.4	0.0	0.022	0.025		96.0	4.0	0.0	0.005
	0.077		69.6	22.5	7.9	0.015	0.018		80.0	12.5	7.5	0.004
2	0.241		72.2	23.7	4.1	0.030	0.009		100.0	0.0	0.0	0.001
	7.232		58.3	12.9	28.8	0.914	0.040		45.0	47.1	7.9	0.005
3	0.273		83.9	11.7	4.4	0.044	0.004		100.0	0.0	0.0	0.001
	0.104		68.5	17.3	14.2	0.017	0 003		100.0	0.0	0.0	0.001
4	0.027		96.3	3.7	0.0	0.015	0.000		0.0	0.0	0.0	0.000
	0.022		77.1	16.7	6.2	0.012	0.000		0.0	0.0	0.0	0.000
5	0.046		82.6	15.2	2.2	0.015	0.000		0.0	0.0	0.0	0.000
	0.087		65.0	20.9	14.1	0.029	0.000		0.0	0.0	0.0	0.000
6	0.184		85.7	13.0	1.3	0.034	0.001		0.0	0.0	100.0	0.000
	0.561		58.5	14.9	26.6	0.103	0.004		47.0	6.0	47.0	0.001
7	0.159		64.2	33.3	2.5	0.028	0.000		0.0	0.0	0.0	0.000
	0.788		2.6	96.4	1.0	0.140	0.002		10.0	0.0	90.0	0.000
10	0.047		85.1	14.9	0.0	0.016	0.002		0.0	0.0	100.0	0.001
	0.041		73.7	12.3	14.0	0.014	0.001		0.0	0.0	100.0	0.000
11	0.000		0.0	0.0	0.0	0.000	0.000		0.0	0.0	0.0	0.000
	0.011		96.1	3.9	0.0	0.005	0.000		0.0	0.0	0.0	0.000
13	0.046		100.0	0.0	0.0	0.023	0.034		87.5	12.5	0.0	0.017
	0.043		72.0	12.7	15.3	0.022	0.044		65.7	24.1	10.2	0.022
14	0.052		53.8	25.0	21.2	0.012	0.000		0.0	0.0	0.0	0.000
	0.043		63.7	16.3	20.0	0.010	0.001		0.0	0.0	100.0	0.000

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III - dormant, cooling-cold (Sept.-Dec.)

** Upper line of values = NAQUADAT Method, 1976 only

Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

*** Estimates only - many concentrations below detection limit

TABLE 10.2.h. Total loads, unit-area loads and seasonal distribution of Endosulfan and Polychlorinated Biphenyls, 11 agricultural watersheds, 1975-77.

W/SHED	ENDOSULFAN ***						POLYCHLORINATED BIPHENYLS					
	TOTAL** LOAD kg/yr	±%	SEASON* I %	II %	III %	UNIT AREA LOAD g/ha/yr	TOTAL** LOAD /yr	±%	SEASON* I %	II %	III %	UNIT AREA LOAD g/ha/yr
1	0.032		95.6	4.4	0.0	0.006	0.403		92.6	7.4	0.0	0.079
	0.108		86.1	4.6	9.3	0.020	0.545		62.7	23.1	14.2	0.107
2	0.094		84.1	15.9	0.0	0.012	1.710		75.0	9.7	17.1	0.216
	0.087		69.7	11.9	18.4	0.010	1.540		58.2	17.0	24.8	0.195
3	0.002		100.0	0.0	0.0	0.000	1.151		78.7	15.4	5.9	0.186
	0.001		50.0	50.0	0.0	0.000	0.846		68.7	17.2	14.1	0.136
4	0.006		100.0	0.0	0.0	0.003	0.191		90.6	1.6	7.8	0.103
	0.002		81.8	18.2	0.0	0.001	0.189		67.5	8.5	24.0	0.102
5	0.013		98.5	0.0	1.5	0.004	0.641		82.5	11.1	6.4	o.214
	0.012		100.0	0.0	0.0	0.004	0.505		76.4	13.7	9.9	0.168
6	0.053		98.5	0.0	1.5	0.010	0.628		64.2	18.3	17.5	0.115
	0.041		68.9	17.8	13.3	0.007	0.803		37.0	33.0	30.0	0.147
7	0.000		0.0	0.0	0.0	0.000	0.977		73.4	17.1	9.5	0.173
	0.011		0.0	0.0	100.0	0.002	0.952		46.3	24.8	28.9	0.169
10	0.000		0.0	0.0	0.0	0.000	0.292		81.8	16.4	1.8	0.097
	0.001		0.0	0.0	100.0	0.000	0.260		60.6	20.0	19.4	0.086
11	0.000		0.0	0.0	0.0	0.000	0.201		97.5	2.0	0.5	0.084
	0.000		0.0	0.0	0.0	0.000	0.358		99.3	0.5	0.2	0.150
13	0.093		79.4	18.9	1.7	0.046	0.266		94.0	4.9	1.1	0.134
	0.108		45.6	41.0	13.4	0.054	0.254		71.1	14.9	14.0	0.128
14	0.023		100.0	0.0	0.0	0.005	0.639		82.6	2.5	14.9	0.142
	0.016		95.8	0.0	0.2	0.004	0.510		73.1	4 7	22.2	0.113

* I = Dormant, cold-warming (Jan.-April); II = active (May-August); III - dormant, cooling-cold (Sept.-Dec.)

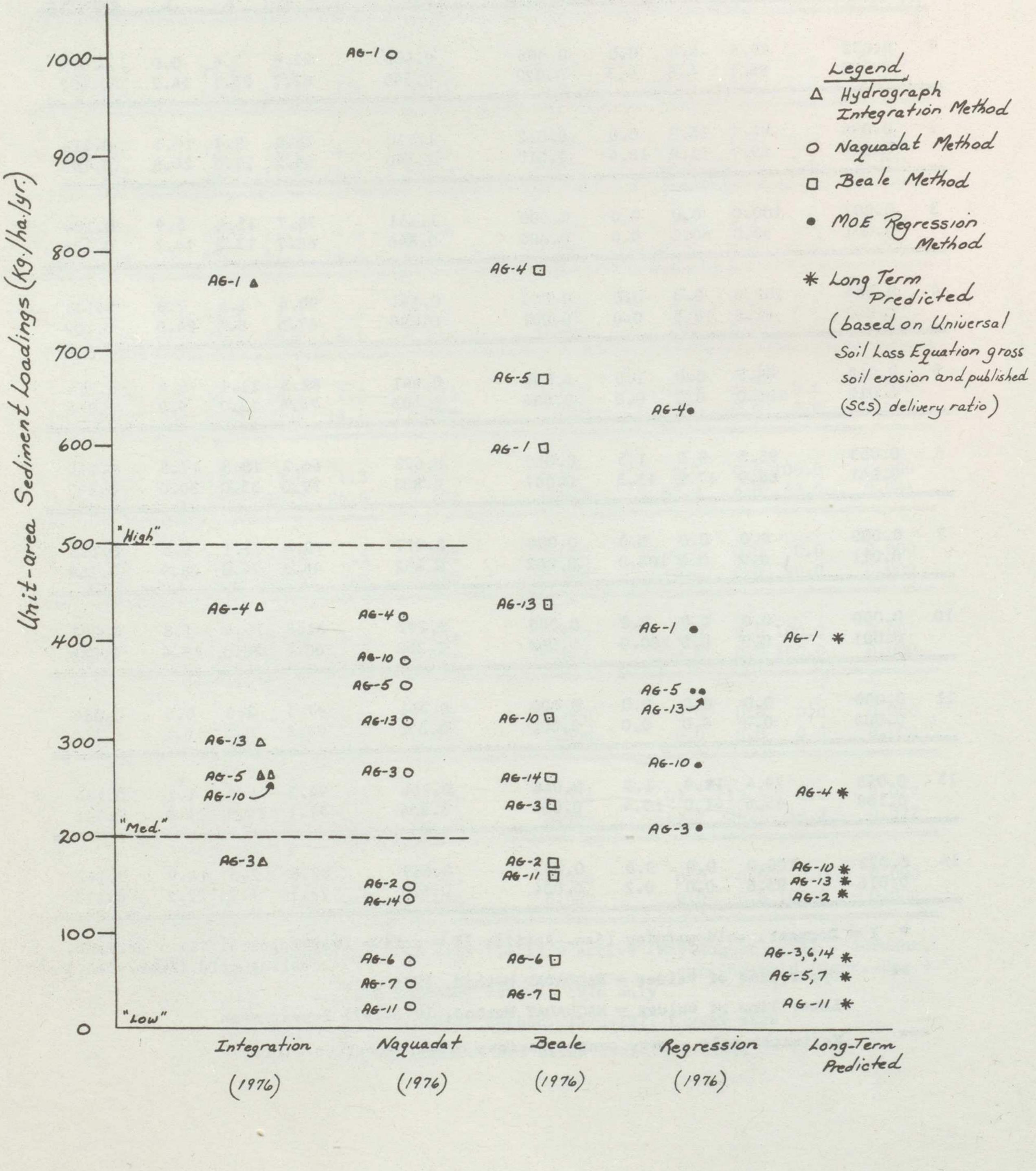
** Upper line of values = NAQUADAT Method, 1976 only

Lower line of values = NAQUADAT Method, 1975-1977 2-year mean

*** Estimates only - many concentrations below detection limit

Figure 10.2.a

1976 Sediment Loads For Agricultural Watersheds, Computed By 4 Different Methods, And Long-Term Predicted Loads



The temporal pattern of suspended sediment loads for the eleven agricultural watersheds is revealed in Figure 10.2.b. Most of the total annual load leaves the mouths of the watersheds during the months of February through April as summarized in Table 10.2.i for 1976. This same pattern has been confirmed for many rivers in larger drainage basins in Ontario.

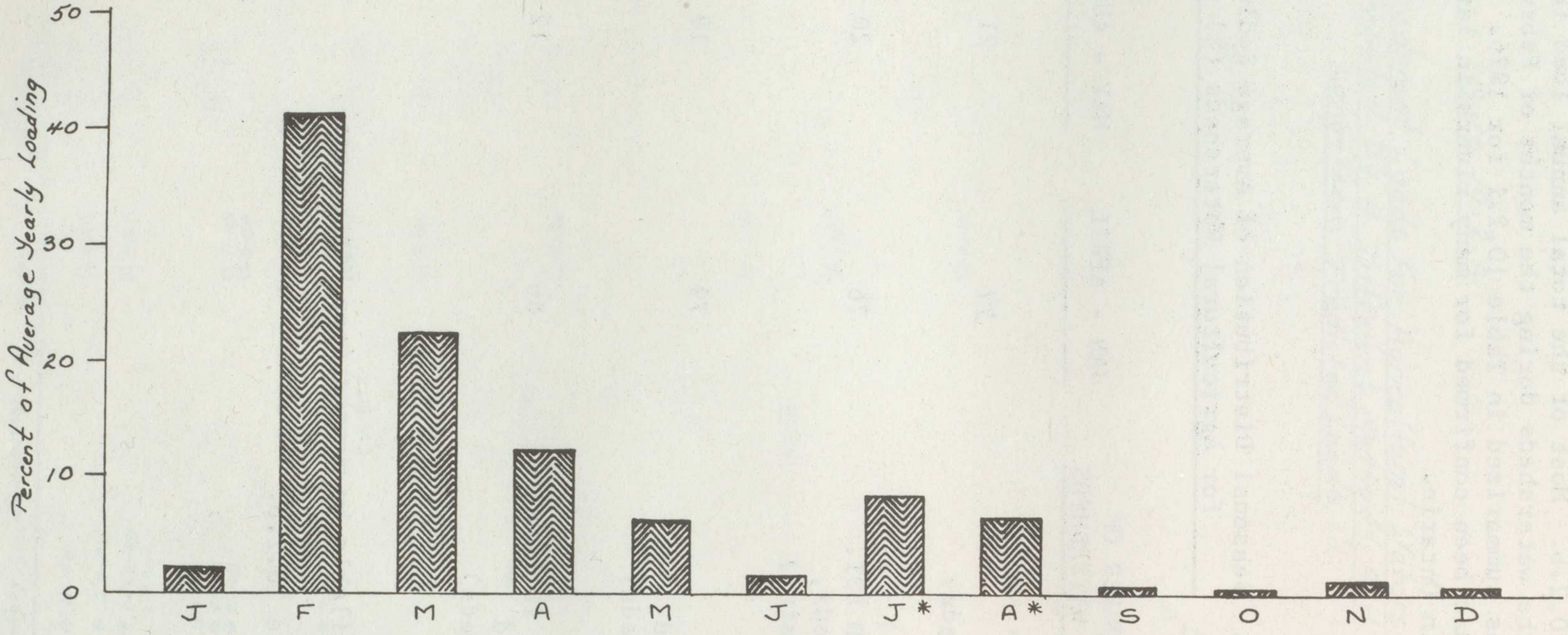
TABLE 10.2.i. Seasonal Distribution of Average Sediment Loadings for Agricultural Watersheds (%) in 1976

METHOD AND NUMBER OF AGRICULTURAL WATERSHEDS	JAN - APRIL	MAY - AUGUST	SEPT - DEC.
* NAQUADAT (11 Watersheds)	77	21	2
** BEALE RATIO EST. (10 Watersheds, AG-11 missing)	76	20	4
* NAQUADAT (6 Detailed Watersheds)	79	19	2
* HYDROGRAPH INTEGRATION (6 Detailed Watersheds)	86	12	2

* Data available by months (see Histograms).

** See Table 10.2.b.

Figure 10.2.b Monthly Distribution of Average Sediment Loadings For The 11 AGricultural Watersheds (1976) (Naquadat Method)



* These values reflect the high values for extreme storm events in Watershed 5 during these months.

10.3 Point : Non-Point Distribution:

There have been no measurable non-agricultural point sources of pollution in the agricultural watersheds. Although many agricultural activities in fact behave as point sources (e.g. drain outfalls, livestock housing runoff discharges, and specific fields or portions of fields draining directly into a waterway), it has not been possible to measure the loads attributable to such specific sources. The lumping of these various agricultural point sources into a diffuse load has been proven convenient. However, the consideration of remedial practices must not lose sight of the nature of the agricultural sources.

10.4 Relative Significance of Land Uses and Practices:

It must be understood that the Agricultural Watershed Study does not, by itself, have the capability of determining the relative significance of agricultural land use *vis a vis* other land uses (e.g. urban, extractive, etc.). The contribution of pollutants to the Grand and Saugeen rivers from sources other than agricultural land has been estimated by scientists in the OMOE studies. The estimates of contributions from agricultural activities obtained in the Agricultural Watershed Studies can be compared with the OMOE estimates of those from other land uses, which are presented in the Summary reports of the Grand and Saugeen River Pilot Watershed Studies. This comparison is discussed in Section 11.3 of this report.

Within the generalized category of agricultural land use, there are identifiable practices and conditions which have varying significance in terms of water quality. For convenience, the relative significance of agricultural practices and conditions can be discussed by water quality parameter group:

10.4.1 Phosphorus:

On a watershed-to-watershed basis, about 86% of the variability in 1976 measured total phosphorus unit-area loads from agricultural land can be accounted for by differences in surface soil clay content (texture) and in the percentages of the area which is cultivated to row crops (corn, soybeans, tobacco, vegetables). The same variables accounted for 92% of the variability in measured flow-weighted mean concentrations. Based on farmland alone, in 1976 the unit-area loadings varied by a factor of about 20 from the lowest yielding area to the highest (i.e. from < .1 to 1.82 kg/ha/yr). The greater portion of this difference can be attributed to differences in soil type with higher P losses from soils with higher clay content. Table 10.4.a. shows the estimated loadings from the major identifiable land uses within the Agricultural watersheds.

Table 10.4.a: Estimated Annual Total Phosphorus load from Sources within the Agricultural Watersheds

Watershed	1976 Measured Total		Estimated Load From				
	Beale R.E.	NAQUADAT	Streambank Erosion[1]	Cropland[2]	Livestock[3]	Unimproved Land[4]	Total Estimated Load
			- - - - - - - - - - - - Tonnes/yr - - - - - - - - - - - -				
Ag-1	6.50	8.69	0.57	7.55	0.06	0.02	8.20
Ag-2	2.06	1.85	0.05	3.17	0.05	0.23	3.50
Ag-3	5.67	5.46	0.13	3.12	0.66	0.04	3.95
Ag-4	1.86	1.40	0.20	1.38	0.34	0.01	1.93
Ag-5	4.60	3.21	0.01	1.96	0.39	0.04	2.40
Ag-6	0.90	0.80	0.02	1.16	0.58	0.15	1.91
Ag-7	0.50	0.53	0.03	0.40	0.28	0.13	0.84
Ag-10	4.64	4.43	0.04	2.60	0.35	0.04	3.03
Ag-11	1.17	0.70	0.15	0.00	0.23	0.01	0.39
Ag-13	1.82	1.51	0.03	2.17	0.01	0.01	2.22
Ag-14	3.67	2.66	0.22	1.26	0.56	0.03	2.07

1. Streambank sediments estimated by K. Knapp x average P conc. (0.733) x P Enrichment ratio (1.1)

2. Sediment associated P + Dissolved P from cropland. Sediment associated P estimated from model based on gross erosion, estimated delivery ratio and estimated P enrichment ratio. Dissolved P calculated assuming proportion of total P from cropland that was in dissolved form was the same as for that from agricultural land:

   Dissolved P from Cropland

   $$= \frac{\text{Sed. Assoc. P from Cropland (Model)}}{\text{Total P from Ag.Land (Regr) - Diss. P Ag.Land (Reg)}} \times \text{Diss. P Ag.Land}$$

3. Estimated by Robinson and Draper (Livestock Integrators)

4. Calculated assuming unit-area load of 0.08 kg/ha

Two-year loading data analysis showed that an estimate of soil extractable phosphorus, based on the records of the Soil Testing Service at the University of Guelph for the county in which each watershed was located, was a better variable than row crops for both total phosphorus unit-area load and flow-weighted mean concentration variability explanation. This is thought to be because this variable is influenced by (statistically correlated with) both row crops and phosphorus fertilizer use.

Soluble ortho-phosphorus is considered to be that which was found in water filtered through a 0.45 u membrane filter. It averages 43% of the total P load in runoff from the 11 agricultural watersheds with a range of 25-60%. About 96% of the variability in the two-year unit-area loads of total dissolved P can be accounted for by surface soil clay content, the sum of the fertilizer and manure P applied in the watershed and the density of rural residences.

The estimates which are presented in Table 10.4.a. show that livestock were contributing phosphorus at rates which ranged from 0.5% to 60%, with a mean of 19.5%. These estimates were made with the use of a livestock input model.

In addition to the sources indicated in Table 10.4.a, private sewage disposal systems are contributing to phosphorus loadings in agricultural areas. Results of a study conducted on an agricultural watershed with a high density of rural residences (AG-13) indicated a definite contribution from septic systems. Other PLUARG studies on P losses from septic tanks have indicated that P will normally be transported only very short distances from the system (probably much less than 30 m). Thus it is only where a system is located very close to a stream or it is linked directly to a field drainage system that these sources would be likely to influence P loadings in streams.

10.4.2. Nitrogen:

Soluble NO_3+NO_2-N concentration (the predominant soluble form of N lost from the agricultural watersheds) occasionally (<10% of the time) exceeded the 10 mg/L drinking water standard on watersheds with more than 20% corn. For these watersheds, concentrations were between 5 and 10 mg/L from 16 to 47% of the time, suggesting that any future inefficient use of N in agriculture may result in water more frequently exceeding the drinking water standard. Algal growth would not be N-limited in the streams of these watersheds except sometimes during very low flow summer conditions.

Correlation and regression analyses have been performed on nitrogen unit-area loading and concentration data with characteristics of the 11 monitored watersheds. Total and nitrate plus nitrite unit-area loads from 2 years of data were best explained ($r^2 = 0.85$ and 0.74 respectively) by multiple linear regression on mean applications of fertilizer and manure nitrogen. Two-year flow-weighted mean concentrations of these same parameters were best explained by multiple linear regression on % row crops and manure nitrogen applications ($r^2 = .92$) and on soil clay content, % cultivated land and tile drainage density ($r^2 = .94$) respectively. Monthly stream NO_3 concentrations were found to be significantly higher with increasing proportions of the land planted with corn or other high N input crops, with increasing use of fertilizer N and with larger percentages of the land tile drained. NH_4-N concentrations were high where rural residences (private waste disposal) and livestock densities were high suggesting N inputs from these sources. Elevated total Kjeldahl N concentrations did not appear to be related to land use but they did occur in watersheds with a higher proportion of low permeability soils.

During 1976, annual N loss rates ranged from 3.8 to 40.2 kg/ha (Table 10.2.c). Table 10.4.b summarizes the NO_3+NO_2 and total N loss rates from various agricultural activities as estimated from a statistical model developed for the agricultural watersheds. In watersheds where livestock densities were high, N losses from manure are important, in some cases exceeding those from cropland.

TABLE 10.4.b. Component 1976 Total N and NO_2^- + NO_3^- -N Losses from Livestock and Various Cropping Activities in PLUARG Agricultural Watersheds

	Unit TN Loss Rates kg-N/ha							Unit NO_3^- + NO_2^- -N Loss Rates (kg-N/ha)						
	High Nit. Crops †	Low Nit. Crops ††	Hay Past. *	Cropping Total	Live-stock	Predicted Total	1976 Total **	High Nit. Crops	Low Nit. Crops	Hay and Pasture	Cropping Total	Live-stock	Pred. Total	1976 Est.
AG-01	7.2	2.8	<.1	10.0	1.0	11.0	16.0	6.1	1.9	<.1	8.0	0.7	8.7	10.7
AG-02	5.8	2.2	<.1	8.0	0.6	8.6	6.4	4.9	1.5	<.1	6.4	0.4	6.8	4.2
AG-03	16.2	2.6	<.1	18.8	15.3	34.1	41.6	13.7	1.7	<.1	15.4	11.0	26.4	37.4
AG-04	6.3	1.6	<.1	7.9	12.2	20.1	20.3	5.4	1.1	<.1	6.5	8.6	15.1	14.9
AG-05	18.1	0.7	<.1	18.8	17.6	36.4	31.1	15.3	0.5	<.1	15.8	13.3	29.1	24.1
AG-06	4.3	1.1	<.1	5.4	11.8	17.2	14.3	3.7	0.7	<.1	4.4	8.2	12.6	11.4
AG-07	3.2	0.4	<.1	3.6	3.5	7.1	3.2	2.7	0.3	<.1	3.0	2.3	5.3	2.1
AG-10	6.0	0.9	<.1	6.9	14.9	21.8	15.6	5.1	0.6	<.1	5.7	10.6	16.3	7.1
AG-11	4.0	1.4	<.1	5.4	5.3	10.7	11.1	3.4	1.0	<.1	4.4	2.6	7.0	8.3
AG-13	16.7	1.1	<.1	17.8	0.4	18.2	25.2	14.1	0.7	<.1	14.8	0.3	15.1	21.0
AG-14	4.8	0.8	0.1	5.7	5.1	10.8	9.4	4.1	0.5	0.1	4.7	3.4	8.1	5.3

† high nitrogen crops include corn, potatoes, burley tobacco

†† low nitrogen crops include cereals, soybeans, beans, flue cured tobacco

* hay and pasture includes all remaining improved farmland

** loads estimated by Beale's ratio estimator method (courtesy B. Bodo, O.M.O.E., 1977)

For comparison of these values with NAQUADAT loadings see Table 10.2.b.

Elevated groundwater N concentrations frequently were observed beneath or downslope of heavily N fertilized crops, especially in coarse textured soil material. These high levels were also found downslope of an unpaved feedlot. A detailed study of groundwater N movement was conducted in one watershed (AG-13), and groundwater N inputs to the stream were estimated to exceed those from surface runoff. However, it is not possible to predict the N loss associated with groundwater movement into streams because of the site specific distribution of N and possible denitrification of groundwater N. It is also, therefore, not possible to determine whether increased N useage in the recent past (six-fold increase in fertilizer N sales from 1960 - 1975) will significantly increase the N content of the groundwater component of stream flow in the future.

10.4.3. Sediment:

Measured suspended sediment loads are not available for various agricultural land uses and practices. However a picture of the effects of land use and practice on potential soil losses has been developed both for long-term average annual and 1976 rainfall conditions. Sheet and rill erosion losses, predicted by a modified Soil Loss Equation with a delivery ratio, are shown in Figure 10.4.a for the agricultural watersheds, the estimates having been modified to include snowmelt effects. Long-term crop averages have also been included in the Figure. The temporal pattern of these soil losses has been included in Figure 10.4.b.

High long-term average erosion rainfall values account for some of the higher soil losses in AG-1 and AG-13, but the watersheds exhibiting relatively high potential soil losses are also those which are intensively farmed with a high percentage of row crops.

The monthly patterns of the "R" factor representing the rainfall effect on erosion are shown in Figure 10.4.c. It should be noted that 1976 exhibited a rainfall erosional factor that on the average for the eleven watersheds was double the long-term rainfall factor. It is for this reason that the predicted soil losses for 1976 are substantially higher than those for the long term. Similarly sediment loads for 1976 may be higher than average annual values.

With present trends towards changing land use practices (for example, more continuous row cropping systems) often in combination with increased transport capacity (for example reduced vegetative buffering along streams, increased delivery ratios, increased drainage density), watersheds in the low (AG-2, 14, 6, 7, 11) and medium (AG-4, 10, 5, 13, 3) sediment load category have the potential to become medium or high sediment producing watersheds respectively. Classification into 3 sediment load categories according to the Integration and NAQUADAT approaches is shown in Figure 10.2.a.

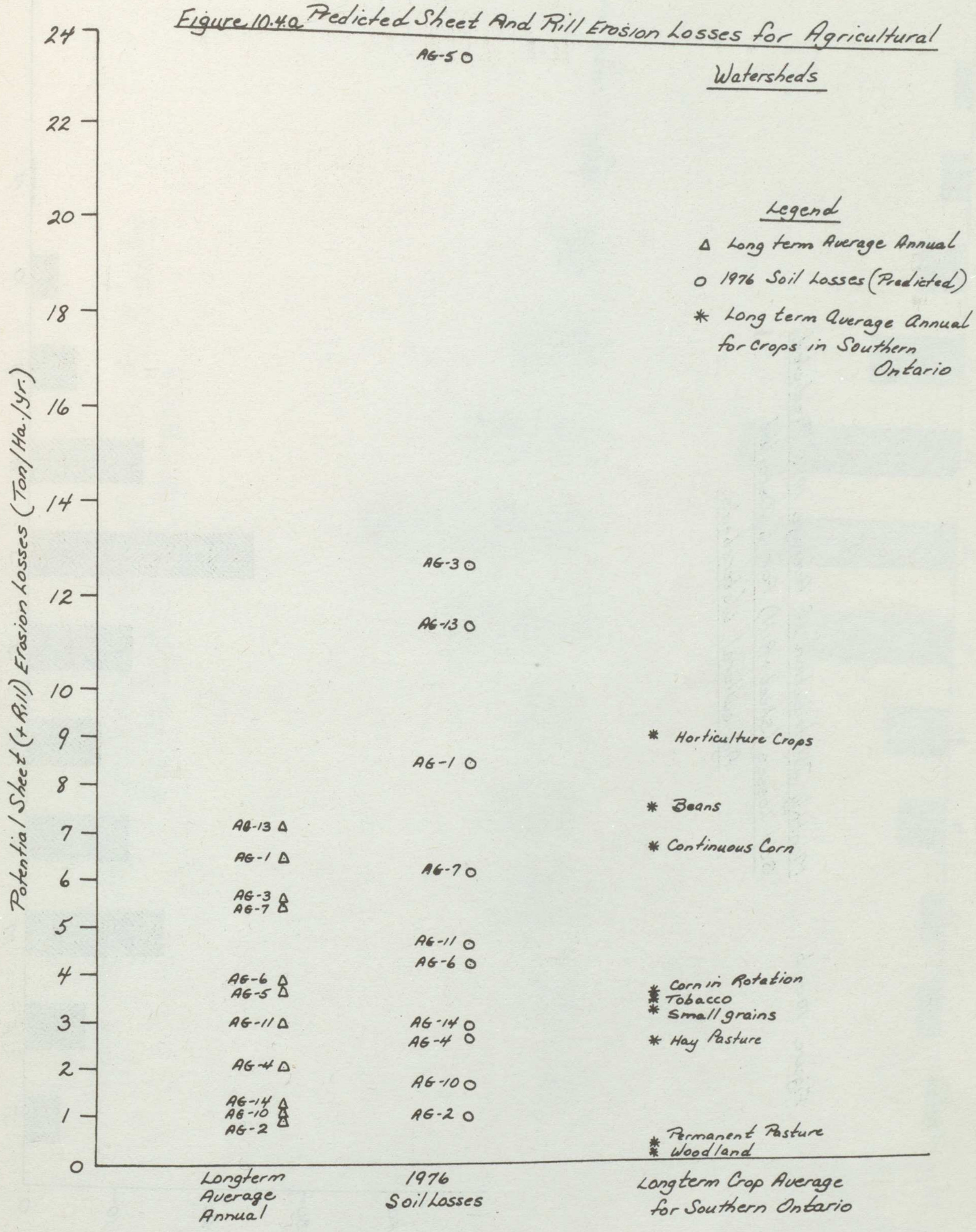


Figure 10.4a Predicted Sheet And Rill Erosion Losses for Agricultural Watersheds

Figure 10.4.b Monthly Distribution of Average 1976 Predicted Soil Losses (Sheet + Rill) For 6 Detailed Agricultural Watersheds.

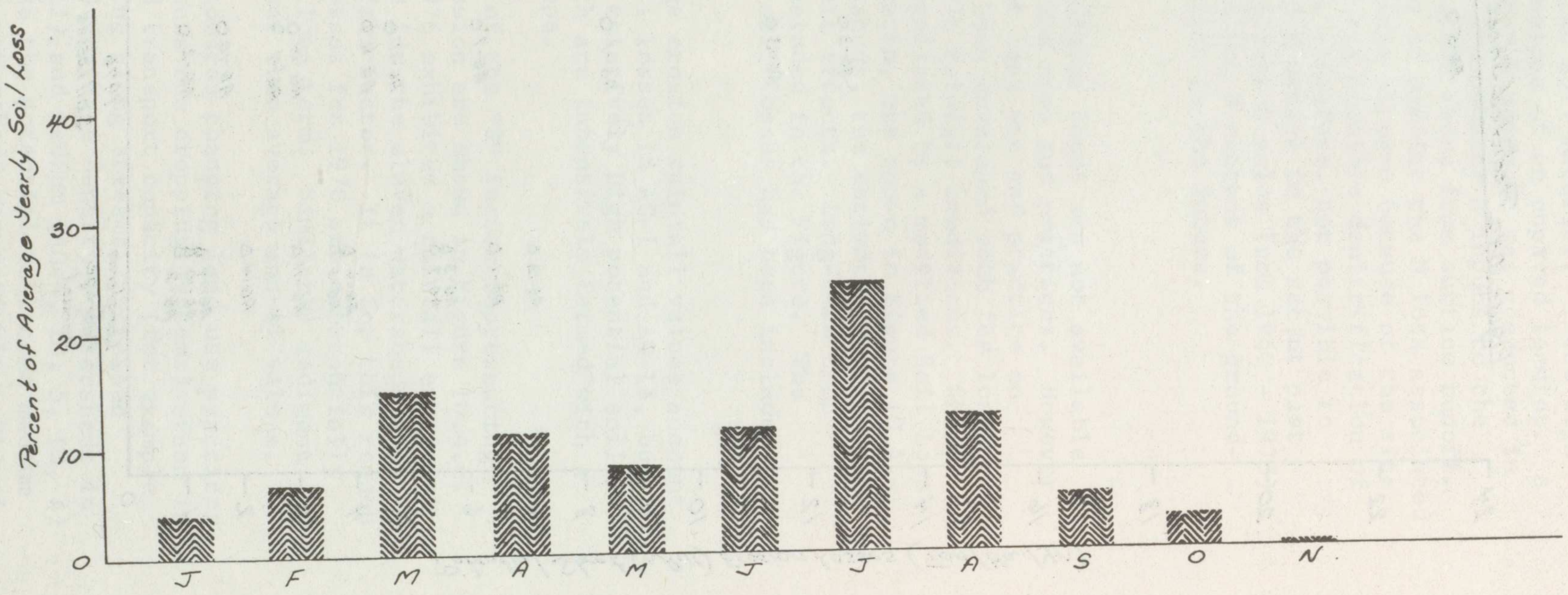
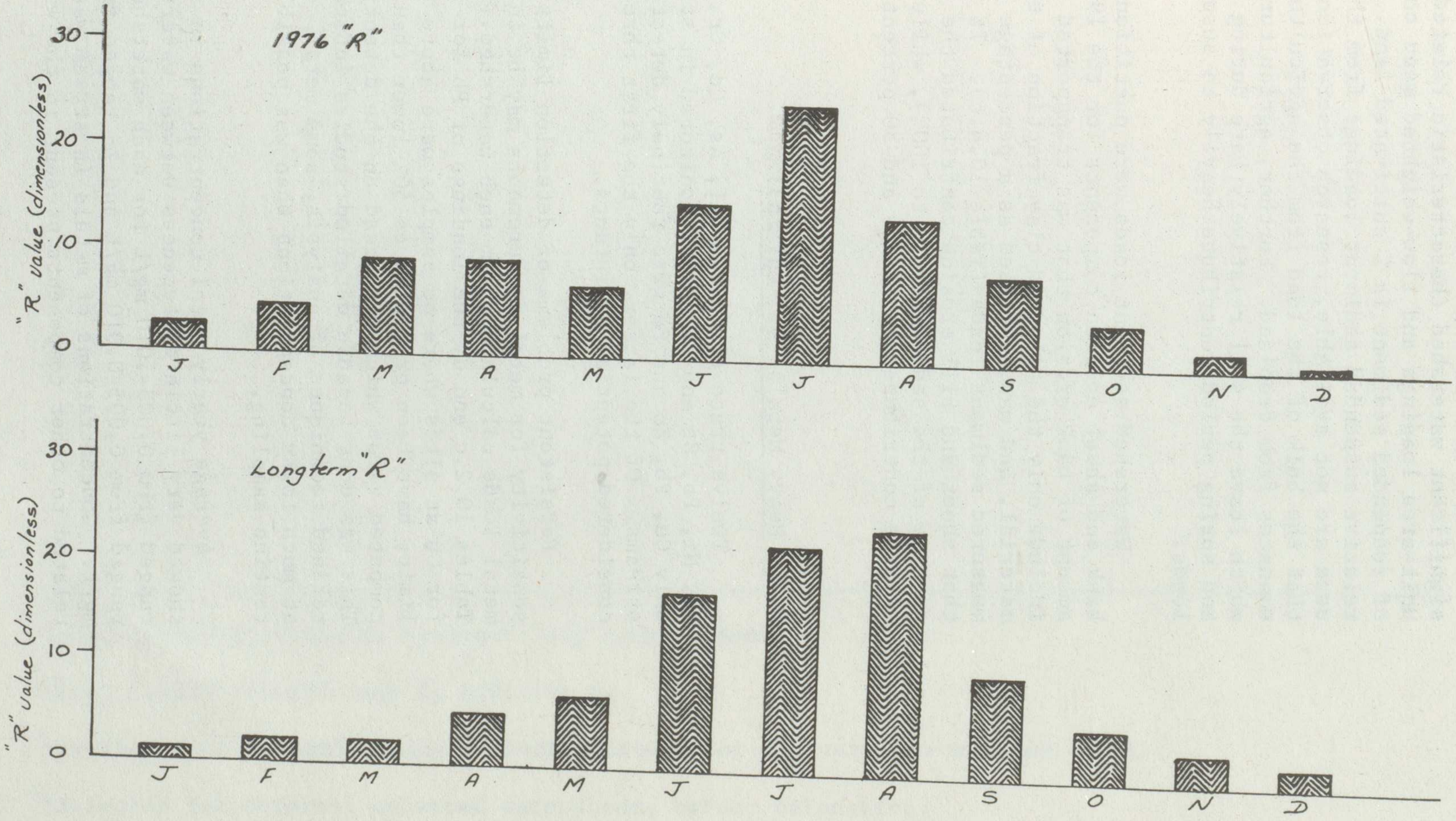


Figure 10.4. C Monthly Distribution of Average Annual Rainfall "R" Values For The 11 Agricultural Watersheds



Correlation analysis has indicated that the most significant watershed characteristic related to two-year unit-area loadings and flow-weighted mean concentrations of suspended sediment is % cultivated land. Although the relative suspended sediment loadings from the various land uses are not available, research observations have revealed that the bulk of the load from the agricultural watersheds emanates from cropland. Further, agricultural practices which leave the soil relatively bare during the snowmelt and spring period contribute heavily to suspended sediment loads.

Watershed sediment loads were partitioned into streambank and sheet erosion components for the 1976 data. The amount of bank erosion that was transported was assumed to include only the silt and clay fraction of the eroded material, and was expressed as a percentage of the 1976 measured sediment loads (Table 10.4.c). It is evident that sheet and rill erosion contributed the largest percentage of the sediments (70 to 100%), while the bank erosion contributed between 0 and 30 percent.

10.4.4. Heavy Metals (Pb, Cu, Zn):

Twelve trace elements - Al, As, Cd, Cr, Cu, Fe, Hg, Mo, Ni, Pb, Se and Zn - were monitored in stream waters. Only Cu, Pb, Zn and Fe were routinely detected in the streams. Of the latter, only the first three are considered potential pollutants.

Persistent problems of detection limits and lack of sensitivity for metal measurements may be influencing the metal loads calculated from each watershed. In Tables 10.2.c and d, the loadings of Pb for all sites, and for Cu at sites where no samples were above the detection limit, have been presented as 50% lower than the originally computed value which was based on the detection limit. This was done because detailed studies indicated that with refined techniques of analysis, some metal could be detected at much lower concentrations than was possible under the routine sampling.

Average yearly metal concentrations in stream waters showed very little differences between watersheds; Pb ranged from 0.003-.010 mg/L for each watershed, while Cu ranged from 0.005-0.010 mg/L and Zn ranged from .006-.020 mg/L. Concentrations of metals in stream waters were often related to other components present in the water - the most

TABLE 10.4.c. - Partitioning of 1976 measured suspended sediment loads into streambank and cropland erosion components.

WATERSHED	1976 SEDIMENT LOADS[1] (kg/ha/yr)	1976 STREAMBANK[2] EROSION ESTIMATES (kg/ha/yr)	STREAMBANK AS PROPORTION OF TOTAL SEDIMENT LOAD (%)	CROPLAND AS PROPORTION OF TOTAL SEDIMENT LOAD (100 -% STREAMBANK)
AG-1	998	223	22	78
AG-2	140	10[4]	7	93
AG-3	258	24	9	91
AG-4	419	137	33	67
AG-5	351	5	15	98.5
AG-6	64	10[4]	16	84
AG-7	43	7[4]	16	84
AG-10	375	17	5	95
AG-11[3]	19	65	--	--
AG-13	310	41[4]	13	87
AG-14	135	75[4]	--	--

---

[1] Using NAQUADAT method of sediment load computation.

[2] Knap, (1978) PLUARG Task C, Activity 6.

[3] Problems with streamflow measurements account for the very low sediment load.

[4] Estimates for original selected watersheds, before relocation.

important of which was suspended sediment. Pb and Zn did not have particularly strong relationships with any of the components and multiple regression did not give statistically significant relationships at the $p = .05$ level. Cu is one metal that is expected to be less associated with particulates than most metals. Cu is usually highly associated with organic matter and in these watersheds organic carbon gave the strongest positive relationship with Cu ($r^2 = 0.64$). There was also a significant positive correlation with nitrogen ($r^2 = 0.53$) because of the positive relationship between N and organic carbon ($r^2 = 0.62$). Depending on the individual element, suspended sediments, total carbon, organic carbon, total phosphorus or total nitrogen in water may be associated with the element. When consideration was given to loadings for extrapolation purposes, some statistically significant relationships were found. For example, suspended solids loadings accounted for 58 and 74% of the variability in Cu and Zn loadings respectively.

Relating the metal concentrations in water to watershed characteristics, it was found that the strongest correlations were between the metals and the natural aspects of the watershed, such as surface clay content or stream density, with very little influence from the agricultural activities.

10.4.5. Toxic Organics and Pesticides:

The farm-to-farm survey revealed 77 different pesticides were being used in the 11 agricultural watersheds. The analytical monitoring survey included a number of pesticide types which was sufficient to account for 93% of the total volume of insecticides used, 0.1% of the fungicide volume and 75% of the herbicide volume. It did not cover the nematocides, growth regulators nor petroleum products (i.e. oils) used. Included in the analytical procedure were the two industrial chemicals PCB and mirex. Table 10.4.d. presents levels and frequency of occurrence for insecticides, PCB's and herbicides.

The occurrence of most of these pesticide and toxic organic materials in streamwater is not consistent enough to allow statistical correlations with watershed characteristics to be developed. Atrazine was one exception to this rule, and in spite of its only being used in corn, unit-area loadings were found to be best correlated with soil clay content and with the index of surface water pollutant transfer potential. In multiple linear regression, either of these characteristics, together with corn area, (which was not statistically significant at the $p = .05$ level), accounted for about 81% of the variability in atrazine unit-area loadings.

TABLE 10.4.d.

Herbicides in 949 stream waters of 11 Agricultural Watersheds between May 1975 and April 1977

	Percent water samples at each level ug/L					Content in water ug/L		
	Not Detected	Trace .02-.09	Low 0.1-1.0	Medium 1.1-10.0	High 10.1+	Mean	S.D.	Highest Reading
Alachlor	99.7	0.2	0.0	0.0	0.0	<0.02	-	9.0
Atrazine**	19.8	8.9	50.5	17.5	3.3	1.4	8.4	32.8
Cyprazine	98.6	0.7	0.6	0.0	0.1	<0.02	-	18.0
2,4-D	93.1	*	6.1	0.6	0.2	0.4	20.0	320.0
Dicamba	99.1	*	0.1	0.0	0.0	<0.1	-	0.3
MCPA	99.4	*	0.6	0.0	0.0	<0.1	-	0.3
Metribuzin	98.6	0.3	0.9	0.2	0.0	<0.02	-	1.4
Prometone	99.2	0.8	0.0	0.0	0.0	<0.02	-	0.07
Simazine	90.9	5.4	3.4	0.3	0.0	0.04	0.35	3.4
2,4,5-T	97.8	*	2.1	0.1	0.0	<0.1	-	1.1

* Detection limit for 2,4-D, 2,4,5-T, MCPA and Dicamba was 0.1

** Atrazine - The mean residue of 1.4 was made up of 0.26 ppb de-ethylated atrazine and 1.14 ppb atrazine in a ratio of 1 : 4 : 3

TABLE 10.4.d. continued

Insecticides and PCB in 949 water samples from 11 Agricultural Watersheds between May 1975 and April 1977

Organochlorine	Percent water samples at each level ng/L					Content in water ng/L		
	Not Detected	Trace 0.4 -0.9	Low 1-10	Medium 11-100	High 101+	Mean	S.D.	Highest Reading
a) Past Use ΣDDT *	6.8	3.6	74.5	14.0	1.1	7.1	28.	347.
a) Past Use Dieldrin	79.4	4.1	11.9	4.5	0.1	1.6	12.	120.
b) Present Use Chlordane	98.4	0.0	1.4	0.2	0.0	<0.4	-	47.
b) Present Use Heptachlor epoxide	94.0	0.9	3.5	1.5	0.1	0.8	24.	370.
b) Present Use Endosulfan	80.7	1.5	9.0	8.5	0.3	3.3	23.	100.
3)Non Pesticide PCB	0.0	(<2) 5.6	(2-10) 16.2	77.7	0.5	31.	42.	200.

Organophosphorus	Percent water samples at each level ng/L					Content in water ng/L		
	Not Detected	Trace 0.01-0.1	Low 0.11-1.0	Medium 1.1-10.0	High 10.0+	Mean	S.D.	Highest Reading
Chlorpyriphos	99.7	0.0	0.2	0.1	0.0	<0.01	-	1.6
Diazinon	90.9	1.7	4.5	2.3	0.6	0.49	-	140.
Ethion	99.8	0.2	0.0	0.0	0.0	<0.01	-	0.04
Malathion	99.6	0.0	0.3	0.1	0.0	<0.01	-	1.8

* ΣDDT The mean residue of 7.1 ng/L consisted of 4.1 ng/L DDE, 1.6 ng/L TDE and 1.4 ng/L DDT.

10.4.6. Bacteria

From April 1974 to April 1977, surface water samples were collected from 11 agricultural watersheds. The samples collected in 1974 were taken from the originally selected sites, some of which were re-located in March 1975. The six detailed study sites (AG-1, 3, 4, 5, 10, 13) were extensively monitored with uniform sampling frequencies; the other five agricultural sites were sampled 1-13 times per month. All water samples were analyzed for densities of pollution indicator bacteria (TC-total coliforms, FC-fecal coliforms, FS-fecal streptococcus), *Pseudomonas aeruginosa* and *Salmonella* sp. Table 10.4.e. summarizes the minimum and maximum monthly geometric mean levels of TC, FC and FS in surface waters from each of the agricultural watersheds. The densities of these pollution indicator bacteria showed wide variations at all sites. Population fluctuations of bacteria were noted during the various seasons with the highest levels found during the summer and fall. In general, during the entire study period, the densities of TC, FC and FS were consistently higher in watersheds 1, 3, 5, 10 and 13 than in watersheds 2, 6, 7 and 11. Indicator bacteria were higher in morning samples than afternoon samples. Densities of indicator bacteria and pathogens increased substantially following precipitation on two separate occasions during the course of the survey.

TABLE 10.4.e.

MINIMUM AND MAXIMUM MONTHLY GEOMETRIC MEAN LEVELS OF POLLUTION INDICATOR BACTERIA IN SURFACE WATERS FROM AGRICULTURAL WATERSHEDS

(BASED ON APRIL 1974 TO APRIL 1977 DATA)

BACTERIA PER 100 ML

	TOTAL COLIFORM		FECAL COLIFORM		FECAL STREPTOCOCCUS	
SITE	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
AG-1	40	22900	31	1340	6	2470
AG-2	83	5050	15	608	35	1090
AG-3	817	730000	12	85000	70	5440
AG-5	101	880000	24	62000	42	88000
AG-6	84	3800	10	444	10	230
AG-7	10	1240	8	165	8	275
AG-10	20	180000	4	8000	30	7100
AG-11	20	8100	10	2500	4	940
AG-13	200	76000	10	5970	10	2250

10.5. Pollutant Delivery

The delivery of a pollutant from its point of origin to the Great Lakes is a complex process that can vary for each pollutant. For some pollutants the delivery to the Great Lakes is essentially complete, while for other depositional or atmospheric losses can render the delivery incomplete. Deposition in streams and losses to the atmosphere from streams are difficult to measure or estimate, and few additional data are available from the Agricultural Watershed Studies by which to evaluate in-stream transport. However, considerable effort has been expended in these studies to determine the rates of delivery of sediment from the soil surface to streams. The ratio of eroded soil to sediment measured in the stream is referred to here as the delivery ratio.

Delivery ratios have been used in both the Canadian and United States Great Lakes Basin Studies for the prediction of fluvial suspended sediment loads when erosion rates at the point of sediment origin were known. For the case of sediments, delivery ratio has been defined as:

$$\text{Delivery Ratio } \% = \frac{\text{Stream Sediment Load}}{\text{Sheet and Rill Erosion} + \text{Streambank Erosion}} \times 100$$

Published sediment delivery ratios were available for use in PLUARG studies but in many cases these values were not developed from Great Lakes Basin data. Since measures of fluvial suspended sediment load as well as potential gross erosion values were available for the 11 agricultural study watersheds in Canada, it was possible to compute a sediment delivery ratio for these watersheds. Table 10.5 shows the computed sediment delivery ratios for the 11 agricultural study watersheds as well as estimated values of delivery ratios based on published drainage basin area and soil texture relationships. In many cases the computed and published delivery ratios compare favourably (e.g. AG-1, 2, 4, 5, 10, 14), while in the other watersheds the computed delivery ratios are (AG-3, 6, 7, 11, 13) significantly less than the published values (Table 10.5). As these discrepancies cannot be quantifiably predicted at this time, it is apparent that extreme care should be used in the selection of sediment delivery ratios to avoid over-estimation of fluvial sediment loads.

Sediment delivery ratios were also computed from 1976 data on a monthly basis for the Canadian agricultural study watersheds in order to investigate seasonal variation in sediment delivery. The general seasonal picture that evolved was a high delivery of eroded sediments in the cool, wet spring months (February, March, April) and a low delivery of eroded sediments in the summer months (June, July, August) that increased only slightly during the autumn months prior to freeze up. While soil erosion may be active throughout the year, there appears to be only a rather short time period in the spring of the year when the transport of eroding sediments to streams is significant. These data give credence to the suggestion that effective soil erosion remedial measures must take into account both temporal and spacial aspects of the erosion process.

Further to the above analysis, a two-year field study (1975, 1976) on areas that contribute sediments into the streams indicated that an average of only 10% in AG-4 and 15% in AG-5 of the watershed area is actively contributing to stream sediment loads. Under high soil moisture conditions such as occur in the spring months, the sediment producing areas are largest (15-20% of the watershed area). Under low soil moisture conditions, such as in summer, the sediment contributing areas are much smaller than the annual average, varying between 0-5% of the area. During the summer period most of the rainfall infiltrates into the soil and very little or no sediment from the land system reaches the stream system. For large storms, observed contributing areas on an event oriented basis were found to be in close agreement with predicted overland runoff from a Hydrologic Model developed as part of the detailed agricultural watershed studies. In addition, the time period when maximum contributing areas were observed coincided with time periods of maximum sediment delivery to stream courses.

Delivery of sediment-associated phosphorus in overland flow will always be greater than the delivery ratio of sediments. The degree will be related to the phosphorus enrichment ratio which was found to vary from 1 to 4. Delivery of heavy metals will also be affected by the enrichment process, as will the particulate forms of nitrogen and certain pesticides. No data are available on these expected enrichment ratios However, delivery of pollutants subject to volatilization or biological activity causing loss to the atmosphere, such as nitrogen and some of the pesticides, will generally be reduced by these processes.

TABLE 10.5. Delivery ratios for the agricultural study watersheds

Watershed	Delivery Ratio (D.R.) %		
	A[a]	B[b]	C[c]
AG-1	13	16	30
AG-2	15	14	7
AG-3	4	15	20
AG-4	21	19	23
AG-5	7	18	21
AG-6	2	15	19
AG-7	2	15	9
AG-10	26	18	37
AG-11	5	18	38
AG-13	3	19	10
AG-14	10	16	30

[a] Computed for the agricultural study watersheds as follows:

$$\text{D.R.} = \frac{\text{Suspended Sediment Load (2 yr mean, NAQUADAT)}}{\text{Average Annual Sheet and Rill Erosion + Gross Streambank Erosion}}$$

[b] Based on drainage basin area (S.C.S., National Engineering Handbook, Chap.6, Sediment Sources, Sediment Yields and Delivery Ratios, U.S.D.A., 1973)

[c] Based on drainage basin area with modification for drainage basin texture (S.C.S., Sediment Requirements for Reservoirs, Engineering No. 16, S.C.S. Iowa State Office, DesMoines, Iowa, 1973.)

10.6. Watershed Physical Characteristics

See Table 10.6.

10.7. Soil: Sediment Composition

See Table 10.7.

Table 10.6. Physical Characteristics of PLUARG Agricultural Watersheds

Watershed	Surface Soil Type Clay mean %	 Sand mean %	Average Slope * m/km	Surficial Geology	** Drainage Density	1976 Rainfall (mm)	Tile Drainage Density est. % ***
1	35.0	35.0	1.14	lacustrine clay over till plain over limestone bedrock	0.288	729	high
2	6.6	80.0	2.86	deep level deltaic sands	0.503	-	low
3	30.0	10.0	2.86	level clay till plain over shale	0.567	860	moderate
4	25.0	25.0	8.57	silty clay ground moraine	0.641	925	moderate
5	20.0	25.0	8.57	calcareous loamy till	0.732	1018	high
6	15.7	24.0	1.27	drumlinized loam till	0.816	823	low
7	9.9	61.0	10.96	wind blown sand and silt on sloping sandy calcareous till	0.609	840	low
10	40.0	10.0	1.25	locustrine and reworked clay over dolomite	2.164	779	low
11	30.0	27.4	5.70	stratified clay over shale and limestone till	1.220	737	low
13	10.5	75.0	3.92	shallow moraine sand over clay till plain over limestone bedrock	1.002	770	high
14	27.5	25.6	3.81	reworked lacustrine clay over clay till	0.651	924	low

* Average gradient from outlet to most distant watershed divide, as estimated from 1:50,000 topographical maps.

** Based on streams and ditches shown on N.T.S. maps at 1:50,000 scale.

*** high = 75-100% ; moderate = 25-75% ; low = 0-25%.

Table 10.7 COMPOSITION OF SOILS, BOTTOM SEDIMENTS AND SUSPENDED SEDIMENTS IN AGRICULTURAL WATERSHEDS.

	Cu ppm	Pb ppm	Zn ppm	Clay %	Total Carbon %	Organic Matter %	N %	P ppm	pH
Soils (Ap Horizons)									
AG 1	25	25	120	31	2.6	3.4	.22	645	6.5
3	27	25	98	34	3.3	4.7	.29	739	7.4
4	19	21	75	24	2.8	4.3	.24	550	6.7
5	16	22	85	19	2.6	4.2	.26	976	6.8
10	16	29	125	36	3.2	3.9	.24	1668	6.2
13	13	21	54	8	1.4	2.2	.11	810	6.2
Bottom Sediments									
AG 1	31	23	117	23	3.2	1.9	.08	400	7.2
3	18	17	67	15	6.5	1.8	.05	700	7.0
4	15	20	67	9	4.2	1.3	.07	700	7.5
5	16	34	75	9	5.3	1.7	.33	600	7.2
10	28	54	401	25	3.3	.6	.08	700	7.1
13	15	19	61	1	2.2	1.1	.09	600	7.3
Suspended Sediments									
AG 1	72	92	218	90	3.8	2.7	.2	---	---
3	40	28	155	5.8	4.8	3.7	1.1	---	---
4	34	60	141	61	7.2	2.0	.6	---	---
5	93	48	213	79	8.3	---	1.1	---	---
10	86	125	305	75	3.4	2.2	.5	---	---
13	60	51	250	69	.3	---	.1	---	---

11. DATA INTERPRETATIONS AND CONCLUSIONS

11.1. Causes and Localities of Agricultural Contribution to Pollution

11.1.1. Phosphorus

The analysis of the phosphorus data from the 11 representative agricultural watersheds indicates that the agricultural land use contributing the greatest amount of total P to water courses is cropland. In addition to this conclusion, it is clear that cropland on clay soils contributes more than cropland on sandy soils.

Within the cropland areas, the loss of total phosphorus to streams is dependent on the erosion of the soil, the P content of the soil, and the degree to which this P content is enriched by the erosion process and by fertilizer and manure practices. Individual field runoff samples have shown the effect of enrichment by fertilizers and manure practices on cropland. On a watershed basis, it must be concluded that the greater erosion and the higher P additions associated with the culture of row crops, together with the tendency of clay soils to yield more fine particles in the erosion process, are the major causes of the loss of total P from agricultural land.

Streambank erosion, brought about by a variety of factors which include natural stream meandering, poor bank protection from drainage (surface and subsurface) outfalls and by cattle trampling can also contribute total P to streams. This source is considered to be of lesser importance to phosphorus loss than it is for sediment losses since the eroded materials have lower phosphorus contents than cultivated surface soils.

Livestock have also been noted as contributing phosphorus, mainly as dissolved P, at estimated rates which average 20% of the agricultural loads studied. Using a livestock source model, estimates have been made of the input of phosphorus to streams from each animal unit (that number of livestock which excretes 68-77 kg/nitrogen/year as defined by the Ontario Agricultural Code of Practice). In the agricultural watersheds the average estimate of input ranged from 0.09 to 0.24 kg P/animal unit/yr.

The dissolved phosphorus is also influenced by the type and phosphorus content of the sediments present, since there is a dynamic equilibrium between the concentration of dissolved P in water and that associated with solid particles. Other major factors which appear to influence dissolved phosphorus concentrations in the agricultural watersheds in addition to the livestock noted above (presumably by way of manures), are fertilizer use, and the presence of faulty septic tanks. Thus clay soil regions with high densities of livestock and rural human population, and where high phosphorus fertilizer application rates are used tend to have higher soluble phosphorus levels in stream water. In addition to these, organic soil areas which have been monitored intensively in other studies have been shown to yield high unit area loadings of dissolved phosphorus, especially where excessively high (far above soil test recommendations) applications of fertilizer P had been made.

The practice of applying more fertilizer P to row crops than would be recommended from soil test has been observed throughout the eleven agricultural watersheds. The effect this may have on stream loadings is unclear, but it may contribute to the effect which fertilizer is seen to have on soluble P loadings, and to the effect of row crops on total P loadings.

11.1.2. Nitrogen

Nitrogen is found at some level in all waters draining agricultural land, (exceeding the 10 mg/L drinking water standard in some instances) and will contribute to the Great Lakes Waters. Stream runoff N is transported as soluble NO_3-N + NO_2-N or as total Kjeldahl N (mostly associated with suspended material). Higher groundwater N concentrations occur in localized areas but the significance of this in terms of Great Lakes Waters has not been determined.

Results from the 11 agricultural watersheds indicate that stream NO_3-N concentrations were higher in watersheds with high fertilizer N inputs, greater corn acreage, and more extensive tile drainage. Frequently, the soils of these watersheds also have high organic N contents, so much of the stream N may be mineralized organic-N in excess of crop needs rather than fertilizer N.

From 40 to 90% of the fertilizer N applied in the representative watersheds was applied to corn. Other crops receiving high unit area N inputs were burley tobacco and potatoes, but the occurrence of these crops was restricted in area as they are throughout the Great Lakes Basin. This implies that efficient N use in corn production would have the greatest affect on reducing N losses from cropping activities.

NO_3 + NO_2-N and total N inputs to streams from livestock as estimated from a statistical model, are high in watersheds with a high livestock density, and in some cases appear to exceed those from cropland.

Total Kjeldahl-N comprised from 10 - 55% (with an average of 29%) of the total N lost in stream drainage and was therefore an important fraction of the N lost from some watersheds. Watersheds with less permeable soils and high sediment output tended to have higher TKN concentrations. Because of this association of TKN with sediment and thus with soil organic -N reserves, management of nitrogen use may have less impact on TKN than on nitrate losses.

N concentration generally increased with increased discharge and most of the annual N runoff loads occurred during November to March, at which time large quantities of runoff coincided with dormant plant growth. Success in decreasing winter and early spring runoff N concentrations would result in the most dramatic annual N loss reduction. This may be achieved by more closely matching fertilizer N input and crop N uptake during the previous growing season. This will require the development of an adequate soil N test.

In one study conducted in an intensive agricultural watershed, groundwater N inputs to streams were estimated to exceed those in storm runoff. In this same watershed, higher nitrate concentrations were found in the shallow groundwater under cultivated fields than under adjacent unimproved land where nitrate was seldom detectable. However, no direct correlation between these concentrations and fertilizer applications could be found.

Nitrogen is contained in precipitation falling on all watersheds, and amounts to between 10 and 20 kg/ha/yr. This nitrogen input is distributed more or less uniformly in the basin, and is essentially uncontrollable. It has thus not been considered as a variable in explaining nitrogen levels in streams draining to the Great Lakes.

11.1.3. Sediment

On the basis of monitoring and modelling data on representative agricultural watersheds in Ontario, it is safe to conclude that rural land use is contributing to the suspended sediment load of the Great Lakes. However, the rural sediment loading rates are found to be below average North American values.

The potential rural sources of suspended sediments have been considered as cropland, grassland, woodland, and streambanks. In rural Ontario, 70 to 100% of the sediment load has been attributed to rainfall and runoff (sheet and rill) induced erosion on cropland, grassland, and woodland, while 0 to 30% of the sediment load has been attributed to streambank erosion.

Suspended sediments are not transported from rural land uniformly throughout the year. Figure 10.2.b. illustrates the monthly distribution of sediment loads from rural lands in Southern Ontario for 1976 data. About 75% of the annual suspended sediment load is transported in February, March and April.

These months are characterized by soils with saturated surface layers, low rainfall energy and snowmelt events. High energy rainfall events that occur in the summer months can cause high on-site sheet erosion losses but because the soils are generally not saturated at this time, infiltration of water is enhanced and the transport of eroded sediments is minimized. Streambank erosion has also been observed to be maximum in the February-March-April time period.

Any rural land practice that exposes the soil to the erosive forces of rainfall and run-off can represent an erosion hazard. In general, the greater the canopy and ground cover protection, the lower the erosion potential. Rural land uses with progressively greater erosion potential are: permanent pasture, pasture, small grains, corn in rotation, continuous corn, white beans, some horticultural crops and plowed land. A survey of streambanks in rural watersheds indicated that 37% of the banks showed evidence of erosion and one-third of these eroded banks were totally devoid of vegetation.

Since sediment production from grasslands and woodlands is minimal, the primary sources of sediments are croplands and streambanks. Average predicted sheet erosion losses for cropland in Southern Ontario is 4.6 tonnes/ha/yr while the average annual streambank erosion rate is 0.038 tonnes/ha/yr.

While soil erosion occurs on all cropland at varying rates, eroded soil does not become a water quality concern until it is transported from the field to the stream. Runoff investigations in Ontario have revealed that as little as 20% of a rural area generally contributes runoff and sediment to surface waters. Therefore, it is apparent that all cropland does not create water quality problems. The potential for stream sediment pollution from rural land is maximum when crops with minimum canopy or ground cover protection are grown in the approximately 20% of the rural land that frequently contributes run-off to streams.

Unit area sediment loads were calculated for agricultural lands on the basis of 1976 monitoring data and long-term predicted data. Comparison of these loadings (Fig. 10.4.a) led to the conclusion that the 1976 data may be overpredicting sediment loads by a factor of about 1.6.

Sediment yields for rural watersheds in Southern Ontario ranged from 100 to 900 kg/ha/yr (when computed by the Hydrograph Integration Method). The causes of the variation observed can be related to soil and land use factors as well as watershed transport capacity. For example, some areas with highly erodible soils and erosion sensitive land uses (corn) did not always reflect high sediment loading rates. Watershed transport factors such as stream channel buffering with grass or trees or stream channel density had a large effect on determining unit area sediment loadings. For these examples the effect was to decrease and increase the loads respectively. In many cases these factors were more significant than soil erodibility and cropping factors.

11.1.4. Heavy Metals

No agricultural activities have been identified which control heavy metal inputs to streams. Metals enter water in two forms - associated with particulates, either soil streambank or streambed or as the soluble form in leachates or groundwater.

On a unit area basis, the losses of metals from each ha of agricultural land are far lower than those being added to the same land from atmospheric sources alone. Five to 16 times more Pb was added from the atmosphere than was lost to the stream, 4 to 8 times more Zn, and 1 to 8 times more Cu. The metal atmospheric inputs to agricultural land were generally lower than the best estimates of unit area loadings from the land to the Great Lakes and it may be that direct atmospheric input of these metals to the lake is a more important source than agricultural land.

Anomalously high metal concentrations in streamwater of one agricultural watershed were traced to a groundwater source. The groundwater had leached metals from the underlying bedrock of the Niagara Escarpment and, upon entering the stream, increased the metal load.

11.1.5. Toxic Organics and Pesticides

Twenty-six pesticide isomers, metabolites or parent compounds were identified in stream water. However only the following nine were found in 10% or more of water samples:

Frequently identified	p,p-DDE (93%), atrazine and desethyl atrazine (80.2%) PCB (94.4%)
Infrequently identified (10-40%)	p,p-TDE (23%), p,p´-DDT (10.5%) dieldrin (20.6%), trans endosulfan (17.6%), endosulfan sulfate (17.2%)

The remaining 18 components were found only rarely or occasionally and invariably were the result of spills and carelessness around streams.

ΣDDT (o,p-DDT, p,p´-DDT, p,p´-TDE and p,p´-DDE). DDT was used as an insecticide for a multiplicity of uses up to the time it was restricted in 1970. Hence components of DDT have been found in all watersheds. Between 1970 and 1972, uses of DDT were continued in vegetables and tobacco production areas, hence the unit area loadings for AG-2, AG-3 and AG-13 are higher than other watersheds in the two-year period of this study. ΣDDT was present in 93% of water samples of which 41% were above the 3 ng/L IJC criterion.

Atrazine and Desethyl Atrazine. Atrazine is exclusively used to control weeds in corn. Between 9.5 and 31.3% of the (mean 17.6%) agricultural watersheds which were studied were devoted to corn and 53.3 to 93.6% (mean 63.1%) of the corn was treated with atrazine. The average application was 1.7 kg/ha. Atrazine and desethyl atrazine were found in 80.2% of the water samples at a ratio of about 2.5:1. However only 0.3% were above the 28 µg/L IJC criterion. Losses to streams were the result of runoff (64%), spills (18%) and tile drainage (18%).

PCB. No known uses of PCB occurred in the watersheds although there must be some PCB containing transformers located in all watersheds. PCB was measured in precipitation at all six watersheds checked and the concentrations ranged from <2 to 100 ng/L. PCB were present in 94.4% of the water sampled at levels above 2 ng/L. If a 2 ng/L criterion is accepted by IJC then 94.4% of waters were above this level. Precipitation appears to be the most likely source in these agricultural areas, although oil containing PCB may have been used to control dust on roads in these areas in the past, which could be another source.

Dieldrin. All the dieldrin found in the watersheds came from past uses of aldrin that were discontinued in 1969. Aldrin was used as an insecticide to control soil insects and hence was used in watersheds growing cash crops and vegetables. Over the two-year period 20.6% of water samples from the agricultural watersheds contained dieldrin and 16% were above the 1 ng/L IJC criterion.

Total Endosulfan. This insecticide is used for foliar insects in tobacco and vegetables. This includes domestic uses in the home garden. Its appearance in 17% of the water samples may have resulted from both agricultural and domestic use. In some watersheds it was found in water where no crops were grown that could account for its use. There were 14.1% of water samples above the 3 ng/L IJC criterion. The major losses occurred as a result of runoff in the January-April period.

Overview. The DDT and dieldrin residues in water are derived from past uses of DDT and aldrin and little can be done to change the slow release to water. PCB appears in water as a result of aerial fallout with no known agricultural input. Endosulfan has recently been dropped from recommendation in tobacco to reduce its residues in the end product.

The volume of atrazine use may have reached a peak and may remain at the current level or drop slightly for the following two reasons. There is a trend towards more rotation and less monoculture necessitating a lower level of use if susceptible crops are not to be damaged in the year after corn; the build-up of populations of resistant weeds is causing a shift to other herbicides that will control them.

The areas which were monitored and found to have the highest levels of atrazine and endosulphan in runoff are shown in Figure 11.1.a. These materials were chosen as examples of presently-used herbicides and insecticides respectively.

11.1.6. Bacteria

Of the agricultural watersheds examined, watersheds 1, 3, 5, 10 and 13 represent problem areas as surface waters in that these watersheds contained significant quantities of TC, FC and FS. At these sites, the densities of indicator bacteria were consistently high throughout the study period.

Although livestock operations appeared to be the major source of bacterial pollution to watersheds 3, 5 and 10, where the animal densities were 0.48, 0.61 and 0.77 animal units per hectare respectively, there were no consistent data obtained in any of the detailed watershed studies which related indicator bacteria to the presence or absence of livestock. The bacterial water quality was extremely poor in watersheds 1 and 13, although the livestock was very low (<0.09 animal units/ha). This suggests that sources other than livestock contribute substantial numbers of bacteria to surface waters. Septic tanks, tile drains, soil contaminated with animal waste and animal and bird populations may also contribute to fecal pollution of rural runoff.

The levels of bacterial populations at the sites with greatest contamination were high throughout the study period and frequently were greater than the MOE Standards for Recreational Water Quality. In fact, the levels of TC, FC and FS many times approached concentrations found in dilute sanitary wastewater and could be considered therefore, to constitute a health hazard. The implied public health risk is substantiated by the detection of pathogenic bacteria in surface waters at selected sites examined intensively. It must be emphasized that bacterial contamination is hazardous only in areas where the surface waters are used for recreational purposes and drinking water supplies. No evidence exists of upstream bacterial pollution being a threat to water quality in the Great Lakes but nevertheless, high levels of contamination of waters which may be used for upstream recreational or water supply purposes should not be overlooked.

11.2. Extent of Unit Area Loadings

See Section 10.2.4.

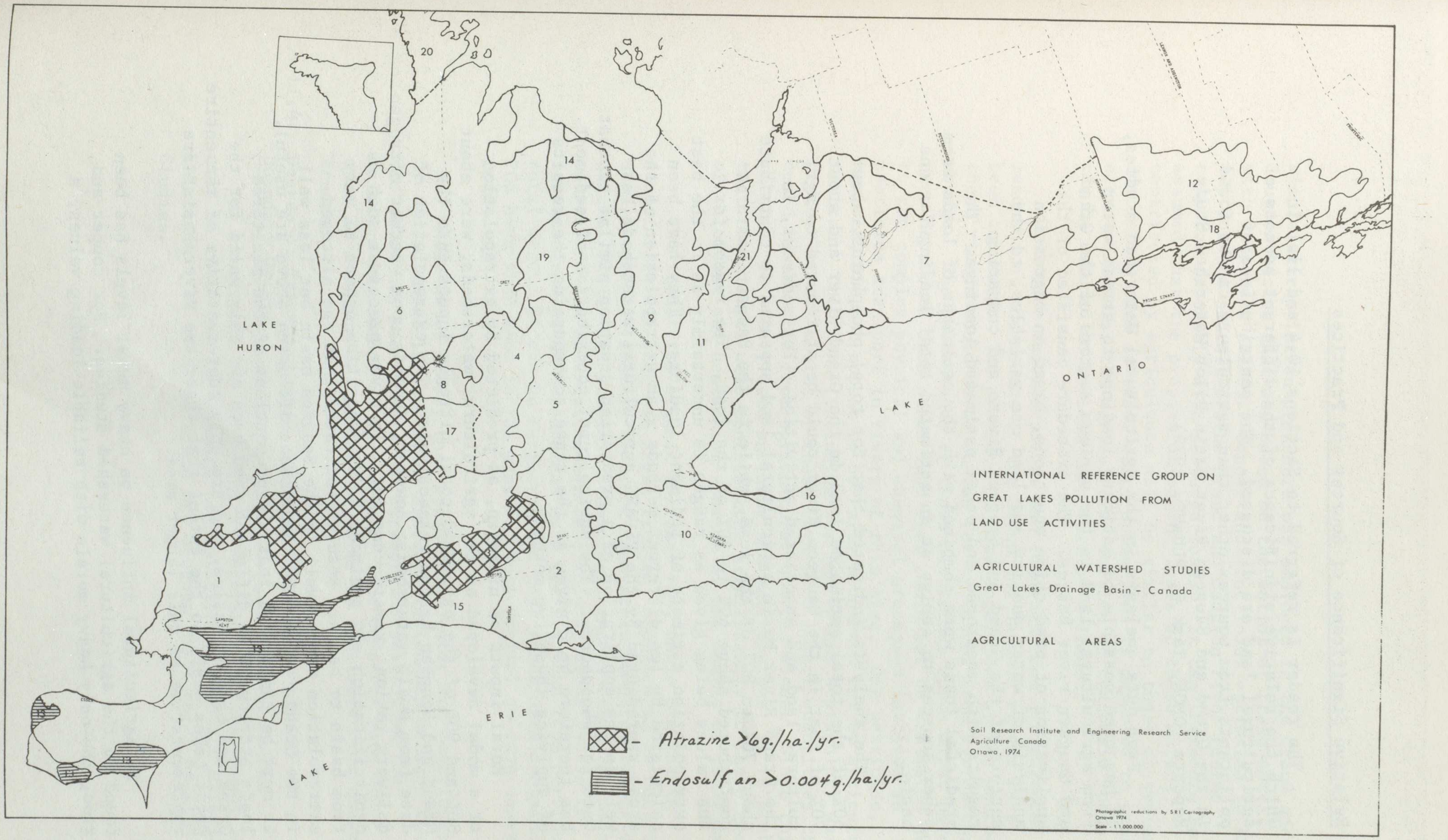


Figure 11.1.a: Atrazine and Endosulfan Loads as Measured in Stream-water in Areas Represented by the Agricultural Watersheds

11.3 Relative Significance of Sources and Practices

The reader is referred to Sections 10.4 and 11.1 in which the relative significance of the different aspects of agricultural land are discussed. The contributions of pollutants from sources other than agriculture can be found in the Grand and Saugeen River Basin Pilot Watershed Study Reports (OMOE, Task C, PLUARG, 1978).

From data analasis in the Agricultural Watershed Studies, it has been possible to estimate loadings to stream water from agricultural land in the various sectors of the Grand and Saugeen river basins. The procedure consisted of the application of prediction equations, based on regression analysis of water quality and land use variables, to the sectors of the Grand and Saugeen Rivers and comparing results with monitored and other estimated loadings. The predicted loads were combined with the estimates of loads from other sources to arrive at an estimated total loading for the basin.

The analysis indicated that for total phosphorus, about 60% of the total estimated load in the Grand River and about 70% of that in the Saugeen River could be attributed to agricultural land and associated activities. For sediment, in the Grand River basin agricultural land appeared to contribute about 70% to 80% of the load, while in the Saugeen basin it contributed about 60% to 70% of the load. The reason for the values being given as ranges is uncertainly as to the best extrapolation estimate of sediment loadings. They have been calculated by two different methods - an extrapolation of the areas represented by the PLUARG agricultural watersheds, as well as the application of a prediction equation similar to that used for phosphorus. The agricultural contribution of sediment has therefore been given as the range encompassing the results of applying these two methods.

Rural inputs of nitrogen, as predicted by extrapolation of a model developed on the agricultural watersheds, were about 80% and 90% of the estimated total nitrogen inputs into the Grand and Saugeen basins respectively. The extrapolation of data from small watersheds, however, depends upon whether nitrogen delivery ratios remain constant. In-river processes such as denitrification and sediment (TKN) deposition appear to vary from basin to basin. Results indicated that the nitrogen extrapolation worked well in the Saugeen basin but less well in the Grand. While the comparisons discussed above are useful, it must be remembered that the proportions of the monitored loads attributed to different land uses are only valid for the Grand and Saugeen basins, and are only representative of the entire Great Lakes Basin to the extent that these two river basins are representative of this larger area.

No agricultural influence on heavy metal levels has been found in the agricultural watershed studies. For copper and zinc, the only heavy metals with reliable loading values, a simple extrapolation procedure was employed in the Grand and Saugeen basins that was based on the ratios of these metals with suspended solids. Copper and zinc loads estimated in this way for the sectors of the Grand and Saugeen river basins compared favorably with measured loads. It can therefore be assumed that the proportion of the loads of these metals contributed by agriculture will be similar to those of sediment. For metals such as lead, where urban land is expected to generate elevated levels, the agricultural portion of the basin loads can be assumed to be less than that of sediment.

Pesticide concentrstions and loadings from agricultural land and at the mouths of the Grand and Saugeen rivers have been compared. The presence of most pesticides at the mouths of these rivers could be accounted for by losses from agricultural useage. The percentages of those pesticides which might have been delivered from other land uses could not be estimated due to the complex physical and chemical processes involved in pesticide transport in rivers of this size. One pesticide, however, did not appear to be fully accounted for by agricultural sources. Chlordane (including its ingredient Heptachlor) was present at the mouths of these rivers in larger quantities than could be expected from agricultural sources alone. Since this material is widely used on lawns and golf courses, it is probable that these areas were contributing significantly to the presence of chlordane and heptachlor epoxide at the mouths of these rivers.

The industrial organic toxicant PCB, while present in runoff from all land use areas studied, appeared to be contributed disproportionately by urban land areas compared to agricultural land. The probable atmospheric input, being the major source of this material, would be likely to be delivered to streams from paved urban areas more readily than from pervious rural land. It can be further noted that spent oils containing PCB have been used in the past for dust control on some unpaved roads.

While it is likely that bacteria in water are contributed by agricultural livestock, no direct relationship between these variables has been found. No further information on the relative importance of agricultural land compared with other land uses as a source of bacteria in water is available from these studies.

11.4. Degree of Transmission of Pollutants fron Source Areas to Boundary Waters

The results of the Agricultural Watershed Studies cannot be used on their own to estimate transmission to boundary waters. This task lies with the Grand and Saugeen River Pilot Watershed Studies.

11.5. Information Extrapolation

From the analyses which have been made, there appears to be no reason why the results of the Agricultural Watershed Studies should not be transferable to the rest of the Great Lakes Basin. Care must be taken, however, if the approach is applied to areas outside the range of conditions covered by the agricultural watersheds - e.g. areas with soil clay or organic matter contents higher than those of any of the eleven study watersheds; areas subject to excessively high runoff or stream bank erosion due to climatic or hydrologic anomalies; and areas modified by agricultural or non-agricultural (e.g. atmospheric fallout) effects beyond the scope of the eleven agricultural watersheds. Some form of information extrapolation to the agricultural portion of the Canadian Great Lakes Basin has been developed for each water quality parameter included in the integration studies (i.e. phosphorus, sediment, nitrogen, heavy metals, pesticides) and for livestock sources.

Phosphorus and sediment have been identified by PLUARG as priority parameters, and so only the extrapolation results for these two parameters are included in this summary report. Further details of the extrapolation procedures for the other parameters may be found in the respective Integrators' reports.

11.5.1 Phosphorus

The extrapolation of total phosphorus to the Grand and Saugeen river basins has given sufficient confidence in the regression equation approach to justify its use in extrapolations to other basins and sub-basins of the agricultural portion of the Canadian Great Lakes Basin. The regression equation used in the extrapolation procedure was based on analyses of two years of data collected at the agricultural watersheds:

$$\underset{(\text{kg/ha/yr})}{\text{Total P}} = 0.149 + 0.000655\ (\%\ \text{clay})^2 + 0.000162\ (\%\ \text{row crops})^2 \qquad (r^2 = 0.92)$$

The sources of the data used in the extrapolation were the generalized soil maps which have been incorporated into the Canada Land Inventory Geographic Information System by Agriculture Canada for use in PLUARG studies, and the 1971 Statistics Canada Census of Agriculture data listed by enumeration area and by watershed sub-basin, and updated to reflect 1976 values using Ontario Agricultural Statistics by counties.

The unit-area loads of total phosphorus from farm land for each sub-basin in the agricultural portion of the Canadian Great Lakes Basin have been grouped into six classes (Figure 11.5.a). The values are the unit area loads from only the farm land in each sub-basin and do not reflect the unit-area loads from the sub-basin as a whole unless a large percentage of the sub-basin area is in farm land, and there are no other major sources such as urban centres. The proportion of the rural area of each sub-basin in the extrapolation of figure 11.5.a. which is in farm land is presented in Figure 11.5.b.

Use of the regressions to estimate the loadings from watersheds larger than the 11 agricultural watersheds requires the assumption of an in-stream delivery ratio of 1.0 for total phosphorus. On the basis of this assumption, the loading of total P from agricultural land in the Canadian Great Lakes Basin has been estimated to be 3000 tonnes* annually. Applying the proportions developed in the agricultural watersheds to the whole basin, about 2100 tonnes would be related to runoff from cropland, 600 tonnes to livestock operations, and 150 tonnes to each of streambank erosion and unimproved farmland. The latter figure is probably low due to the larger amount of unimproved land in the basin as a whole compared with the eleven study watersheds. The distribution of the total load of 3000 tonnes was approximately as 26% in the Lake Huron Basin (including Georgian Bay), 53% in the Lake Erie Basin (including Lake St. Clair) and 21% in the Lake Ontario Basin.

Estimates of the livestock contribution of total phosphorus to the Canadian Great Lakes Basin have also been made by a different procedure which utilizes a model developed in the livestock integration study. Using a range of representative input values for livestock units, developed from the application of different assumptions in the model, a range of probable livestock loads to the lakes was found. With inputs estimated to be between 0.08 and 0.22 kg/animal unit/yr, the total load was estimated to be between 170 and 466 tonnes per year. (An animal unit was as defined by the Ontario Agricultural Code of Practice.)

11.5.2. Sediment

The extrapolation methods used in the Grand and Saugeen river basins have also been used to extrapolate sediment loadings to the whole agricultural portion of the Canadian Great Lakes Basin. The extrapolation method based on the agricultural areas represented by the study watersheds yielded an average value of 215 kg/ha/yr, while the regression method based on two years of data generated an average value of 209 kg/ha/yr. Since these results were so similar, only the regression method has been mapped, and the results are presented in Figure 11.5.c. The data bases for this extrapolation were the same as those used for the phosphorus extrapolation. The regression equation

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* About 40% of this was estimated to be in the 'total dissolved P' form

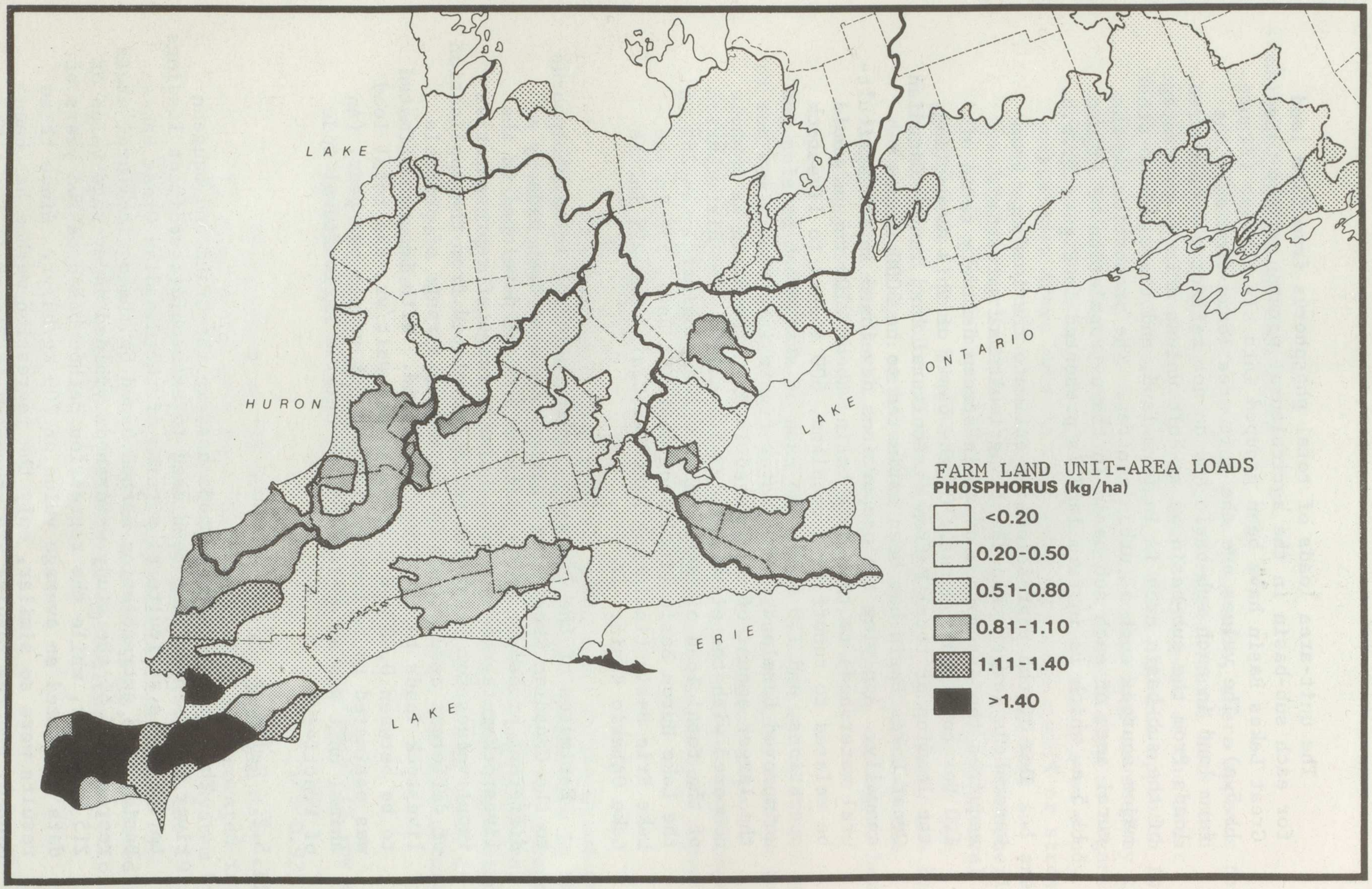
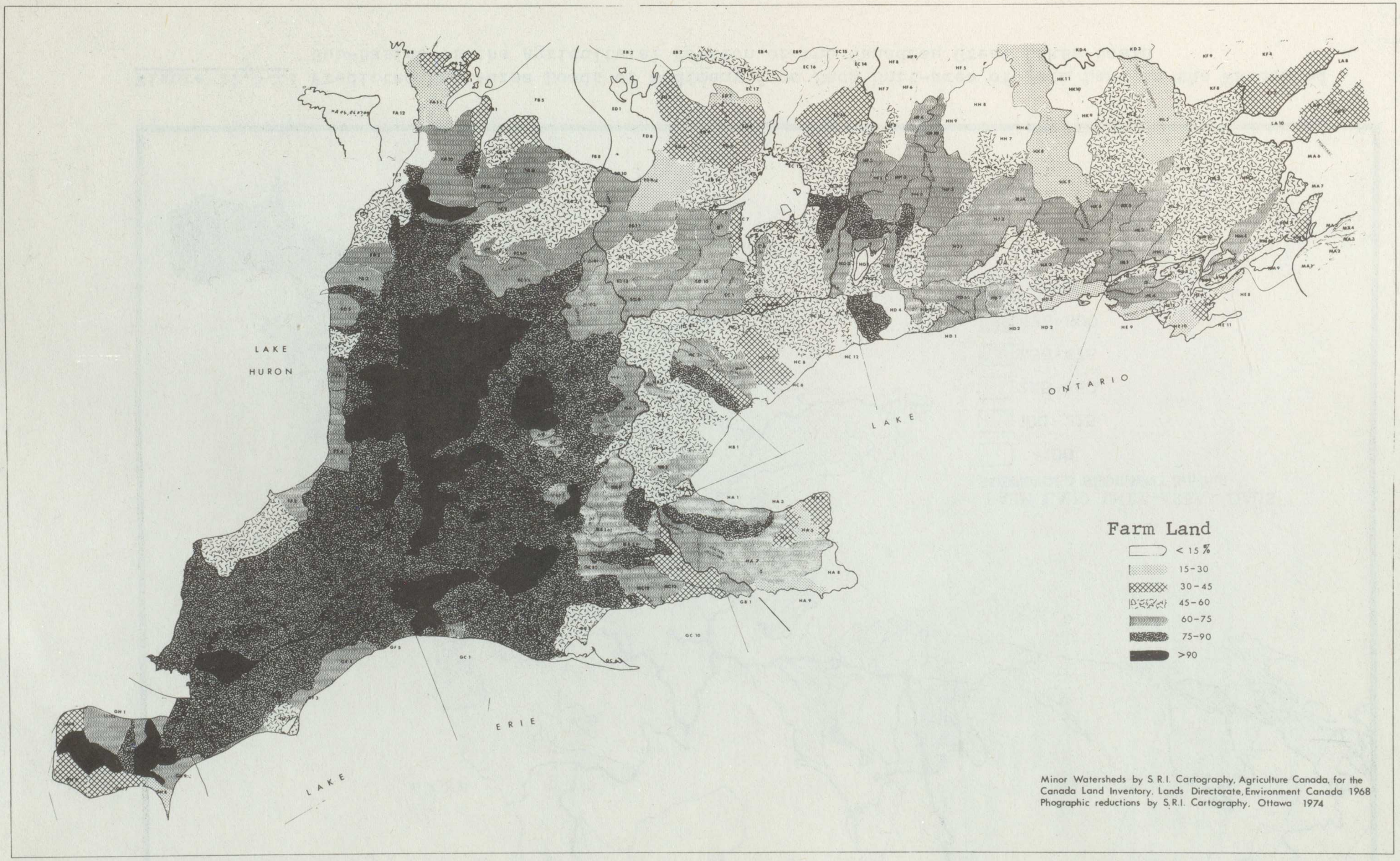


Figure 11.5.a: Predicted Unit-Area Loads of Total Phosphorus from Each Unit-Area of Farm Land in the Watershed Sub-Basins of the Agricultural Portion of the Canadian Great Lakes Basin



Minor Watersheds by S.R.I. Cartography, Agriculture Canada, for the Canada Land Inventory, Lands Directorate, Environment Canada 1968
Phographic reductions by S.R.I. Cartography, Ottawa 1974

Figure 11.5.b: 1976 Farm Land Density in the Canadian Great Lakes Basin

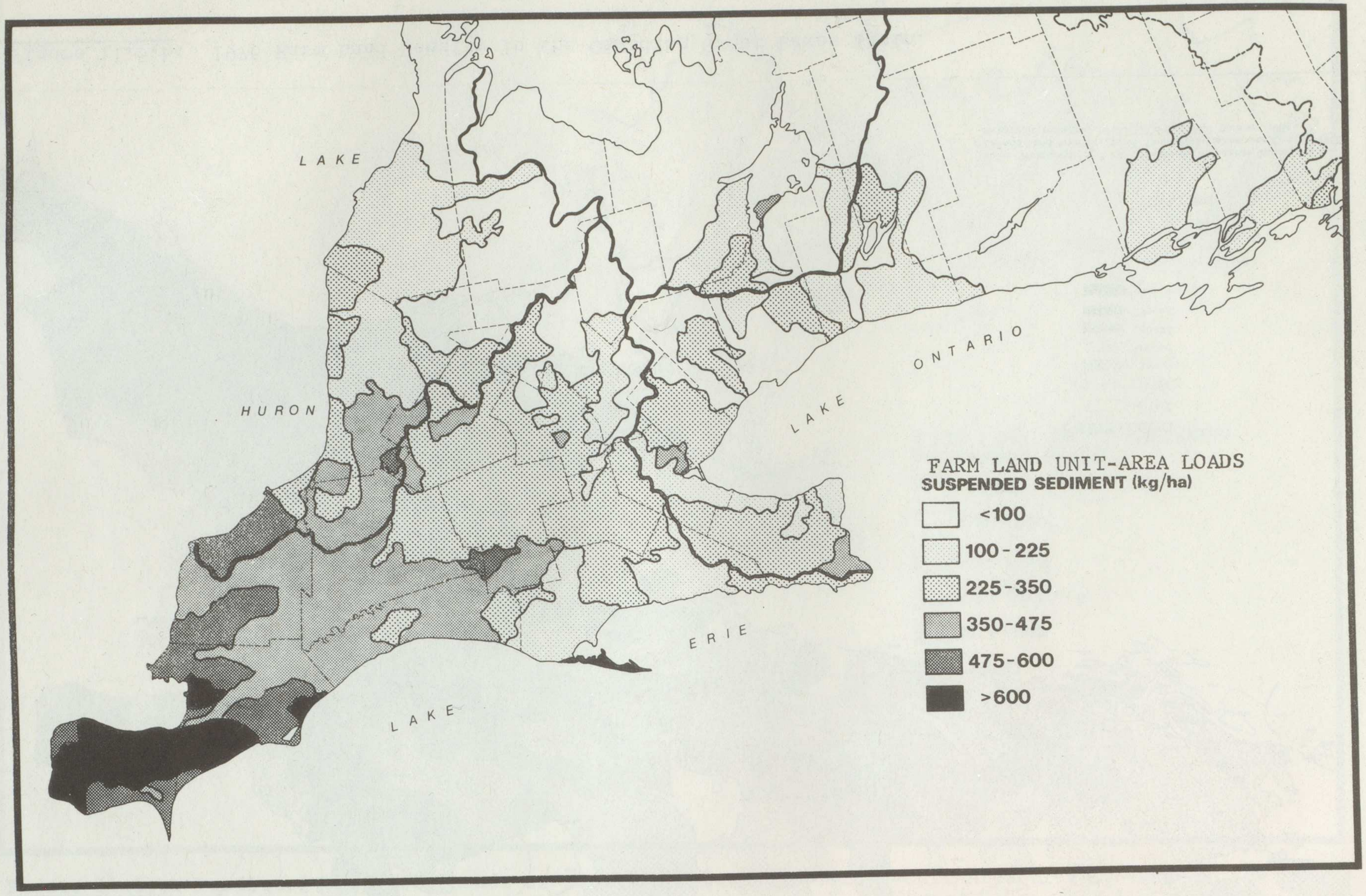


Figure 11.5.c: Predicted Unit-area Loads of Sediment from Each Unit-area of Farm Land in the Watershed Sub-Basins of the Agricultural Portion of the Canadian Great Lakes Basin

used was:

$$\text{Sediment load (kg/ha/yr)} = -204 + 7.9\,(\%\ \text{clay}) + 11.0\,(\%\ \text{row crops}) \qquad (r^2 = 0.64)$$

As with total phosphorus, the mapped values represent the anticipated loads from farm land, and not from all of the watershed sub-basin areas. To estimate the net effect of agricultural sediment loadings, reference must be made to the distribution of farm land as a percentage of the total rural area, as presented in Figure 11.5.b.

Based on the extrapolation procedures used for Figure 11.5.c., it is possible to estimate the total annual agricultural sediment load to the Canadian Great Lakes Basin. This total load was estimated to be 1,084,200 tonnes, of which 22% was derived from farm land in the Lake Huron basin (including Georgian Bay), 64% in the Lake Erie basin (including Lake St. Clair), and 14% in the Lake Ontario basin.

12. REMEDIAL MEASURES RECOMMENDATIONS

This section is divided into two parts. The first deals with the summarization of the specific alternatives for remedial measures which have been suggested through the "integration" activity, and which relate to specific water quality parameters. Since the Task C studies were never formulated for the measurement of the efficiency of specific remedial measures, the remedial measures which are suggested are drawn primarily from the experience and observations of the investigators involved in these studies rather than from any comparative research.

The second section presents an attempt to combine the information available on specific sites with the suggested alternatives, and develop an approach to the selection and evaluation of a set of remedial measures suitable for implementation, at various levels of cost and benefit, to a selected "problem" agricultural watershed. Since the exercise involves all of the integrators, it has not been possible to present this approach in other documents. It is therefore covered in some detail in this summary report.

12.1. Alternative Preventative and Remedial Measures Recommended for Agricultural Land

The following measures are those which appear, from the perspective of the Task C results, to be most likely technically feasible. Most of these recommended alternatives have been developed from qualitative analyses of Task C data, and from field observations by individuals experienced in the problems associated with reducing loads of specific water pollutants from agricultural land. Because of the dependency of many parameters on the movement of sediment as a means of transport, the sediment control alternatives are discussed first.

12.1.1. Suspended Sediments from Agricultural Land

Agricultural land has been found to contribute sediment and associated contamination to the Great Lakes from a combination of sheet, rill, gulley, and bank erosion processes. The temporal pattern of sediment loading from agriculture reveals that the majority of the sediment load (i.e. 70 to 80 percent) is delivered to the stream and lake system during the months of February through April during snowmelt and spring runoff events. PLUARG studies have revealed that the spatial sediment loading pattern associated with agricultural sources indicate wide differences in loading rates -

(a) across the Canadian Great Lakes Basin,
(b) within agricultural basins,
(c) within individual fields and farms.

The areas of the Canadian agricultural basin contributing the highest unit area loads and comprising less than 10 percent of the agricultural area, contribute about 30 percent of the total agricultural sediment load to the Great Lakes. These areas are generally characterized by row cropland on erodible soils with well-developed surface drainage systems. A further twenty-five percent of the agricultural area contributes loads of intermediate magnitude (for the basin) and accounts for about another 45 percent of the agricultural sediment load to the lakes. These areas include either regions which are moderately to highly erodible with poor transport mechanisms or regions which exhibit low erosion rates but which have efficient mechanisms for the transport of material to the streams and lakes. Although these areas are presently grouped in a moderate category for contributing sediment, many of them could contribute much higher loadings if relatively minor changes occurred. For example, an area that is highly erodible but in which buffer strips of vegetation exist along most waterways, ditches, and stream courses probably exhibits a moderate sediment loading. If a number of the buffer strips were removed and cropping was carried out to the ditch and stream edge, the unit area sediment loading would increase rapidly into the high range of values.

The portions of agricultural watersheds contributing the majority of the sediment load comprise a relatively small percentage (10% to 20% depending on storm conditions) of the watershed area. These portions are usually located in close proximity to drainageways and natural stream courses. Within fields and farms, row crops - and particularly continuous row crops - contribute significantly more sediment material than other cropping systems. The lack of adequate buffer strips along water courses leads to large amounts of material being transported from field to stream and to increased ditch and bank erosion.

If agriculturally derived suspended sediments are assumed to be contributing pollution to the Great Lakes, several general recommendations with respect to remedial measures may be made on the basis of PLUARG data. Erosion - and sediment - control programs should be developed and implemented differentially throughout the agricultural region of the Canadian Great Lakes Basin. Prime emphasis for remedial measures should be in the areas contributing the highest sediment loading rates, where the greatest benefits can be realized. However, emphasis should also be placed in areas of intermediate contribution, not only to reduce present loadings but also to prevent increased loadings in the future.

Erosion - and sediment - control programs should include a watershed perspective with emphasis being given to those portions of the agricultural landscape contributing sediment most significantly to stream channels, i.e. those areas adjacent to drainageways and natural stream channels.

Reducing soil erosion rates can be accomplished by any number of well tested techniques which either reduce the impact energy of rain drops (e.g. mulch or cover crops) or reduce the soil erodibility (e.g. maintaining soil structure by increasing organic matter content or by minimum tillage). Reducing transport of eroded soil to stream channels can be accomplished by the application of established measures such as contour cropping, diversion terraces, etc. Another approach is to separate cropping and cultivation activities from streams and drainage channels by vegetated "buffer strips" or "field borders". These reduce the velocity of runoff water and increase infiltration causing sediment to settle out before reaching the stream. Dense vegetation may also act partially as a filter. Sediment thus deposited is unlikely to be remobilized if the soil remains undisturbed. Grassed waterways may perform a similar function in areas where surface drainage is controlled and diverted away from stream banks and into artificial channels or conduits. These artificial channels should also be designed and maintained for maximum stability by using bank slopes suitable for good soil stability and for vegetation maintenance. They should be disturbed by cleaning and regrading operations as infrequently as possible. At the field and farm level, it is recommended that erosion-control programs be focussed on the development of modified cropping and tillage systems (primarily for the row crops of corn, beans, and horticultural crops). It is also recommended that erosion-control programs be aimed at the development of buffer strips along drainageways and natural stream channels, and at improved drainageway design.

All remedial measures should be viewed with a temporal perspective. Emphasis should be placed on those measures affecting the erosion and transport of material during the snowmelt and spring runoff period.

Some aspects of agricultural land management also directly influence the stability of stream banks and should be considered as part of an overall agricultural remedial plan. Tillage operations close to stream banks can increase the susceptibility of the banks to slumping, and is an additional justification for maintaining vegetated buffer or border strips. Restricting the access of livestock to stream banks during periods of high soil moisture, such as in the spring months, will also reduce the incidence of bank instability and slumping. Subsurface drainage outlets into streams and ditches should be designed and constructed to give stability in terms of their resistance to disintegration or misalignment and in terms of minimizing scouring and undercutting of the stream or ditch bank (e.g. by providing erosion resistant protective material where necessary).

12.1.2. Phosphorus from Agricultural Land

Sediments from agricultural land may be enriched in phosphorus due to applications of manure and/or commercial fertilizer. In the zones which are frequently hydrologically active and which yield eroded sediment to streams, measures designed to minimize the enrichment of these soils with phosphorus may have some effect on phosphorus loads, though the phosphorus content of the soil is generally so high compared to agriculturally added phosphorus that reductions in total phosphorus may be very small. Greater reductions (in percentage terms) would occur in the forms of P which are more readily available to aquatic life. Measures such as restricting phosphorus inputs as fertilizer or manure to those recommended from a soil phosphorus plant-availability test should be considered. However, it must be recognized that these measures would not significantly reduce the phosphorus in runoff for several years. Once a soil is enriched by addition of fertilizer and/or manure, it requires several years of cropping to reduce the concentration of plant-available P. The measures would, however, avoid further unnecessary enrichment.

Soluble phosphorus in runoff water from frequently hydrologically active zones may also be increased by poor management of phosphorus fertilizer or manures. Specifically, failure to incorporate fertilizer and manure into the soil may lead to high concentrations of soluble phosphorus in the runoff water. Remedial measures to reduce this problem would include incorporation of manure into the soil as soon as possible after application, and prior to a runoff-causing event (this would also eliminate spreading on frozen soils). Similar restrictions are suggested for manure spreading on floodplain soils even though these may not be frequently hydrologically active. Much of the phosphorus fertilizer is band applied and hence incorporated on application. Incorporation of broadcast fertilizers should be encouraged in areas where water quality may be affected.

Organic soils may yield large quantities of phosphorus to drainage water as a result of drainage works which increase soil decomposition rates, and as a result of fertilizer applications for crop production. These fertilizer applications have been found to be excessive in some instances, and reducing application rates to crop needs would be a remedial measure which would reduce loadings from these areas. Although the reductions would occur more rapidly than with mineral soils, excessive concentrations in drainage water would continue for 10 years or more. The area of cultivated organic soils is very small, being in essentially five locations in Ontario, an area in New York near the shouth shore of Lake Ontario and some scattered sites in Michigan. Thus the impact on the total load to the Great Lakes is extremely small. Localized effects may be significant. It is suggested that the potential for water pollution be considered in any proposals to develop additional organic soil areas.

Direct manure inputs from runoff or seepage from manure storage or livestock feeding areas will add phosphorus, primarily in a soluble form, to streams. Remedial measures are recommended which will separate livestock facilities from streams unless runoff and seepage is contained within the operation. The degree of separation necessary to protect water quality will depend on soil type, slope and other features of each site. Guidelines should be prepared which will result in the siting of all future operations in non-contributing areas. Existing operations may need runoff control measures if stream contamination is evident. Runoff would need to be contained and later pumped or transported to non-contributing areas for disposal or use for crop production. The Ontario Agricultural Code of Practise or the Canada Animal Waste Management Guide should be consulted for recommended structural options, especially for large beef operations which have been found to contribute the greatest proportion (about 44%) of the livestock phosphorus pollution potential. Livestock defecating directly into streams is an unquantified source of phosphorus. It could be controlled by restricting access to streams which cross pastures, but costs and acceptability may present many problems.

Other agricultural sources of phosphorus can be considered for control by site specific measures. Examples are those farm silos from which drainage liquor is allowed to flow into a stream or into a farm drainage system leading to a stream. Farm yard and milk-house drainage may also contaminate drain systems. Connections from these sources to field drainage systems may need to be traced and eliminated, with contaminated water being diverted instead into seepage disposal beds, or stored and pumped out to field disposal.

In terms of priority based on technical effectiveness (including the extent of controllable sources) it is suggested that the remedial measures which can be utilized for phosphorus reduction from agricultural land should be applied as follows (all only in frequently hydrologically active areas): i) reduction of sediment from soil erosion; ii) control of runoff from manure storage and livestock feeding areas; incorporation of manure into the soil immediately after spreading; iii) application of fertilizer phosphorus according to "soil test" recommendations; iv) control of drainage from silos, barn yards which are connected to subsurface field drains.

12.1.3. Nitrogen from Agricultural Land

While not a parameter of major significance to lake water quality at this time, concentrations exceeding the 10 mg/L drinking water standard in many upstream areas in both surface and ground water suggest that preventative measures to reduce N losses from land to water are desirable where practicable. While some 25-30% of total N loss in monitored agricultural watersheds is associated with sediments, and will therefore be controlled by remedial measures implemented for sediment, the most abundant form of nitrogen is the highly soluble nitrate ion which moves freely through soils and into drainage systems and ground water.

Evidence suggests that much nitrogen in drainage waters originates either as natural organic matter in soils which is undergoing mineralization with successive years of cultivation, or as fertilizer or manure nitrogen which is added to promote optimum crop growth. Improved efficiency in the use of the added sources would reduce leaching losses. Optimum timing of applications (which may include the use of slow N release fertilizers), matching rates of application to crop needs and planting cover crops after harvest of the main crop to take up excess available nitrogen will help reduce these losses. Efficient N management considerations are particularly important for corn, for which a large portion of the N used within the Great Lake Basin watersheds is applied. A suitable soil test procedure for determining soil available nitrogen is currently needed in order to allow reduced N fertilization on soils with high natural organic N contents and mineralization rates.

Many of the suggested measures for control of soluble phosphorus from manure storage and livestock operations will help reduce concentrations of nitrogen in runoff, but they will do little to reduce leaching to groundwater or to tile drains. Tile drains should not be placed under unpaved manure storages or livestock feeding areas if nitrogen is to be kept out of streams. Best remedial measure for these sites is probably the roofing of areas where manure is deposited so that the manure will dry out and not be leached of its nitrogen by rain and snow melt into groundwater or drainage systems.

Most of stream N losses occur during winter and spring runoff. Consequently, an important conservation of annual N loss would occur by reducing soil NO_3 concentration prior to this period. Fall cover-cropping and incorporation of organic residues of a high C/N ratio hold promise for the achievement of this conservation of nitrogen. Once water with a high nitrate content enters a stream there is potential for denitrification, by which the nitrogen is returned to the atmosphere. PLUARG studies suggest that stream renovation which includes the revegetation of stream banks with trees and shrubs would create conditions under which denitrification would remove some nitrogen from stream water, particularly at times of low flow and high temperature.

12.1.4. Trace Elements (Heavy Metals)

Since trace elements are present naturally in geological materials, trace elements are contributed to water by all land uses. In rural areas, the loading rates are directly proportional to sediment yields. Little can be done in these areas to reduce metal loadings other than controlling sediment (already discussed). However, increases in metal levels in soils due to man's activities should be prevented so that the input of metals to water from rural lands does not also increase. Fertilizers and manures have had negligible effects on raising metal levels in Ontario soils. However, because of variability in source materials, phosphatic fertilizers should be monitored to ensure that only those with low metal contents (especially cadmium) are used. Disposal of sewage sludge onto agricultural land has been a major source of increases in trace elements in the past; adherence to the guidelines presently under consideration by the Ontario Ministries of the Environment and Agriculture and Food should reduce the contamination of agricultural lands by toxic metals. The most difficult source to control will be the atmospheric input of metals, particularly near large urban-industrial centres where inputs to the soils are high. These inputs may be masked for many years to come, however, by the natural variability of metals in soils. Any increase of metals in soils will also increase the metal loadings to the Great Lakes as the soils are subjected to erosive forces.

12.1.5. Pesticides

12.1.5.1. Insecticides and fungicides

While biological control of insects and diseases is the ultimate in control measures, it is doubtful that it will be applied to a wide range of crops in the immediate future. Releases of parasites and predators of both the cereal leaf beetle and the alfalfa weevil are examples of its successful use in Ontario. The breeding of disease resistance into crop varieties has accomplished much in the last two decades on a world-wide basis. However, these approaches take decades to perfect so work on them should be increased if the long-term production of food is to be assured and the environment is to be protected.

A second and more immediately viable endeavour, and one concurrently receiving considerable attention by agricultural agencies, is a combination of physical, biological and chemical control measures referred to as 'integrated control'. This involves the monitoring of pest population dynamics, assessing physical and biological inputs and, by timely applications of fungicides and insecticides, maximizing chemical effects while safeguarding biological integrity. This complex procedure should be encouraged and expanded to include more crops and pests.

The persistent organochlorine insecticides have virtually been eliminated from use in agriculture and have been replaced by organophosphorus and carbamate insecticides. While many of these newer insecticides appear to be non-persistent and rarely contaminate stream water, over-use promoted by the appearance of insect resistance is leading to a build-up of residues in some muck soils, which in time, may contaminate water. This problem has not developed on mineral soils.

The appearance of resistance in insects and fungi is a constant threat to the usefulness of chemicals. Increasing tolerance of insects to organophosphorus insecticides has seen the introduction of newer synthesized chemicals based on natural occurring chemical groups, on toxins and attenuated bacteria, and on insect growth regulators. These trends should be continued and encouraged by increased research.

The organophosphorus and carbamate insecticides range from low to extreme toxicity. Humans have been poisoned as a result of crude methods of handling and application. Careless handling, misuse and spillage have lead to the occasional contamination of stream water and the killing of fish. Recent advances in application techniques demonstrate that such problems can be overcome using closed system dispersion of toxicants both into the equipment and onto the target area. This work should be supported and fostered for all end users of pesticides.

The promotion of alternatives to chemicals is receiving more attention by agricultural agencies and this approach should be further pursued. The use of crop rotation for the control of the northern corn rootworm is an excellent approach to stemming the advance of this insect into the corn belt of Ontario.

Useage of insecticides and fungicides is not confined to the agricultural sector, but is common to the domestic and industrial sectors and to the protection of forests. The same rules apply to these sectors of our society. The Ontario Pesticide Act has gone far in removing the highly toxic insecticides and fungicides from the domestic sector and has made it mandatory that only trained personnel can apply such compounds in the industrial, forestry and aquatic environments, and professional commercial application in agriculture.

Strict enforcement of regulations, adequate training of users and general education on new procedures and safeguards should contribute to lowering the incidence of environmental contamination and allay future concerns.

12.1.5.2. Herbicides

The use of herbicides has grown dramatically over the last decade. These are employed by all facets of human society to control weeds in agriculture, on industrial and home properties, in forests and in recreational areas.

Mammalian and avian toxicities are generally much lower than with the insecticides and persistence is normally short-termed, ranging from a few weeks to a season. A few herbicides can persist for longer periods, for example, simazine, atrazine and diuron. Although there is no evidence of any environmentally related problems, the rates at which atrazine (a corn production herbicide) is present in stream water may be cause for concern. This herbicide is readily removed from treated fields by storm runoff waters and can also be removed, in lower quantities, via tile drainage waters. Other herbicides, such as cyanazine, can be substituted for atrazine under appropriate weed conditions and do not appear to either persist or move to stream water. Remedial measures which reduce soil erosion and storm water runoff should greatly reduce the loss of atrazine to water.

2,4-D type herbicides have been used in cereals and corn, but have not appeared at other than minimal levels in stream waters. These same materials are quite widely used for the control of weeds on roadsides, ditches, utility corridors, and to control aquatic vegetation. While application personnel are generally aware of the dangers of spray drift damaging susceptible crops and garden plants, they have not always recognized the need to keep their sprays from contaminating water in ditches and streams around which weeds are being controlled.

The Pesticide Act of Ontario regulates the application of herbicides to water by permit and stipulates that application to public lands be done by licenced operators. However, education is needed to prevent the contamination of water when spraying such public properties.

12.1.6. Industrial Organic Contaminants

The problems associated with organic toxicants in Great Lakes water appear to be severe and reminiscent of the problems of the persistent organochlorine insecticides. Industrial organic toxicants like PBB, PCB, CN and mirex are not used in agricultural production, but arrive on land through aerial fallout, misuse or disposal in rural areas - e.g., disposal of oil containing PCB on roadways.

Persistence, toxicology and use data are urgently required for currently used industrial organic toxicants. In addition, a system of collecting these data before new organics are introduced should be mandatory if future damage to the environment is to be averted. Continued monitoring and surveillance of industrial contaminants is paramount to safeguard food and water quality and alleviate the current chronic contamination of the Great Lakes basin.

12.1.7. Microbiological Indicator Organisms

Diffuse sources of bacteria have been recognized in agricultural areas although no specific sources have been identified. Some general measures appear feasible for the reduction of the likelihood of bacterial contamination of streams in agricultural watersheds. Many of these have already been suggested for control of phosphorus from livestock operations, i.e. separate feeding and manure storage areas from streams by sufficient distance to assure attenuation of microbes by soil and vegetation before runoff reaches a stream; cover manure immediately after spreading, before runoff occurs; avoid spreading manure in the frequently hydrologically active area adjacent to streams, or in flood plains. In addition, some benefit may accrue from keeping pasturing livestock away from streams, with the provision of alternative watering facilities.

12.2. Application of Remedial Measures Alternatives to Specific Sites

Generalized recommendations and discussion of some technical alternatives with respect to remedial measures were covered in the preceding section. However, it must be emphasized that localized variations in pollutant sources, soil properties and landscapes, cropping systems and active pollutant contributing areas make a general approach to application of remedial programs impossible. The erosion and transport of pollutants from any point on the agricultural landscape must be considered as a site specific problem requiring the implementation of site specific remedial measures on the active contributing areas. A set of practices can only be developed through detailed consideration of a specific area. In order to illustrate this approach to remedial measure recommendations, sets of practices were developed for four agricultural watersheds. These examples demonstrate (a) the selection of remedial measures commensurate with an existing viable agricultural industry and (b) the estimated probable cost and effectiveness of the implemented remedial program (Tables 12.2a-d).

The relative magnitude of a pollutant source is a site specific factor governing the implementation of remedial programs. For example, the streambank erosion component of the total sediment load varies from greater than 30% as in Watershed AG-1 to less than 5% as in Watershed AG-5. In remedial programs, the greater streambank erosion component in Watershed AG-1 as opposed to Watershed AG-5 is reflected in the extensive and costly drainage engineering measures implemented (Table 12.2.a and 12.2.d).

Soil properties such as texture can also affect the suitability of a remedial practice at a given location. Clay soils such as located in Watershed AG-1 are not suited to spring plowing or zero tillage remedial practices since the corresponding yield reductions would make corn or soybeans production uneconomical. However, spring plowing or zero tillage are viable remedial programs in areas with medium to coarse textured soils such as illustrated in Watersheds AG-4 and AG-5 (Tables 12.2.c and 12.2.d). The shape of the landscape can also affect the selection of remedial measures. For example, strip or contour cropping as employed in Watersheds AG-4 and AG-5 are most applicable on simple, uniform slopes rather than hummocky, complex topography.

Table 12.2.a.: Application of some feasible remedial measures alternatives in Agricultural Watershed AG-1, - estimated costs and effectiveness.

Watershed description: Area - 5080 ha; soil - 35% to 40% clay; relief - level; stream length - 91 km; hydrologically active contributing area - 50%; land use - 62% row crops, 23% corn, 37% soybeans, 27% wheat, 1% hay; livestock - 0.08 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	900 (kg/ha/yr)	1.8 (kg/ha/yr)
Potential minimum - zero row crops[1]	260	0.8
Potential maximum reduction	640	1.0

Remedial Measure[2]	Effectiveness[2]				Cost ($)		Explanatory Note
	Sediment		Phosphorus				
	% Reduction	Residual	% Reduction	Residual	Annual	Capital	
1. Good management practices	5	850	5	1.70	0	0	3
2. Crop rotations (corn-soybeans - wheat - hay)	10	765	10	1.50	130,000	0	4
3. Winter cover (oats) - shorter season corn	10	690	10	1.35	57,500	0	5
4. Stream channel buffer strips	15	590	10	1.25	61,820	0	6
5. Drainage engineering:	40	350	15	1.00			
a. Grading channel banks to 3:1 slopes					31,000	57,000	7, 8
b. Drop inlet structures						100,000	9
c. Amortization of capital costs					17,900		10
Total annual costs - $58/watershed ha.					298,200	157,000	

Explanatory Notes: 1. As computed by the following regression equations (row crops = 0) Sediment(kg/ha/yr)= -281 + 18.3 (%row crops) + 13.6 (% clay); Total phosphorus (kg/ha/yr) = $-0.0939 + 0.000846\,(\%\ \text{clay})^2 + 0.000212\,(\%\ \text{row crops})^2$.

2. Relative benefits obtained by each remedial measure (i.e. cost effectiveness) depends on the order in which they are implemented.

3. Good management practices include the following no cost items that are applicable to all agricultural land: - a. fertilize by soil test; b. retain surface residues over winter; c. minimum tillage for optimum yield; d. manure incorporation and restricted use near streams; e. residue management for soil organic matter maintenance; f. cross slope farming.

4. Assumed costs and returns for cropping practices:

	Corn and Soybeans	Cereal Grains	Hay
Returns	300 bu/ha @ $2.50/bu = $750/ha	150 bu/ha @ $2.0/bu = $300/ha	25 bu/ha increase in subsequent corn yield= $60/ha. Nitrogen added @ 114kg/ha @ 44¢ = $50/ha $80/ha (assumed equal to costs since no market)
Costs	$300/ha	$100/ha	$80/ha
Net	$450/ha	$200/ha	$110/ha

Revenue Lost by Crop Conversions
Corn or soybeans to hay - $340/ha
Corn or soybeans to grains - $250/ha
Grains to hay - $90/ha

2500 ha in contributing area (currently 500 ha corn, 1000 ha soybeans, 750 ha wheat, 50 ha hay, 200 ha other improved) is changed to meet rotation requirements (575 ha corn, 575 ha soybeans, 575 ha wheat,575 ha hay) requiring 350 ha of corn or soybeans and 125 ha of wheat to be converted to hay.

5. 575 ha corn with 25bu/ha yield reduction ($60/ha) and cost of $40/ha for oats establishment.

6. 182 ha in contributing area lost from production (110 ha corn and soybeans and 55 ha wheat to uncut hay) for $60,000; buffer strip maintenance @ $10/ha.

7. Lost from production by grading channels to 3:1 bank slopes - 10m X 91 km = 91 ha (55 ha corn or soybeans and 30 ha wheat)

8. Grading costs @ $600/km for 91 km of channel; 9. Drop inlet structures @ $4/\text{km}^2$ @ $500/structure; 10. Amortization over 20 years @ 10%

Table 12.2.b.: Application of some feasible remedial measures alternatives in Agricultural Watershed AG-3, - estimated costs and effectiveness.

Watershed description: Area - 6200 ha; soil - 25% to 30% clay; relief - gently sloping; stream length - 40 km; hydrologically active contributing area - 25%; land use - 45% row crops, 32% corn, 12% beans, 22% small grains, 5% wheat, 10% hay; livestock - 0.48 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	260 (kg/ha/yr)	1.1 (kg/ha/yr)
Potential minimum - zero row crops[1]	60	0.4
Potential maximum reduction	200	0.7

Remedial Measure[2]	Effectiveness[2]				Cost ($)		Explanatory Note
	Sediment		Phosphorus		Annual	Capital	
	% Reduction	Residual	% Reduction	Residual			
1. Good management practices	10	230	10	1.00	0	0	3
2. Strip cropping	5	220	5	0.95	2,900	1,000	4
3. Crop rotations (corn - corn - grain - hay - hay)	10	200	10	0.85	25,000	0	5
4. Winter cover (oats) - shorter season corn	10	180	10	0.75	42,000	0	6
5. Stream channel buffer strips (20m width)	15	150	10	0.70	18,000	0	7
6. Drainage engineering:	10	135	0	0.70			
a. Tile outlet stabilization						15,000	8
b. Bank stabilization on 13 ha						5,200	9
c. Amortization of capital costs					2,500		10
Total annual costs - $15/watershed ha.					90,400	21,200	

Explanatory notes: 1, 2, and 3 - see notes for Table 12.2.a.(Note 1 includes 0.1 kg P/ha/yr subjective reduction estimate for applying remedial measures)

4. Strip cropping on 75% of the "C" slopes in the contributing area (290 ha) @ $10/ha plus a capital cost of $1,000 for some tree and fence-row removal.
5. Assumed costs and returns for cropping practices:

	Corn(net same for soybeans)	Cereal grains	Hay	Revenue Lost by Crop Conversions
Returns	250 bu/ha @ $2.50/bu = $600/ha	150 bu/ha @ $2.00/bu = $300/ha	25bu/ha increase in subsequent corn yield = $60/ha/2 yrs 114 kg/ha N added @ 44¢ = $50/ah/2 yrs 7.5 tonnes/ha hay @ $30/t = $225/ha	Corn or soybeans to hay - $100/ha Corn or soybeans to grains - $100/ha Grains to hay - nil
Costs	$300/ha	$100/ha	$80/ha	
Net	$300/ha	$200/ha	$200/ha	

1550 ha in contributing area (currently 700 ha corn/beans, 340 ha grain, 280 ha hay) is changed to meet rotation requirements (525 ha corn/beans, 265 ha grains, 525 ha hay) requiring 175 ha of corn/beans and 75 ha small grains to be converted to hay.

6. 420 ha corn with a 25 bu/ha yield reduction ($60/ha) and cost of $40/ha for oats establishment.
7. 80 ha in contributing area lost from production (36 ha corn/beans @ $300/ha, 18 ha grains @ $200/ha, 14 ha hay @ $200/ha): buffer strip maintenance @ $10/ha.
8. 150 drain outlets @ $100/outlet.
9. 13 ha of eroding banks stabilized @ $400/ha.
10. Amortization over 20 years @ 10%.

Table 12.2.c.: Application of some feasible remedial measures alternatives in Agricultural Watershed AG-4, - estimated costs and effectiveness.

Watershed description: Area - 1860 ha; soil - 25% clay; relief - gently sloping; stream length - 20 km; hydrologically contributing area - 25%; land use - 20% row crop (all corn), 32% small grains, 38% hay/pasture; livestock - 0.75 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	425 (kg/ha/yr)	0.75 (kg/ha/yr)
Potential minimum - zero row crops[1]	75	0.30
Potential maximum reduction	350	0.45

Remedial Measure[2]	Effectiveness[2]				Costs ($)		Explanatory Note
	Sediment		Phosphorus				
	% Reduction	Residual	% Reduction	Residual	Annual	Capital	
1. Good management practices	10	380	10	0.67	0	0	3
2. Strip cropping	15	325	10	0.60	1,400	500	4
3. Crop rotation (corn - grain - grain - hay - hay)	-	-	-	-	-	-	5
4. Spring plowing (corn and hay)	5	310	5	0.57	12,000	0	6
5. Stream channel buffer strips (20m); grassed waterways	40	185	25	0.43	18,400	0	7
6. Drainage engineering:	10	165	0	0.43			
a. Tile outlet stabilization						5,000	8
b. Stream bank stabilization						1,200	9
c. Amortization of capital costs					800		10
Total annual cost - $18/watershed ha.					32,600	6,700	

Explanatory notes: 1, 2, and 3 - see notes for Table 12.2.a. (Addition to Note 1. - includes subjective 0.1 kg/ha/yr livestock input reduction assumed to result from the implementation of the remedial measures listed.)

4. Strip cropping on 75% of the "C" slopes in the contributing area (140 ha) @ $10/ha, plus $500 capital costs for fence row removal.
5. Crop rotation is not applicable as a new remedial measure, since, in this watershed, they are already generally practiced.
6. To avoid fields in the contributing area being left bare over the winter period, either plow in the spring, or use cover crop over winter; - 100 ha corn with expected yield loss of 25 bu/ha @ $2.50/bu = $6,000 and 200 ha grain @ a loss of $30/ha = 6,000 - total $12,000/yr.
7. 40 ha to buffer strips and lost from production (8ha corn @ $300/ha, 16 ha grain @ $200/ha, 16 ha hay @ $200/ha = $8,800); grassed waterways established on an equal land area with the same costs. Assumed that the buffer strips and waterways are clipped and not harvested for hay - maintenance costs @ $10/ha = $800. Total cost $18,400.
8. 50 tile outlets stabilized @ $100/outlet.
9. 3 ha of eroding streambanks stabilized @ $400/ha.
10. Amortization of capital costs at 10% for 20 years.

Table 12.2.d.: Application of some feasible remedial measures alternatives in Agricultural Watershed AG-5, - estimated costs and effectiveness.

Watershed description: Area - 3000 ha; soil - 20% clay; relief - gently sloping; stream length - 22 km; hydrologically active contribution area - 25%; land use - 48% row crops (all corn), 13% small grains, 25% hay; livestock - 0.61 animal units/ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	250 (kg/ha/yr)	1.00 (kg/ha/yr)
Potential minimum - zero row crops[1]	25	0.15
Potential maximum reduction	225	0.85

Remedial Measure[2]	Effectiveness[2] Sediment % Reduction	Sediment Residual	Phosphorus % Reduction	Phosphorus Residual	Cost ($) Annual	Cost ($) Capital	Explanatory Note
1. Good management practices	10	225	10	0.90	0	0	3
2. Strip cropping	15	190	10	0.80	2,000	500	4
3. Crop rotations (Corn - corn - grain - hay - hay)	20	150	15	0.67	10,000	0	5
4. Spring plowing (corn)	10	135	10	0.60	15,600	0	6
or - no-till corn					(24,700)	0	7
5. Stream channel buffer strips (20m) and grassed waterways	40	70	15	0.50	20,800	0	8
6. Drainage engineering:	10	60	0	0.50			
a. Tile outlet stabilization					5,000	5,000	9
b. Stream bank stabilization					800	800	10
c. Amortization of capital costs					750		11
Total annual cost - $16/watershed ha.					49,150	6,300	

Explanatory notes: 1, 2 and 3 - see notes for Table 12.2.a.(Note 1 includes 0.05 kg P/ha/yr subjective reduction estimate for applying remedial measures)
4. Strip cropping on 75% of the "C" slopes in the contributing area (200 ha) @ $10/ha plus a capital cost of $500 for fence-row removal.
5. Assumed costs and returns for cropping practices - see note 5 to table 12.2.b.
6. 260 ha corn with 25 bu/ha yield reduction ($60/ha) = $15,600.
7. No-till corn with 35 bu/ha yield reduction ($95/ha) = $24,700 for 260 ha.
8. 40 ha in contributing area lost to productoin (16 ha corn @ $300/ha, 8 ha grain @ $200/ha, 16 ha hay @ $200/ha = $10,000; grassed waterways established on an equal land area with the same costs. Assumed that the buffer strips and waterways are clipped and not harvested for hay - maintenance costs @ $10/ha = $800. Total cost = $20,800.
9. 50 tile outlets stabilized at $100/outlet.
10. 2 ha of eroding stream banks stabilized @ $400/ha.
11. Amortization of capital costs @ 10% over 20 years.