INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL JOINT COMMISSION

ENVIRONMENTAL MANAGEMENT STRATEGY FOR THE GREAT LAKES SYSTEM

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"Is the purpose of our civilization really to see how much the earth and the human spirit can sustain? The decision is still ours to make assuming we recognize that the goal of humanitarianism is not the quantity but the quality of life. If we evade the choice, the inevitable looms ahead of us – even sterner forces will make the decision for us. We cannot delay or evade. For now, as we look, we can see the limits of the earth."

Fairfield Osborn,
"The Limits of the Earth",
Little, Brown and Company, Boston.
1953.

ENVIRONMENTAL MANAGEMENT STRATEGY FOR THE GREAT LAKES SYSTEM

FINAL REPORT TO THE INTERNATIONAL JOINT COMMISSION

FROM THE INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

PLUARG

JULY 1978

WINDSOR, ONTARIO

International Joint Commission
Canada and the United States

Gentlemen:

We are pleased to forward our final report to the IJC. This document summarizes the main findings and conclusions of the PLUARG study and presents the Reference Group's recommendations. The main report is supported by a technical report series of considerable volume.

Some of the main accomplishments do not, in fact cannot, appear in written form. These include the logistic developments on pilot watersheds, most of which lend themselves to pilot programs which would be useful in fine tuning remedial measures. As well, the Reference Group has assembled a substantial management information base and has explored analytical methods to aid in the decision-making process. Rivermouth monitoring data have been interpreted in new ways and suggestions made to enhance such programs. Public participation has been rewarding in terms of ideas on present issues and experience with the process itself.

The Reference Group has recognized the need for improved, socially meaningful yardsticks against which the cost of remedial programs should be weighed. We urge the Commission to encourage resolution of societal goals for the lakes in order to promote public motivation for desirable programs. The ecosystem approach, considering man and resources of the lakes and basins in a meaningful social context, has been implicit in the PLUARG approach.

The PLUARG study, IJC's deliberations and response of governments are only stages in a long period of steady progress in land management. Many examples of conservation are as applicable today as they were 50 years ago, and they will remain so. What is changing markedly is the clearer recognition of the inter-relationships among man's activities and effects on quality of life. It is a dynamic world, in the Great Lakes basin as much as any other place. Our hope is that PLUARG has contributed knowledge and information to expedite beneficial additions to policy, programs and ways to help meet the goals of the Agreement.

Respectfully submitted,

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ACKNOWLEDGEMENTS

The Pollution from Land Use Activities Reference Group (PLUARG) wishes to acknowledge the assistance of the numerous individuals and agencies involved in the various aspects of this study. The enthusiasm and dedication demonstrated by the PLUARG task group investigators and associated agencies on the local, state, provincial and federal levels have been invaluable during the course of this five year, multi-component study. The cooperation and quality of participation displayed by the public consultation panels were also instrumental in producing this report. Although too numerous to mention individually, participants and agencies are recognized in the appropriate PLUARG documents listed in Appendix 3.

Special recognition is given to the PLUARG Core Group for their dedicated and disciplined efforts in preparation of this volume, under what were frequently taxing circumstances. Members of this group were Dr. Walter Rast, Chairman (IJC Regional Office), Mr. Garth Bangay (Fisheries and Environment Canada), Mr. Marty Clark (PLUARG), Mr. Dennis Gregor (Fisheries and Environment Canada), Mr. Eugene Jarecki (Great Lakes Basin Commission), Ms. Sally Leppard (PLUARG), Dr. Harvey Shear (Fisheries and Environment Canada), Mr. Bill Skimin (Great Lakes Basin Commission), Dr. William Sonzogni (Great Lakes Basin Commission) and Dr. Darnell Whitt (IJC Regional Office). Individuals also deserving special mention include Dr. Thomas Bahr (Michigan State University), Dr. Gordon Chesters (University of Wisconsin), Dr. D. Richard Coote (Agriculture Canada), Ms. Elsie MacDonald (Agriculture Canada), Mr. Robert Ostry (Ontario Ministry of Environment), Dr. John Robinson (University of Guelph) and Dr. Robert Stiefel (Ohio State University).

To all the various individuals involved directly or indirectly with the PLUARG study, the Reference Group offers its sincere thanks.

EXECUTIVE SUMMARY

INTRODUCTION

The Canada-United States Agreement on Great Lakes Water Quality signed at Ottawa, April 15, 1972, by the President of the United States and the Prime Minister of Canada, *requested the International Joint Commission to conduct a* study of pollution of the boundary waters of the Great Lakes System from agricultural, forestry and other land use activities. As a result, an intensive inquiry was conducted by the *International Reference Group on Great Lakes Pollution from* Land Use Activities (PLUARG), established by the International Joint Commission.

The scope of this inquiry was broader than previous Great Lakes studies conducted under the sponsorship of the Commission in that the entire land area, as well as the water, in the Basin was studied. The Basin totals 755,200 km^2 (292,000 mi^2) in area, with 538,900 km^2 (208,000 mi^2) of land and 216,300 km^2 (84,000 mi^2) of water surface area. The Great Lakes contain approximately 20 percent of the world's fresh surface water supply.

The Basin, with 37 million residents of Canada and the United States, is the industrial heartland of both countries. A major portion of their gross national product is generated here.

Until recently, the Great Lakes have been viewed as a virtually inexhaustible supply of high quality water. However, increasing population, advancing technological innovation and intensification of water and land use in the Basin have resulted in a continuing degradation of the lakes.

Eutrophication, due to elevated nutrient inputs, particularly in the lower lakes (Erie and Ontario), and the increasing contamination of these water bodies by toxic substances, have been identified as the major pollution problems in the Basin. It has also become apparent that while the Great Lakes themselves are a focal point of concern, they are but a part of a complex system in which interaction of the climate and the land and its use have a major influence on the lakes.

Past studies ("Report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, 1969") indicated that current conditions in the lakes could not be related entirely to pollutant loadings from readily identifiable point sources. These studies indicated that 30 and 43 percent of the total phosphorus load for Lakes Erie and Ontario, respectively, were due to sources other than municipal sewage treatment plant and industrial effluents. In attempting to quantify and describe nonpoint sources of pollution, PLUARG reviewed and studied the pollution potential of several land use activities, including agriculture, urban, forestry, transportation and waste disposal, as well as natural processes such as lakeshore and riverbank erosion. PLUARG also examined atmospheric deposition of materials on land and water surfaces. Pilot watershed studies were established and monitoring programs initiated to further define the relationship between land use activities and water quality. While these studies shed considerable light on this relationship, the complexity of the problem makes a quantitative interpretation difficult.

Although the Great Lakes are an interconnected system, *each basin is unique in terms of its limnology*, the socio-economic characteristics of its communities, the type and degree of pollution and the kinds of required control measures. Diffuse source pollutants are not derived uniformly from *whole watersheds or even sub-basins*. Problem areas may represent only a small proportion of a drainage basin area. As a result, PLUARG has developed criteria for the identification of potential contributing areas and within these, the most *hydrologically active areas, which are the zones most likely to* produce water pollution from land use activities.

It is important to recognize: (1) the long term nature of the solutions to most problems of pollution from land use activities; (2) their ramifications through most sectors of society; (3) the involvement of many agencies in the implementation of these solutions; and (4) their public consequences in such policy areas as food production, housing and public health. Population growth and location, industrial development and technological innovation will all have impacts on the loadings of pollutants to the lakes from land use activities. These factors will affect both the need for nonpoint source control and the ability to control some of these sources. As populations grow and industrial development continues, given current technology, pollutant inputs from point sources will undoubtedly continue to grow. However, the finite capacity of the lakes to accept these inputs must be recognized, appropriate pollutant loading targets established and proper monitoring programs undertaken to quantify these loads so as to insure that the capacity of the lakes is not exceeded.

Effective strategies at the international, national and local level must be developed to cope with these factors, since they transcend jurisdictional and political boundaries. Flexible management systems and control measures capable of incremental adjustments in response to a changing environment will be required. As well, questions of equity must be taken into account and a formula arrived at for the reasonable allocation of responsibility between governments, institutions and individuals. Above all, it is essential to recognize that the management of nonpoint sources will require a dramatic departure from the traditional approach followed for the control of point sources.

CONCLUSIONS

The International Joint Commission instructed the International Reference Group on Pollution of the Great Lakes from Land Use Activities to inquire into and report on the following questions:

> *"Are the boundary waters of the Great Lakes System being polluted by land drainage (including ground and surface runoff and sediment) from agriculture, forestry, urban and industrial land development, recreational and parkland development, utility and transportation systems and natural sources?"*

PLUARG finds that the Great Lakes are being polluted from land drainage sources by phosphorus, sediments, some

GREAT LAKES WATER QUALITY POLLUTANTS

I. Parameters for which a Great Lakes water quality problem has been identified

POLLUTANT	PROBLEM		SOURCES				REMARKS
			DIFFUSE				
	Lakewide	Nearshore or Localized	Land Runoff	Atmosphere	In-Lake Sediments	POINT	
Phosphorus[1]	Yes	Yes	Yes	Yes	Yes[a]	Yes	[a] percentage unknown; not considered significant over annual cycle
Sediment[b,1]	No	Yes	Yes[c]	Negligible	Under some Conditions	Negligible	[b] may contribute to problems other than water quality (e.g., harbor dredging) [c] including streambank erosion
Bacteria of Public Health Concern	No	Yes	Minor[d]	No	No	Yes	[d] land runoff is a potential, but minor source; combined sewer overflows generally more significant
PCBs[1]	Yes	Yes	Yes	Yes	Yes	Yes	
Pesticides[1] (Past)	Yes[e]	Yes[e]	Yes	Yes	Yes	No	[e] some residual problems exist from past practices
Industrial Organics[1]	Yes	Yes	Yes	Yes	Yes	Yes	
Mercury[1]	Yes	Yes	Minor	Yes	Yes	Yes	
Lead[1]	Potential[f]	Potential[f]	Yes	Yes	Yes	Yes	[f] possible methylation to toxic form

II. Parameters for which no Great Lakes water quality problem has been identified, but which may be a problem in inland surface waters or groundwaters

POLLUTANT	Lakewide	Nearshore or Localized	Land Runoff	Atmosphere	In-Lake Sediments	POINT	REMARKS
Nitrogen	No	No[g]	Yes	Yes	Minor	Yes	[g] some inland groundwater problems
Chloride	No	No[h]	Yes	Negligible	No	Yes	[h] some local problems exist in nearshore areas due to point sources
Pesticides[i] (Present)	No	No	Yes	No	No	Yes	[i] new pesticides have been found in the environment; continued monitoring is required
Other Heavy Metals	Potential[f]	Potential[f]	Yes	Yes	Yes	Yes	
Asbestos[j]	No	Yes	No	?	Yes	Yes	[j] see Upper Lakes Reference Group Report[37]
Viruses[k]	← No Data Available →					Yes	[k] better detection methods needed
Acid Precipitation	No	No[m]	No	Yes	No	No	[m] a potential problem for smaller, soft water, inland lakes

[1] Sediment *per se* causes local problems; phosphorus and other sediment-associated contaminants have lakewide dispersion.

industrial organic compounds, some previously-used pesticides and, potentially, some heavy metals, as indicated in the following table.

Phosphorus loads from land drainage and atmospheric deposition contribute to both offshore and nearshore water quality problems related to eutrophication. Depending on the magnitude of the point source loads PLUARG estimated that the combined land drainage and atmospheric inputs to individual Great Lakes ranged from 32 percent (Lake Ontario) to 90 percent (Lake Superior) of the total phosphorus loads (excluding shoreline erosion). Phosphorus loads in 1976 exceeded the recommended target loads in all lakes. Point source control programs alone will be sufficient to meet the target loads only in Lakes Superior and Michigan.

Toxic substances such as PCBs have been found to gain access to the Great Lakes System from diffuse sources, especially from atmospheric deposition.

Residues of previously used organochlorine pesticides (e.g., DDT) are still entering the boundary waters through land drainage in substantial quantities, although in significantly declining amounts, as shown by declining levels in fish tissues.

Mercury has been detected in fish tissues in all the lakes. A continuous buildup of lead in the sediments of the Great Lakes has also been noted. In light of the potential for the methylation of lead, this poses a potential problem of unknown dimensions. Lead enters the Great Lakes System in substantial quantities through atmospheric deposition. It is believed mercury enters the system in a similar manner, although this has not been verified.

Sediment affects the Great Lakes System primarily as a carrier of phosphorus and other pollutants, contributing to the overall pollution of the lakes. Sediment affects nearshore areas through siltation of fish habitat and siltation of drainage channels, harbors and bays, necessitating expensive dredging.

Microorganisms enter the Great Lakes System from diffuse sources, resulting in localized problems affecting some nearshore waters.

While in many cases it is difficult to ascribe pollution (i.e., violation of a specific existing or proposed water quality objective) to any particular land use, it is important to note that it is the cumulative effect of a variety of land use activities that ultimately contributes to pollution of the Great Lakes.

"If the answer to the foregoing question is in the affirmative, to what extent, by what causes, and in what localities is the pollution taking place?"

PLUARG finds that the lakes most affected by phosphorus and toxic substances are Erie and Ontario. Local problems associated with phosphorus, microorganisms and sediment are seen in such areas as Green Bay, Saginaw Bay, southern Georgian Bay, Lake St. Clair, the Bay of Quinte, and the south shore red clay area of Lake Superior.

Intensive agricultural operations have been identified as the major diffuse source contributor of phosphorus. The following table indicates the relative loading of phosphorus to each lake from the indicated land uses.

Erosion from crop production on fine-textured soils and from urbanizing areas, where large scale land developments have removed natural ground cover, were found to be the main sources of sediment. Urban runoff and atmospheric deposition were identified as the major contributors of toxic substances from nonpoint sources.

The most important land-related factors affecting the magnitude of pollution from land use activities in the Great Lakes Basin were found to be soil type, land use intensity and materials usage. For example, intensive agricultural activities such as row cropping (e.g., growing corn, soybeans and vegetables) on soils with fine textures (i.e., high clay content) contributed the greatest amounts of phosphorus. Areas of high phosphorus loading from intensive agricultural activities include northwestern Ohio and southwestern Ontario.

Mercury in the Great Lakes is associated with sediment and, in large measure, reflects "in-lake" redistribution of this material from past industrial point sources. Other sources include municipal and industrial waste water discharges and atmospheric deposition of unknown dimensions, which have resulted in significant tributary loadings throughout the Great Lakes watershed. Highest loadings were observed in Lake Erie.

Eighty-five to ninety-nine percent of the lead that enters the Great Lakes comes from nonpoint sources, with the highest loadings being found in Lakes Erie and Michigan. Lead is

GREAT LAKES PHOSPHORUS LOADS

Lake	Total Load[a] (metric tons/yr)	Atmospheric Load (percent of total load)	Total Diffuse Tributary Load (percent of total load)	Estimated Contributions of Major Land Uses to Diffuse Tributary Loads (percent of diffuse load)		
				Agriculture	Urban	Forest & Other
Superior	4,200	37	53	7	7	86
Michigan	6,350	26	30	71	12	17
Huron	4,850	23	50	68	12	20
Erie	17,450	4	48	66	21	13
Ontario	11,750	4	28	66	19	15

[a]1976 load rounded off to nearest 50 metric tons

mainly associated with vehicular emissions and enters the Great Lakes through tributary and atmospheric inputs.

Loadings of organic substances (e.g., PCBs) enter the Great Lakes via tributaries and atmospheric deposition. Main sources are atmospheric emissions, industrial and municipal point sources and urban diffuse sources.

> *"If the Group should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable and what would be the probable cost thereof?"*

PLUARG finds that the remedy of nonpoint source pollution will not be simply nor inexpensively accomplished. Nonpoint sources of water pollution are characterized by their wide variety and large numbers of sources, the seemingly insignificant nature of their individual contributions, the damaging effect of their cumulative impact, the intermittent nature of their inputs, the complex set of natural processes acting to modify them and the variety of social and economic interactions which affect them.

PLUARG does not favor across-the-board measures for nonpoint source pollution control, but rather recommends a methodology whereby problem areas are defined on a priority basis to which the most practicable control means for a particular source are then applied. Management plans must be formulated which include a number of considerations which have not be comprehensively addressed in past point source control programs. Four major components have been identified: (1) planning; (2) fiscal arrangements; (3) information, education and technical assistance; and (4) regulation.

In addition, the successful implementation of these management plans will rely heavily on the interest, concern and action of individual members of society.

Differences in water quality between and within lakes are the basis for requiring different degrees of management in different watersheds. As a result, implementation programs should be emphasized in those areas of the Basin where water quality is the most degraded, or where a need to preserve high quality waters is identified. Remedial program priorities must then be based on the degree to which the pollutant can be controlled.

A basic tool for estimating the level and location of management required in potential pollutant contributing areas is the identification of the most hydrologically active areas (HAA). These are land areas that contribute directly to ground and/or surface waters, even during minor precipitation and snow-melt events, because of their proximity to streams or aquifer recharge areas. The size of hydrologically active areas varies, being a function of land use and management, slope, infiltration rates and soil moisture content.

Developed urban areas, because of their highly impervious, connected surface area and the extensive alteration of their natural hydrology, have large hydrologically active areas. Many developing urban areas are either within a hydrologically active area or tributary to one, and thus special attention must be given to these areas to insure the control of sediment and associated pollutants.

In agricultural areas, soil conservation techniques reduce erosion, and resulting sediment and associated contaminants, from hydrologically active areas.

In some timber and pulpwood harvesting operations, it is necessary to protect the most hydrologically active areas in order to avoid water quality problems. A common practice has been the maintenance of buffer strips along open water courses. Location of the most hydrologically active areas is important for siting solid and liquid waste disposal facilities. This is pertinent not only in consideration of surface water delivery, but also groundwater contamination. Similar concerns are important for locating disposal areas for mine tailings.

The minimum estimated annual costs to achieve recommended phosphorus target loads are presented in the following table. *These estimated costs are in addition to those of established Water Quality Agreement programs and are based only on economic estimates.* It is noted that population growth and other events will require continual adjustments of programs in order to adhere to the target loads.

In addition to the foregoing conclusions, the International Reference Group on Great Lakes Pollution from Land Use Activities concludes the following as to:

> *"the adequacy of existing programs and control measures"*

While broad legislative authority, which may be construed as covering pollution from diffuse sources, exists at state, provincial and local levels, specific legislation or rules may be necessary in the implementation of remedial programs. Some states have already enacted such specific legislation, while others are currently attempting enactment. In the U.S., the 1972 and 1977 amendments to the Federal Water Pollution Control Program provide the mechanism for the planning and fiscal aspects of nonpoint source pollution control. The 1977 amendments also improve the sediment control programs by providing assistance on a priority water quality related basis.

Federal pesticide control legislation in both countries is deemed to be adequate at present.

Federal legislation and control programs in development appear to be adequate at present to reduce and eventually eliminate discharges of toxic substances.

The legislation and/or control programs and measures concerning landfills, deep well disposal and forestry operations, where boundary waters are affected, are considered adequate at present. These land uses are not deemed to contribute signficantly to the pollution of the Great Lakes. However, local problems related to these activities can occur.

Atmospheric inputs constitute a substantial portion of the total loads of phosphorus and other pollutants directly to the lakes. The quantities of these pollutants being deposited on land, and subsequently reaching the lakes as a result of migration over or through the soil, are, however, only partially known at present.

ESTIMATED MINIMUM ANNUAL COSTS TO ACHIEVE PHOSPHORUS TARGET LOADS

Lake	millions of dollars						
	United States			Canada			
	Point Source	Urban Nonpoint Source	Rural Nonpoint Source	Point Source	Urban Nonpoint Source	Rural Nonpoint Source	Total Costs
southern Huron	1.5	7.5	2.5	1.0	0.5	1.5	14.5
Erie	9.0	34.0	12.5	1.5	2.5	10.0	69.5
Ontario[a]	2.5	7.5*	Minimal	5.0	6.5*	Minimal	21.5
TOTAL	13.0	48.0	15.0	7.5	10.5	11.5	105.5

[a] Conditional on Lake Erie target load being met, in order to reduce the annual Niagara River phosphorus input by 1200 metric tons.

* Value revised from first printing of this report.

The level of awareness among Great Lakes Basin residents, with respect to pollution from nonpoint sources, is inadequate at present. Control of nonpoint sources will require all Basin residents to become involved in reducing the generation of pollutants, through conservation practices. Improved planning and technical assistance are prerequisites to long-term solutions of land drainage problems.

A better definition of pollution in the Great Lakes is required. PLUARG found that traditional yardsticks, such as water quality objectives or standards, were insufficient for adequately evaluating the impact of diffuse or nonpoint sources to the Great Lakes. These sources may not in themselves produce violations of water quality objectives. However, in combination with other sources, they can contribute to the overall pollution of the Great Lakes.

The public consultation panels were concerned that additional layers of government not be introduced and that present governments should better define their objectives regarding pollution control. A renewed commitment and better definition of roles of agencies are required in order to maximize the utility of existing measures.

A wealth of data currently exists in various institutions throughout the Basin. Increased efforts must be made to assess and analyze these data. Due to its dispersal, its availability and potential usefulness is restricted. Current data storage and retrieval mechanisms have been found to be inadequate and require substantial improvement to insure efficient access.

Past Great Lakes research efforts have, for the most part, been piecemeal and without unifying objectives. Future studies on the Great Lakes would be of greater value if they were more holistic in nature. The relationship to the Great Lakes System should be considered as an integral part of new studies.

Greater emphasis must be placed on the study of the nearshore areas and coastal zones of the Great Lakes. Few comprehensive studies have been completed in these areas; yet, they are most affected by man's activities.

PLUARG has contributed new information on the biological availability of phosphorus, but has not been able to satisfactorily resolve all questions concerning availability of phosphorus, heavy metals and toxic organic substances, and their transmission from different land use activities to the Great Lakes.

Immediate attention must be given to determining whether the Great Lakes ecosystem will maintain desirable characteristics of diversity, resilience and stability under man-made perturbations. Knowledge of the capacity of the Great Lakes System to handle waste loads is required so that tolerable loads can be prescribed.

The most hydrologically active areas in the Great Lakes Basin must be more clearly identified. Future protection of such areas must be provided for through proper land use management, and remedial measures applicable to such areas must be developed.

The potential for Great Lakes pollution from the disposal of radioactive and other toxic wastes is of concern. Unless safe, permanent disposal systems are found for the increasing quantities of exotic and radioactive wastes being produced, this may constitute a major future problem in the Great Lakes Basin.

RECOMMENDATIONS

Development of Management Plans

PLUARG RECOMMENDS MANAGEMENT PLANS, STRESSING SITE-SPECIFIC APPROACHES, TO REDUCE LOADINGS OF PHOSPHORUS, SEDIMENTS AND TOXIC SUBSTANCES DERIVED FROM AGRICULTURAL AND URBAN AREAS, BE PREPARED BY THE APPROPRIATE JURISDICTIONS WITHIN ONE YEAR AFTER THE INTERNATIONAL JOINT COMMISSION'S RECOMMENDATIONS ARE TRANSMITTED TO THE GOVERNMENTS. PLUARG FURTHER RECOMMENDS THAT A MUTUALLY SATISFACTORY SCHEDULE FOR THE REDUCTION OF NONPOINT SOURCE LOADINGS BE ANNEXED TO THE REVISED GREAT LAKES WATER QUALITY AGREEMENT.

MANAGEMENT PLANS SHOULD INCLUDE:

(i) A TIMETABLE INDICATING PROGRAM PRIORITIES FOR THE IMPLEMENTATION OF THE RECOMMENDATIONS;

(ii) AGENCIES RESPONSIBLE FOR THE ULTIMATE IMPLEMENTATION OF PROGRAMS DESIGNED TO SATISFY THE RECOMMENDATIONS;

(iii) FORMAL ARRANGEMENTS THAT HAVE BEEN MADE TO INSURE INTER- AND INTRA-GOVERNMENTAL COOPERATION;

(iv) THE PROGRAMS THROUGH WHICH THE RECOMMENDATIONS WILL BE IMPLEMENTED BY FEDERAL, STATE AND PROVINCIAL LEVELS OF GOVERNMENT;

(v) SOURCES OF FUNDING;

(vi) ESTIMATED REDUCTION IN LOADING TO BE ACHIEVED;

(vii) ESTIMATED COSTS OF THESE REDUCTIONS; AND

(viii) PROVISION FOR PUBLIC REVIEW.

PLANNING

PLUARG RECOMMENDS THAT GOVERNMENTS MAKE BETTER USE OF EXISTING PLANNING MECHANISMS IN IMPLEMENTING NONPOINT SOURCE CONTROL PROGRAMS BY:

(i) INSURING THAT DEVELOPMENTS AFFECTING LAND ARE PLANNED TO MINIMIZE THE INPUTS OF POLLUTANTS TO THE GREAT LAKES; AND

(ii) INSURING THAT PLANNERS ARE AWARE OF AND CONSIDER PLUARG FINDINGS IN THE DEVELOPMENT AND REVIEW OF LAND USE PLANS.

FISCAL ARRANGEMENTS

PLUARG RECOMMENDS THAT A REVIEW OF FISCAL ARRANGEMENTS BE UNDERTAKEN TO DETERMINE WHETHER PRESENT ARRANGEMENTS ARE ADEQUATE TO INSURE EFFECTIVE AND RAPID IMPLEMENTATION OF PROGRAMS TO CONTROL NONPOINT POLLUTION. SUCH A REVIEW SHOULD INCLUDE:

(i) DETERMINATION OF THE AVAILABILITY OF GRANTS, LOANS, TAX INCENTIVES, COST-SHARING ARRANGEMENTS AND OTHER FISCAL MEASURES;

(i) DETERMINATION OF WHETHER OR NOT THE TERMS OF FINANCIAL ASSISTANCE PROGRAMS ARE SUFFICIENT TO ENCOURAGE WIDESPREAD PARTICIPATION; AND

(iii) DETERMINATION OF THE EXTENT TO WHICH VARIOUS FINANCIAL ASSISTANCE PROGRAMS ARE CONDITIONAL UPON THE IMPLEMENTATION OF NONPOINT SOURCE REMEDIAL MEASURES.

INFORMATION, EDUCATION AND TECHNICAL ASSISTANCE

PLUARG RECOMMENDS THAT GREATER EMPHASIS BE GIVEN TO THE DEVELOPMENT AND IMPLEMENTATION OF INFORMATION, EDUCATION AND TECHNICAL ASSISTANCE PROGRAMS TO MEET THE GOALS OF THE GREAT LAKES WATER QUALITY AGREEMENT. THIS EMPHASIS SHOULD INCLUDE:

(i) DEVELOPMENT OF BROAD PROGRAMS, THROUGH SCHOOL SYSTEMS, THE MEDIA AND OTHER PUBLIC INFORMATION SOURCES, DESCRIBING THE ORIGINS AND IMPACTS OF POLLUTANTS ON THE GREAT LAKES AND ALTERNATIVE STRATEGIES THAT SHOULD BE FOLLOWED BY THE PUBLIC AND GOVERNMENT AGENCIES TO PREVENT WATER QUALITY DEGRADATION;

(ii) INITIATION OF MORE SPECIFIC PROGRAMS TO IMPROVE THE AWARENESS OF IMPLEMENTORS AND THOSE WORKING IN AND FOR GOVERNMENT, EMPHASIZING THE NEED FOR THE FURTHER CONTROL AND ABATEMENT OF NONPOINT POLLUTION; AND

(iii) STRENGTHENING AND EXPANDING EXISTING TECHNICAL ASSISTANCE AND EXTENSION PROGRAMS DEALING WITH THE PROTECTION OF WATER QUALITY, INCLUDING RURAL AND URBAN LAND MANAGEMENT PRACTICES.

REGULATION

PLUARG RECOMMENDS:

(i) THAT THE ADEQUACY OF EXISTING AND PROPOSED LEGISLATION BE ASSESSED TO INSURE THERE IS A SUITABLE LEGAL BASIS FOR THE ENFORCEMENT OF NONPOINT POLLUTION REMEDIAL MEASURES IN THE EVENT THAT VOLUNTARY APPROACHES ARE INEFFECTIVE; AND

(ii) THAT GREATER EMPHASIS BE PLACED ON THE PREVENTIVE ASPECTS OF LAWS AND REGULATIONS DIRECTED TOWARD CONTROL OF NONPOINT POLLUTION.

Implementation of Management Plans

REGIONAL PRIORITIES

PLUARG RECOMMENDS THAT REGIONAL PRIORITIES FOR IMPLEMENTING MANAGEMENT PLANS DEVELOPED BY THE JURISDICTIONS BE BASED UPON:

(i) THE WATER QUALITY CONDITIONS WITHIN EACH LAKE;

(ii) THE POTENTIAL CONTRIBUTING AREAS (PCA) IDENTIFIED BY PLUARG; AND

(iii) THE MOST HYDROLOGICALLY ACTIVE AREAS (HAA) FOUND WITHIN THESE POTENTIAL CONTRIBUTING AREAS.

CONTROL OF PHOSPHORUS

PLUARG RECOMMENDS THAT PHOSPHORUS LOADS TO THE GREAT LAKES BE REDUCED BY IMPLEMENTATION OF POINT AND NONPOINT PROGRAMS NECESSARY TO ACHIEVE THE INDIVIDUAL LAKE TARGET LOADS SPECIFIED BY PLUARG.

IT IS FURTHER RECOMMENDED THAT ADDITIONAL REDUCTIONS OF PHOSPHORUS TO PORTIONS OF EACH OF THE FIVE GREAT LAKES BE IMPLEMENTED TO REDUCE LOCAL NEARSHORE WATER QUALITY PROBLEMS AND TO PREVENT FUTURE DEGRADATION.

CONTROL OF SEDIMENT

PLUARG RECOMMENDS THAT EROSION AND SEDIMENT CONTROL PROGRAMS BE IMPROVED AND EXPANDED TO REDUCE THE MOVEMENT OF FINE-GRAINED SEDIMENT FROM LAND SURFACES TO THE GREAT LAKES SYSTEM.

CONTROL OF TOXIC SUBSTANCES

PLUARG RECOMMENDS THE FOLLOWING ACTIONS BE TAKEN TO REDUCE INPUTS OF TOXIC SUBSTANCES TO THE GREAT LAKES:

(i) CONTROL OF TOXIC SUBSTANCES AT THEIR SOURCE;

(ii) CLOSER COOPERATION OF BOTH COUNTRIES IN THE IMPLEMENTATION OF TOXIC SUBSTANCES CONTROL LEGISLATION AND PROGRAMS;

(iii) PROPER MANAGEMENT AND ULTIMATE DISPOSAL OF TOXIC SUBSTANCES PRESENTLY IN USE;

(iv) IDENTIFICATION AND MONITORING OF HISTORIC AND EXISTING SOLID WASTE DISPOSAL SITES WHERE THERE IS AN EXISTING OR POTENTIAL DISCHARGE OF TOXIC SUBSTANCES, AND THE IMPLEMENTATION OF CONTROL PROGRAMS AT THOSE SITES AS NEEDED; AND

(v) JOINT EXPANSION OF EFFORTS TO ASSESS THE CUMULATIVE AND SYNERGISTIC EFFECTS OF INCREASING LEVELS OF THESE CONTAMINANTS ON ENVIRONMENTAL HEALTH AND THE RAPID TRANSLATION OF THESE ASSESSMENTS INTO REFINED WATER QUALITY OBJECTIVES, OTHER ENVIRONMENTAL OBJECTIVES AND, WHEREVER POSSIBLE, TOLERABLE LOADS. FOR CERTAIN TOXIC SUBSTANCES, A ZERO LOAD WILL BE NECESSARY.

CONTROL OF MICROORGANISMS

PLUARG RECOMMENDS THAT EPIDEMIOLOGICAL EVIDENCE BE EVALUATED TO ESTABLISH APPLICABLE MICROBIOLOGICAL CRITERIA FOR BODY CONTACT RECREATIONAL USE OF WATERS RECEIVING RUNOFF FROM URBAN AND AGRICULTURAL SOURCES.

AGRICULTURAL LAND USE

PLUARG RECOMMENDS THAT AGENCIES WHICH ASSIST FARMERS ADOPT A GENERAL PROGRAM TO HELP FARMERS DEVELOP AND IMPLEMENT WATER QUALITY PLANS.

THIS PROGRAM SHOULD INCLUDE:

(i) A SINGLE PLAN DEVELOPED FOR EACH FARM, WHERE NEEDED;

(ii) CONSIDERATION OF ALL POTENTIAL NONPOINT SOURCE PROBLEMS RELATED TO AGRICULTURAL PRACTICES, INCLUDING EROSION, FERTILIZER AND PESTICIDE USE, LIVESTOCK OPERATIONS AND DRAINAGE; AND

(iii) A PLAN COMMENSURATE WITH THE FARMERS' ABILITY TO SUSTAIN AN ECONOMICALLY VIABLE OPERATION.

URBAN LAND USE

PLUARG RECOMMENDS THE DEVELOPMENT OF MANAGEMENT PLANS FOR CONTROLLING URBAN STORMWATER RUNOFF. THESE PLANS SHOULD INCLUDE:

(i) PROPER DESIGN OF URBAN STORMWATER SYSTEMS IN DEVELOPING AREAS SUCH THAT THE NATURAL STREAM FLOW CHARACTERISTICS ARE MAINTAINED; AND

(ii) PROVISION FOR SEDIMENT CONTROL IN DEVELOPING AREAS, AND CONTROL OF TOXIC SUBSTANCES FROM COMMERCIAL AND INDUSTRIAL AREAS.

WETLANDS AND FARMLANDS

PLUARG RECOMMENDS THE PRESERVATION OF WETLANDS, AND THE RETENTION FOR AGRICULTURAL PURPOSES OF THOSE FARMLANDS WHICH HAVE THE LEAST NATURAL LIMITATIONS FOR THIS USE.

LOCAL PROBLEM AREAS

PLUARG RECOMMENDS THAT THE INTERNATIONAL JOINT COMMISSION, THROUGH THE GREAT LAKES REGIONAL OFFICE, INSURE THAT LOCAL LEVELS OF GOVERNMENT ARE MADE AWARE OF THE AVAILABILITY OF PLUARG FINDINGS, ESPECIALLY AS THEY RELATE TO LOCAL AREA PROBLEMS, TO ASSIST THEM IN DEVELOPING AND IMPLEMENTING NONPOINT SOURCE MANAGEMENT PROGRAMS.

Review and Evaluation of Management Plan Implementation

REVIEW OF IMPLEMENTATION

PLUARG RECOMMENDS:

(i) THE INTERNATIONAL JOINT COMMISSION INSURE REGULAR REVIEW OF PROGRAMS UNDER-

TAKEN FOR THE IMPLEMENTATION OF RECOMMENDATIONS ARISING FROM THIS REFERENCE; AND

(ii) THAT NONPOINT SOURCE INTERESTS BE REPRESENTED DURING THESE REVIEWS.

SURVEILLANCE

PLUARG RECOMMENDS THAT TRIBUTARY MONITORING PROGRAMS BE EXPANDED TO IMPROVE THE ACCURACY OF LOADING ESTIMATES OF SEDIMENT, PHOSPHORUS, LEAD AND PCBs. SAMPLING PROGRAMS:

(i) SHOULD BE BASED ON STREAM RESPONSE CHARACTERISTICS, WITH INTENSIVE SAMPLING OF RUNOFF EVENTS, WHERE NECESSARY; AND

(ii) SHOULD BE EXPANDED TO INCLUDE TOXIC ORGANIC COMPOUNDS, TOXIC METALS AND OTHER PARAMETERS AS MAY BE DEFINED IN THE FUTURE.

FURTHER, THE ROLE OF ATMOSPHERIC INPUTS SHOULD BE CONSIDERED IN THE EVALUATION OF GREAT LAKES POLLUTION, WITH SPECIAL CONSIDERATION GIVEN TO DETERMINATION OF THE SOURCES OF MAJOR ATMOSPHERIC POLLUTANTS.

EFFORTS SHOULD BE MADE TO IMPROVE THE COORDINATION BETWEEN DATA COLLECTION AND DATA USER GROUPS, AND AGREEMENTS ESTABLISHED REGARDING DATA COLLECTION STANDARDS AND ACCESSIBILITY.

PLUARG FURTHER RECOMMENDS THAT THE ADEQUACY OF U.S. GREAT LAKES NEARSHORE AND OFFSHORE WATER SURVEILLANCE EFFORTS BE EXAMINED.

Role of the Public

PLUARG RECOMMENDS THAT THE INTERNATIONAL JOINT COMMISSION ESTABLISH A COMPREHENSIVE PUBLIC PARTICIPATION PROGRAM AT THE OUTSET OF FUTURE REFERENCES.

INTRODUCTION

BACKGROUND

Studies requested by the International Joint Commission concerning water quality in Lakes Erie and Ontario (i.e., lower Great Lakes), completed and submitted to the Commission in 1969, demonstrated that diffuse land drainage sources of pollutants were not only significant but also extremely variable, and therefore difficult to measure. Subsequent improvements in wastewater treatment for point sources of pollution magnified the relative importance of the land drainage sources of many pollutants, necessitating a clearer definition of the impact of land use activities, practices and programs on water quality in the Great Lakes. For this reason, the governments of Canada and the United States, on signing the 1972 Great Lakes Water Quality Agreement, requested the International Joint Commission to investigate pollution of the Great Lakes system from agriculture, forestry and other land use activities[1].

In November 1972, the International Joint Commission appointed an International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG), composed of nine Canadian and nine United States representatives, to conduct the study under the Great Lakes Water Quality Board. The Terms of Reference for this study are presented in Appendix 1.

The purpose of this study was:

(a) to determine and evaluate the causes, extent and locality of pollution from land use activities;

(b) to gain an understanding of the relative importance of various land uses in terms of their diffuse pollutant loads to the Great Lakes;

(c) to examine the effects of the diffuse pollutant loads on Great Lakes water quality; and

(d) to determine the most practicable remedial measures for decreasing the diffuse pollutant loads to an acceptable level and the estimated costs of these measures.

Detailed plans for this study were developed in early 1973, and assignments made to both Canadian and United States agencies and qualified individuals to commence studies on specific tasks and programs within the PLUARG study. The detailed plans were subsequently updated in 1976.

The PLUARG study considered diffuse (i.e., nonpoint) sources of pollutants, including surface runoff from all land uses and groundwater inflows from the entire Great Lakes Basin. The atmospheric loads were also evaluated to determine their magnitude, relative to the total pollutant load to the Great Lakes. The terms 'diffuse' and 'nonpoint' are used interchangeably in this report. Pollutants from diffuse sources are those polluting materials conveyed to the Great Lakes by natural runoff to tributaries, ditches, groundwater, storm sewers, or as combined sewer overflows. In comparison, point sources define those sources of pollutants which are "pipeline" in nature, such as municipal sewage treatment plant and industrial wastewater discharges, regardless of whether they were discharged directly to the Great Lakes or to tributaries draining to the lakes.

During the PLUARG Study, supporting technical papers and reports of public consultation panels have been developed. Detailed reports are listed in Appendix 2 on: (1) pilot watershed studies; (2) tributary and shoreline loadings; (3) the assessment of problems, management programs and research needs concerning the effects of land use activities on Great Lakes water quality; and (4) the legislative and institutional frameworks of the Great Lakes Basin jurisdictions.

AREA OF STUDY

All five Great Lakes, their connecting channels and the entire Great Lakes land drainage basin, as well as drainage to the international section of the St. Lawrence River, were considered in this study. Lake Michigan, although entirely within U.S. borders, was considered in the PLUARG study because of its drainage to, and water quality effects on, Lake Huron. Figure 1 illustrates the study area, as well as the percentages of each major land use in the five Great Lakes basins[2-5]. More detailed information on land use in the Great Lakes Basin is presented in Table 1. Definitions of specific land uses are presented in the appropriate U.S. and Canadian land use technical reports[4,5]. As indicated in Table 1, 61 percent of the Basin consists of forested/wooded land. Agricultural land, including cropland and pasture, makes up 24 percent of the Basin area. Urban land, including residential, commercial and industrial areas, makes up about three percent of the Basin. The remaining 12 percent of the Basin area consists of recreational lands, wetlands, transportation corridors, waste disposal sites, extractive industries and idle lands.

Major jurisdictions involved in the Great Lakes Basin are the federal governments of Canada and the United States of America, the province of Ontario and the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin[3,4]. As of 1975, there were approximately 6,900,000 and 29,660,000 residents in the Canadian and United States portions of the Basin, respectively. Figure 2 indicates the major political divisions within the Great Lakes Basin.

APPROACH TO STUDY

The following major activities were conducted during the course of the study (the technical reports produced as a result of this study are listed in Appendix 3):

(a) In order to allow PLUARG full benefit of past and present programs and activities pertinent to the overall goals of the study, an assessment of the current state of the art was carried out[6], including an assessment of problems, management programs and effects of present land use activities, from the best information available, on water quality in the Great Lakes, the legislative and institutional frame-

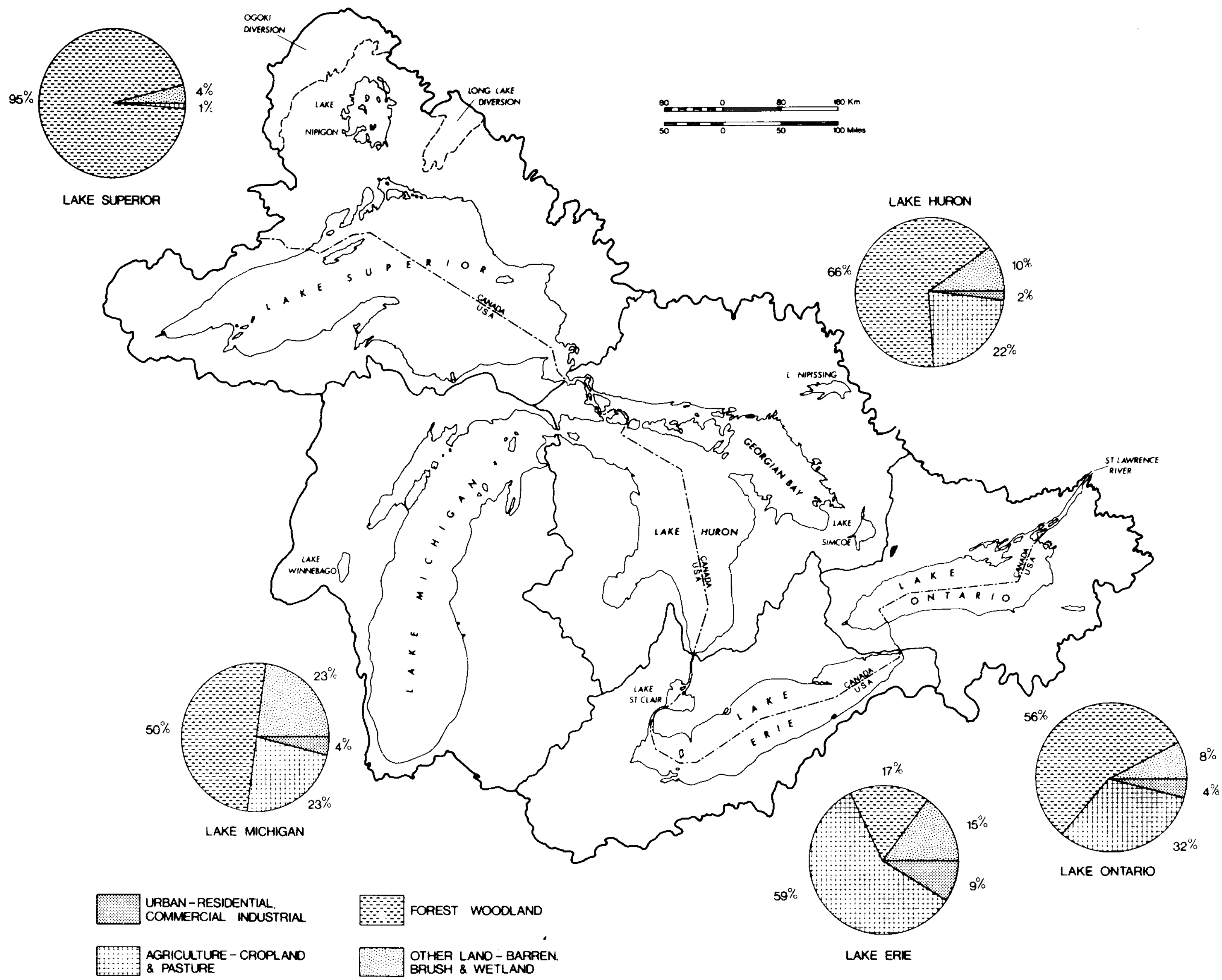


FIGURE 1: MAJOR LAND USES FOR EACH LAKE BASIN (Percent)

TABLE 1

MAJOR LAND USES IN THE GREAT LAKES BASIN[a,b]

	1,000 hectares						
	URBAN LAND USE		RURAL LAND USE				
	DEVELOPED LAND		AGRICULTURAL LAND		NON-AGRICULTURAL LAND		
LAKE BASIN	RESIDENTIAL	COMMERCIAL/ INDUSTRIAL	CROPLAND	PASTURE	FOREST/ WOODLAND	BARREN/BRUSH/ WETLAND	TOTAL LAND
LAKE SUPERIOR							
U.S.	7.1	1.5	25.3	114.5	3,753.6	497.9	4,399.9
Canada	6.0	3.7	2.2	51.1	9,342.6	53.1	9,458.7
TOTAL	13.1	5.2	27.5	165.6	13,096.2	551.0	13,858.6
LAKE MICHIGAN							
U.S.	379.4	28.1	1,453.7	1,295.6	5,842.8	2,741.2	11,740.8
Canada	0	0	0	0	0	0	0
TOTAL	379.4	28.1	1,453.7	1,295.6	5,842.8	2,741.2	11,740.8
LAKE HURON							
U.S.	140.4	5.0	690.1	387.1	2,026.9	942.3	4,191.8
Canada	79.2	9.7	511.9	1,303.9	6,444.0	345.8	8,694.5
TOTAL	219.6	14.7	1,202.0	1,691.0	8,470.9	1,288.1	12,886.3
LAKE ERIE							
U.S.	553.1	79.7	1,923.3	882.3	1,005.7	1,114.8	5,558.9
Canada	65.9	23.3	1,182.2	670.0	342.2	34.4	2,318.0
TOTAL	619.0	103.0	3,105.5	1,552.3	1,347.9	1,149.2	7,876.9
LAKE ONTARIO							
U.S.	155.3	6.7	407.9	526.2	2,942.2	538.7	4,577.0
Canada	110.2	56.4	387.7	1,056.5	1,254.6	84.8	2,950.2
TOTAL	265.5	63.1	795.6	1,582.7	4,196.8	623.5	7,527.2
GREAT LAKES BASIN							
United States	1,235.4	121.0	4,500.3	3,205.7	15,571.2	5,834.9	30,468.5
Canada	261.3	93.1	2,084.0	3,081.5	17,383.4	518.1	23,421.4
TOTAL	1,496.7	214.1	6,584.3	6,287.2	32,954.6	6,353.0	53,889.9

a) definitions and manner of determination of specific land uses differ between the U.S. and Canadian portions of the Basin[4,5].
b) the U.S. data differs from those reported in earlier PLUARG studies[2,3], reflecting subsequent re-evaluation of the U.S. data base.

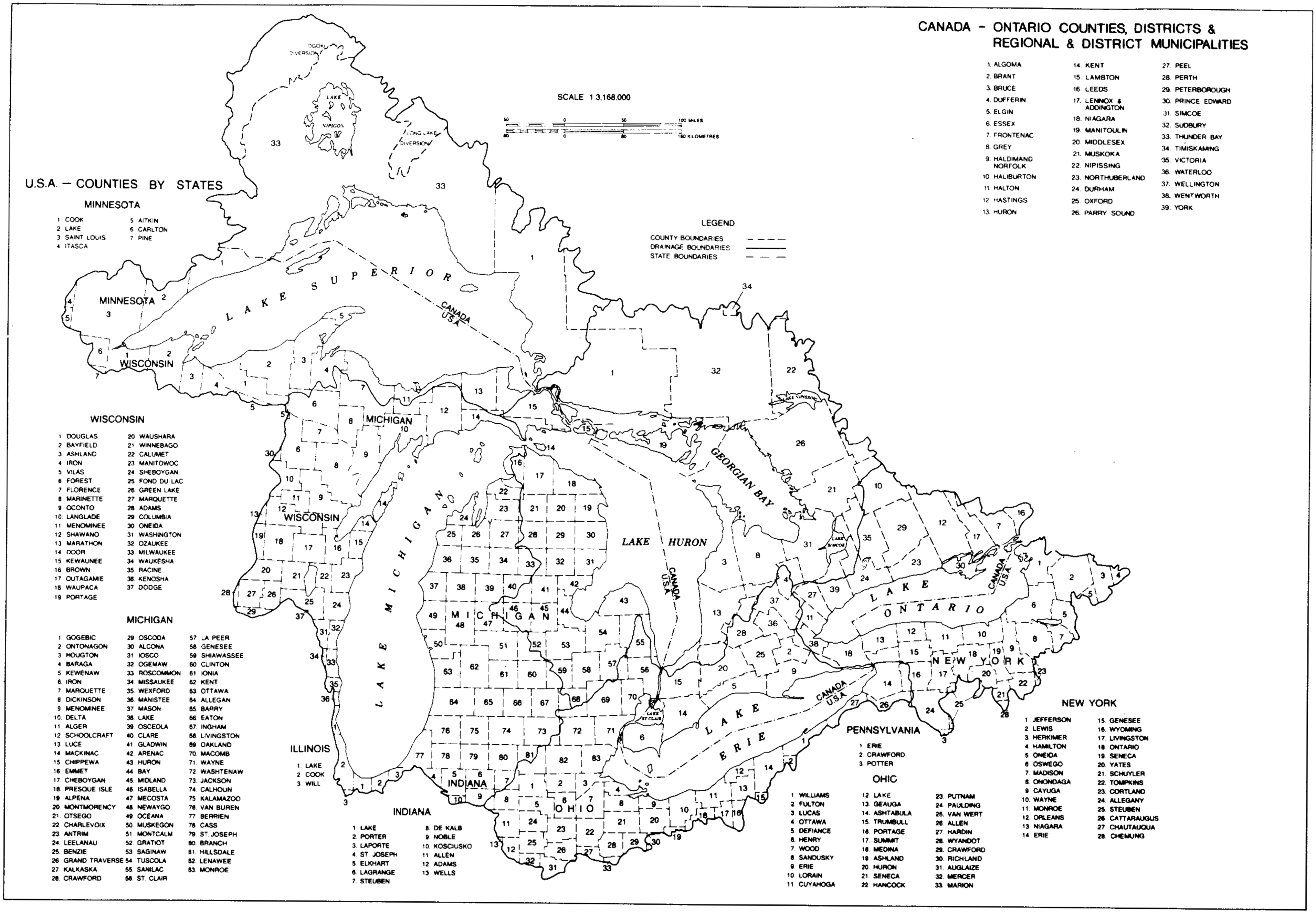


FIGURE 2: GREAT LAKES BASIN DRAINAGE AND POLITICAL DIVISIONS

work[7,8], existing and alternative remedial measures[9], and the probable costs of remedial measures applied to problem areas affecting Great Lakes water quality[10].

(b) In order to provide background information on characteristic Basin properties, an inventory of major and specialized land uses and land use practices in the Great Lakes Basin was conducted, with emphasis on certain trends and projections to 1980 (and to 2020, where appropriate)[2-4]. This inventory included information on Great Lakes Basin geology, soils, mineral resources, climate, hydrology, vegetation, wildlife, waste disposal operations, high density nonsewered residential areas, recreation lands, economic and demographic characteristics, and use of pesticides, commercial fertilizers, agricultural manures and highway salts. In addition, trends in land use patterns and practices were assessed and projections of economic and demographic conditions into future years were made. Information from this inventory was also used to gain a better understanding of the combination of factors that affect pollution from land drainage sources.

In order to evaluate the extent, causes and localities of pollution from land drainage, several areas in the Basin were selected for detailed studies. These areas (pilot watersheds) were selected to represent the full range of Basin land use activities and to permit the extrapolation of results to the entire Great Lakes Basin[11]. These pilot watersheds, illustrated in Figure 3, included:

— *Genesee River watershed*[12]. This pilot watershed was selected to study the effect of diverse land uses on water quality. The watershed of the Genesee contains significant amounts of urban, agricultural and forested land. The investigation focused on identifying the combination of factors that affect the movement and transport of phosphorus, suspended solids and chloride from the watershed to the Great Lakes.

— *Maumee River watershed*[13]. The focus of the investigations on the Maumee River was the effect of agricultural practices on water quality. The Maumee River, the largest tributary to Lake Erie, has more than 90 percent of its land area in agricultural use. Investigations in this watershed concentrated on the generation of sediment and nutrients from intensely cultivated cropland under prevailing management practices at different times of the year, and a comparison of these losses with the yields of these same materials downstream.

— *Menomonee River watershed*[14]. The impact of urban land use on water quality was the focus of study in the Menomonee watershed, which discharges to Lake Michigan at Milwaukee, Wisconsin. This highly urbanized watershed contains land uses ranging from intensely developed commercial-industrial complexes to low-to-medium density residential areas. It also contains land in the process of conversion from rural to urban land uses. The Menomonee study concentrated on assessing the effects of a full range of urban uses on Great Lakes water quality.

— *Felton-Herron and Mill Creek sub-watersheds*[15]. The Felton-Herron and Mill Creek subwatersheds served as the focus for studying the effects of intense land uses on water quality. The Felton-Herron sub-watershed, a tributary of the Grand River (U.S.), discharges into eastern Lake Michigan and was studied as an example of a site subject to wastewater spray irrigation. The Mill Creek sub-watershed, also a Grand River tributary, is located within the "Peach Ridge" fruit farming area in southwest lower Michigan and served as an example of an orchard land use. It emphasized the effects of intensive use of insecticides, herbicides and fertilizers under different practices within a single land use on Great Lakes water quality.

— *Saugeen River watershed*[16]. Since a large part of the Saugeen watershed draining into Lake Huron is in agriculture use, it also served as a focus for the study of the effects of agricultural land use on water quality. Large areas of this watershed are also wooded. Phosphorus, nitrogen, chloride and metal loads to the Great Lakes were extensively studied in this watershed.

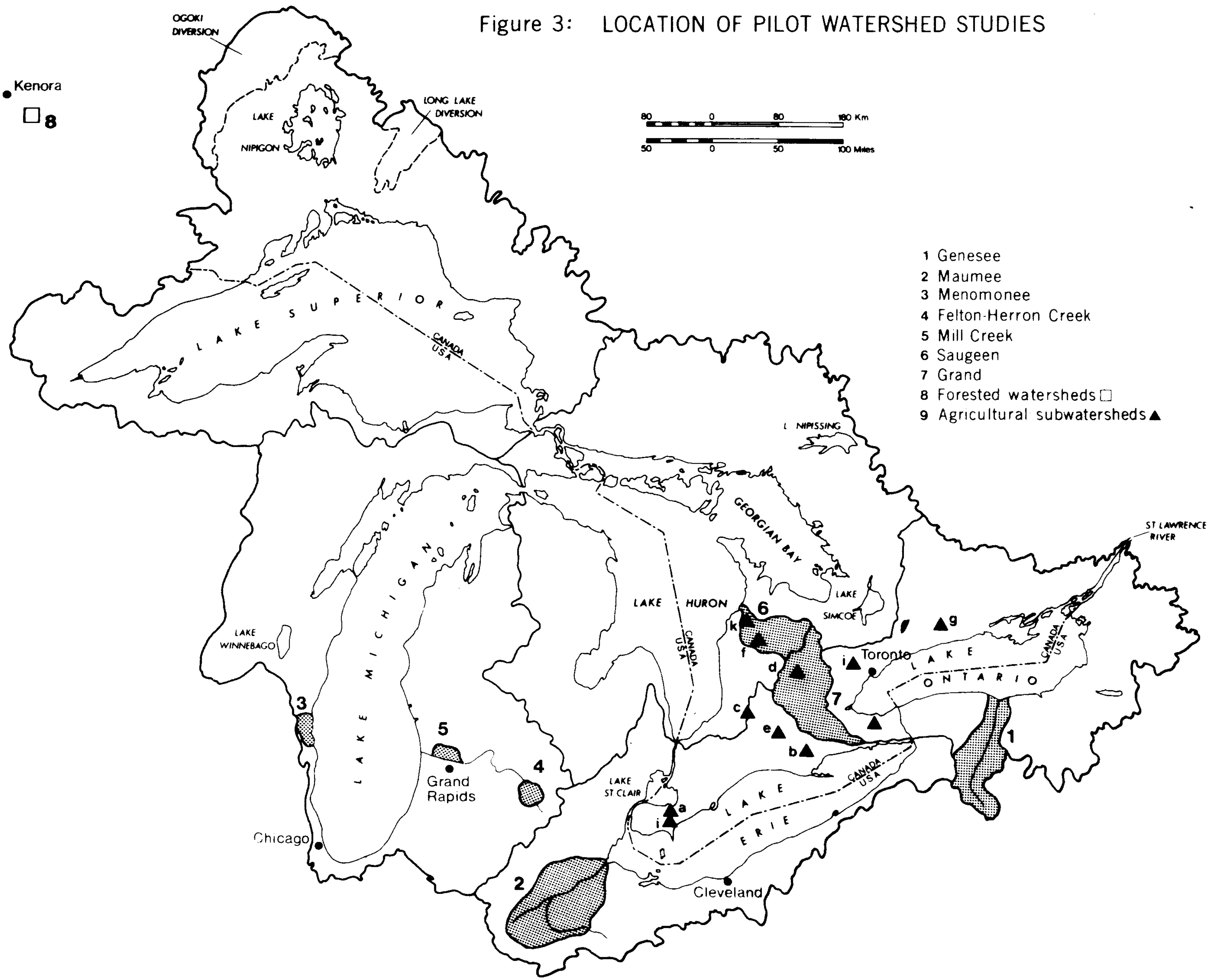
— *Grand River watershed*[17]. The Grand River watershed represents a combination of agricultural and urban land uses and is the largest Canadian watershed draining into Lake Erie. Study of the Grand River watershed focused on the progressive pollution from the headwaters to the mouth and on the land-related factors affecting this pollution.

— *Forested watersheds*[18]. Intense forested land use studies were undertaken in 12 small watersheds within the headwaters of the English and Winnipeg River systems near Kenora, Ontario. Although not within the Great Lakes Basin, the study area is representative of much of the forested watershed located in the northwestern part of the Great Lakes Basin. The study focused on the effects of clearcutting and scarification on water quality.

— *Ontario agricultural watersheds*[19,20]. Eleven small agricultural sub-watersheds, representing major agricultural regions in southern Ontario, were selected for special study. These watersheds represented a wide range of crop-covers and land characteristics, with soils varying from low to high clay content. Several sites served as the focus of investigations on the sources, nature and enrichment of sediments and on the effects of soils, crops, livestock, surface hydrology and groundwater movement on pollution from agricultural areas.

— *Streambank erosion studies*[21-23]. In addition to the pilot watershed studies, representative areas were selected throughout the Basin for the char-

Figure 3: LOCATION OF PILOT WATERSHED STUDIES



acterization and quantification of sediment and nutrients contributed to the Great Lakes as a result of riverbank erosion.

(d) The degree of impairment to Great Lakes water quality resulting from land-derived sources of pollutants was assessed. This portion of the PLUARG study included an assessment of the quantity and quality of Great Lakes shoreline erosion and loads to the Great Lakes[24-26]; the identification, evaluation and quantification of loadings of chemical and biological parameters from Great Lakes tributaries[27-29]; an evaluation of the extent, dispersion and effects of tributary, direct and atmospheric contributions[30] of land-derived pollutants and the resultant lake conditions[31]. The evaluation of impairment to Great Lakes water quality from land drainage included an assessment of pollutants in sediments, fish and other aquatic resources.

(e) In order to develop more workable and publicly-acceptable courses of action, an extensive effort for citizen participation was undertaken[32,33]. In both Canada and the United States, surveys of the agricultural community were made to identify perceptions of the farming community relating to water quality issues[34,35].

(f) Considerable emphasis was placed in the PLUARG study on integrating the results of all these above activities to gain an overall perspective on the relative importance of land-derived pollutants to the Great Lakes. This included the systematic determination of the location of problem areas, the reasons they were problems and how they could be controlled most cost-effectively. An overview model[85] was developed and used to integrate the large amount of data on land-use-related pollutants and to provide a mechanism to evaluate the potential impact and costs of strategies to control nonpoint sources, as a basis for management decisions on needed and effective control programs (Chapters 2 and 3). A comparison of the effectiveness and costs of point versus nonpoint source pollutant control measures was also made. Joint U.S. and Canadian summary reports (Appendix 3) were prepared on the major PLUARG activities. The relationships of the various PLUARG activities are presented in Figure 4.

PUBLIC CONSULTATION PANELS

PLUARG recognized the desirability and need for citizen input to the program to aid in identifying public concerns and practicable management strategies. Nine public consultation panels in the United States and eight in Ontario were established in the autumn of 1977. The panels met formally four times to discuss and make recommendations on the environmental, social and economic aspects of the PLUARG study. Most panels also expressed their goals for the Great Lakes. In early 1978, the panels received and commented upon a draft of the PLUARG final report.

Individual panelists were selected to be as representative as possible of the public in the Great Lakes. Panel members included industrialists, small businessmen, farmers, representatives of labor, educators, environmentalists, representatives of women's groups, sportsmen's and fishermen's associations, wildlife federations and elected or appointed government officials.

Each panel submitted a report to PLUARG containing its views and recommendations of panel-identified problems and proposed solutions[32,33]. The views presented in the panel reports were considered in preparing this report and are part of the PLUARG technical report series (Appendix 3).

The public consultation panels, although the most significant mechanism for public input, were not the only forum. Numerous public meetings were also held throughout the Basin to gain additional public perspective concerning the PLUARG studies.

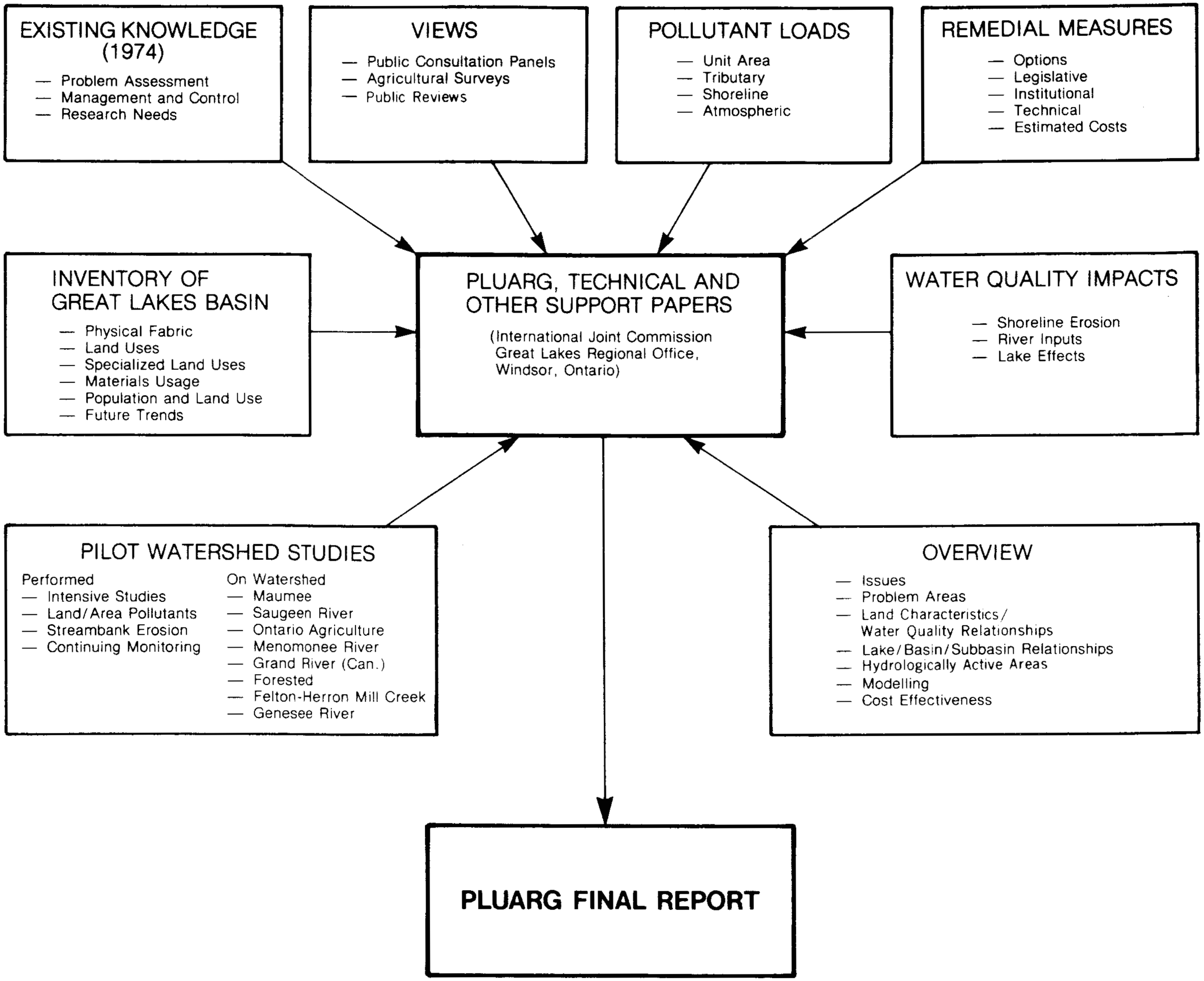


Figure 4 OVERVIEW OF PLUARG STUDY ACTIVITIES

1. POLLUTION FROM LAND USE ACTIVITIES

1.1 MATERIALS STUDIED AS POTENTIAL POLLUTANTS IN THE GREAT LAKES DERIVED FROM DIFFUSE SOURCES

Introduction

Historically, the Great Lakes have provided numerous benefits to the inhabitants of its basins. As a transportation corridor, the lakes provided easy access to the interior of the North American continent. Subsequently, the lakes came to serve a wide variety of uses, including power generation, fishing, recreation and both potable and industrial water supplies. Until recently, the Great Lakes represented an almost inexhaustible supply of high quality water. However, as human activity in the Great Lakes Basin intensified and became more complex, the lakes began to deteriorate in quality. It is now apparent that while the lakes are the focus of concern to Basin inhabitants, they are only part of a complex drainage system encompassing a land area more than twice the size of the lakes themselves. Within this area, the interaction of land use, soils, climate and topography has a major influence on the water quality of the lakes. The delivery of pollutants, either in surface runoff, groundwater flow or atmospheric deposition, is also important in influencing Great Lakes water quality.

In any discussion of pollution of the Great Lakes and of proposals for remedial measures, the goals and values perceived by the public for the lakes must be considered. During the PLUARG public consultation program, the panel members expressed their views concerning preferred uses of Great Lakes water and resources. These preferences, unranked, include: a contaminant-free source of drinking water; water suitable for swimming and recreational boating; water that is visually appealing (i.e., no turbidity or aquatic weeds); a viable commercial fishery; a viable sport fishery; restoration of "clean water" species of fish; preservation of wetlands and important farmlands; preservation of aquatic plant and animal communities and habitats; maintainance of shipping; and continued industrial use of lake water.

The PLUARG Terms of Reference (Appendix 1) call for an investigation of the relationships between land use activities and Great Lakes water quality. However, the thrust of the PLUARG study has been of wider scope, considering the effects of land use activities in the Great Lakes Basin on water quality, sediments and biota. The abatement of pollution should consider not only its effects on water quality, but also its effects on sediment, algae, zooplankton, fish, benthic organisms, wildlife and man. The ultimate effects of any pollutant on the Great Lakes involves a complex interaction of land, air, water and the organisms that live in these environments. Consequently, a study of pollutant effects which does not at least recognize these chemical, physical and biological components may produce a partial or even misleading understanding of such effects. This perspective of the "Great Lakes ecosystem" is also being advocated by the Research Advisory Board in their role as principal scientific advisor to the International Joint Commission on Great Lakes water quality[36].

A substance was considered a pollutant, in the context of Table 2, on the basis of two criteria: (1) demonstrable adverse effects on water quality or biota in either the nearshore zone or offshore waters of the Great Lakes[a]; and (2) the substance had to be derived largely from diffuse sources.

It should be mentioned that many of the substances identified as Great Lakes pollutants are required by many aquatic organisms for growth and reproduction. It is in excessive quantities, relative to these needs, that they present a real or potential hazard to the Great Lakes ecosystem.

Direct atmospheric and in-lake sediment sources are listed among the diffuse sources in Table 2. In the strictest sense, however, these inputs do not constitute land drainage sources. Substances are not produced or derived from the atmosphere. Rather, the atmosphere constitutes a transport mechanism to the Great Lakes for substances derived from point and nonpoint sources, both in and outside of the drainage basin. These sources may include industrial stack emissions, wind erosion and volatilization of contaminants from landfills and industrial operations. In general, the atmosphere delivers a larger percentage of the total load of many pollutants to the upper Great Lakes (i.e., Lakes Superior, Michigan and Huron) than to the lower Great Lakes, because of higher total loadings to the latter, due to the multitude of pollutant sources in the more populated and industrialized lower lakes basins. For example, direct atmospheric deposition onto the surface of Lake Superior accounts for 37 percent of the total phosphorus load (excluding shoreline erosion), while contributing only four percent of the Lake Erie load. Atmospheric deposition onto the land surface is subject to watershed runoff processes and is accounted for in the tributary loads to the lakes. In general, however, the estimation of atmospheric loadings of substances to the Great Lakes is in its infancy and the task of relating atmospheric loadings to specific sources requires considerable improvement in present capabilities.

The in-lake sediment sources refer to the pollutant load derived from lake bottom sediments. Sediments can bind phosphorus, heavy metals, pesticides and other substances. As such, lake sediments can be viewed as a sink for many pollutants. Under the appropriate chemical environment, however, some of these materials can be released to the waters and become potential water quality problems. Another potential problem is the chemical and bacterial methylation of some heavy metals in sediments (see chapter 1.3). The magnitude of recycling from this process is highly variable and its quantitative determination still in an early stage of development.

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[a] An 'adverse effect' was broadly interpreted to mean that the loading of a substance to the Great Lakes exceeded a United States-Canadian recognized or recommended target load, or that its concentration in Great Lakes waters exceeded an existing or proposed U.S. and/or Canadian water quality standard or objective. Also, substances in tissues of aquatic organisms exceeding existing or proposed U.S. and/or Canadian guidelines were included in these criteria. Materials exhibiting a potential for such effects were also included.

TABLE 2

GREAT LAKES WATER QUALITY POLLUTANTS

I. **Parameters for which a Great Lakes water quality problem has been identified**

POLLUTANT	PROBLEM		SOURCES				REMARKS
			DIFFUSE				
	Lakewide	Nearshore or Localized	Land Runoff	Atmosphere	In-Lake Sediments	POINT	
Phosphorus[1]	Yes	Yes	Yes	Yes	Yes[a]	Yes	[a] percentage unknown; not considered significant over annual cycle
Sediment[b,1]	No	Yes	Yes[c]	Negligible	Under some Conditions	Negligible	[b] may contribute to problems other than water quality (e.g., harbor dredging) [c] including streambank erosion
Bacteria of Public Health Concern	No	Yes	Minor[d]	No	No	Yes	[d] land runoff is a potential, but minor source; combined sewer overflows generally more significant
PCBs[1]	Yes	Yes	Yes	Yes	Yes	Yes	
Pesticides[1] (Past)	Yes[e]	Yes[e]	Yes	Yes	Yes	No	[e] some residual problems exist from past practices
Industrial Organics[1]	Yes	Yes	Yes	Yes	Yes	Yes	
Mercury[1]	Yes	Yes	Minor	Yes	Yes	Yes	
Lead[1]	Potential[f]	Potential[f]	Yes	Yes	Yes	Yes	[f] possible methylation to toxic form

II. **Parameters for which no Great Lakes water quality problem has been identified, but which may be a problem in inland surface waters or groundwaters**

POLLUTANT	Lakewide	Nearshore or Localized	Land Runoff	Atmosphere	In-Lake Sediments	POINT	REMARKS
Nitrogen	No	No[g]	Yes	Yes	Minor	Yes	[g] some inland groundwater problems
Chloride	No	No[h]	Yes	Negligible	No	Yes	[h] some local problems exist in nearshore areas due to point sources
Pesticides[1] (Present)	No	No	Yes	No	No	Yes	[i] new pesticides have been found in the environment; continued monitoring is required
Other Heavy Metals	Potential[f]	Potential[f]	Yes	Yes	Yes	Yes	
Asbestos[j]	No	Yes	No	?	Yes	Yes	[j] see Upper Lakes Reference Group Report[37]
Viruses[k]	← No Data Available →					Yes	[k] better detection methods needed
Acid Precipitation	No	No[m]	No	Yes	No	No	[m] a potential problem for smaller, soft water, inland lakes

[1] Sediment *per se* causes local problems; phosphorus and other sediment-associated contaminants have lakewide dispersion.

Identification of Diffuse Source Pollutants Causing Great Lakes Environmental Quality Problems

PLUARG studies indicated that several substances listed in Table 2 were either a present or potential environmental quality problem and that a large part of their input was derived from diffuse sources. These substances included phosphorus, mercury, PCBs and other industrial organic compounds, organochlorine pesticides used in the past, and sediment. Microorganisms are considered a minor Great Lakes problem, while lead is a potential environmental problem. These materials are discussed in greater detail in the following chapters.

1.2 PHOSPHORUS

The Problem

EUTROPHICATION

Eutrophication is a natural aging process generally describing the fertility (mainly aquatic plant productivity) of lakes[38-43]. Over time, a lake will become filled with sediment and organically-derived materials from streams draining its watershed, and from rain and dustfall directly onto its surface and in its watershed. On a geological time scale, all lakes will presumably cease to exist because of this natural process. However, man's activities within a drainage basin can alter natural processes in the watershed and accelerate this extinction process to a human, rather than geological, time scale. This latter phenomenon is frequently referred to as 'cultural' eutrophication to distinguish it from the natural aging process that occurs in the absence of man's activities.

Cultural eutrophication is caused by the excessive loads of aquatic plant nutrients (usually phosphorus) to natural waters. These nutrients, in turn, can produce nuisance growths (i.e., growths that interfere with man's use of the water) of algae and higher aquatic plants. While some lakes are naturally eutrophic, in that they receive a sufficient supply of phosphorus and other nutrients from natural sources to produce nuisance growths, an increased nutrient load to a water body has most often been associated with an intensification of human activity in the drainage area surrounding the water body.

For a more complete description and comparison of the eutrophication process in the Great Lakes, the reader is referred to the 1968 lower lakes report[44] and the 1976 upper lakes report[37].

Eutrophication is generally associated with aesthetic and water quality deterioration. Excessive aquatic plant growth and changes in water quality, resulting from eutrophication, can cause significant changes in the composition of aquatic plant and animal populations in a water body. In addition, water quality deterioration can hinder the use of the water for domestic and industrial water supplies, for irrigation and for recreational pursuits. A comparison of several water quality parameters, illustrating frequently (though not always) observed trends with changes in a water body's fertility, is presented in Figure 5.

Phosphorus has been found to be the nutrient most frequently limiting plant growth in the Great Lakes[45,46]. In addition, it is the nutrient most easily controlled by reduction of municipal waste treatment plant and detergent phosphate contributions to the lakes and by control of runoff from urban and agricultural lands.

TROPHIC CONDITIONS

There is considerable variation in the degree of eutrophication in the Great Lakes, due to variations in their phosphorus loads as related to their water volumes and turnover rates. The term "trophic condition' is commonly used to describe the degree of fertility in a water body. The trophic conditions of the Great Lakes are described below as a composite of several parameters indicative of the algal productivity of water bodies[47], including total phosphorus concentration, chlorophyll *a* concentration and Secchi depth (a measure of water clarity). In general, water bodies receiving small quantities of phosphorus, relative to their water volumes and turnover rates, are described as oligotrophic and possess the highest quality water. By contrast, highly productive water bodies, receiving large quantities of phosphorus, relative to their volumes and turnover rates, are highly fertile and described as eutrophic. Water bodies displaying a range of fertility between these two extremes are described as mesotrophic.

In these descriptive terms, surface offshore waters of Lakes Superior, Michigan and Huron are characterized as oligotrophic. Waters of the western basin of Lake Erie are eutrophic, while those of the eastern basin are mesotrophic. The central basin exhibits a gradient of fertility between these two conditions. Lake Ontario is characterized as mesotrophic.

In contrast to the offshore waters, the nearshore zone of the Great Lakes generally exhibits different water quality. The nearshore zone is a distinct zone separated from the offshore waters by virtue of its relatively shallow depth. In addition to having higher concentrations of most pollutants, the dynamic mixing of waters in this zone generally produces more variable concentrations of phosphorus. This variability results in part from tributary and municipal (urban) phosphorus input patterns and from the hydraulic characteristics of this zone. The physical boundaries of the nearshore zone may vary considerably, ranging from essentially zero width, where the offshore waters of the lakes are completely mixed to the shore, to several kilometers distance from the shore. Such factors as wind direction, intensity and duration, as well as shoreline and lake bottom morphology, influence the extent of the zone.

The nearshore zone, by its nature and location, constitutes the transition between nutrient and pollutant loads from the land and the resultant trophic condition and water quality seen in the offshore waters. This zone is also the zone in which the immediate effects of nutrients are most visible. This is particularly important for use of the water for water supplies, recreational pursuits and other activities.

The trophic conditions of the nearshore waters of the Great Lakes are presented in Figure 6. The trophic characterization is based on the same water quality parameters in the above discussion of offshore lake trophic conditions. Data for the years 1970–1973 were used for Canadian waters, with some earlier Lake Erie and Ontario data for the United States. The data base for the Canadian nearshore zone[31] was more extensive than that available for the U.S. portion of the lakes. Consequently, a more detailed delineation of trophic character is possible for Canadian nearshore waters than for U.S.

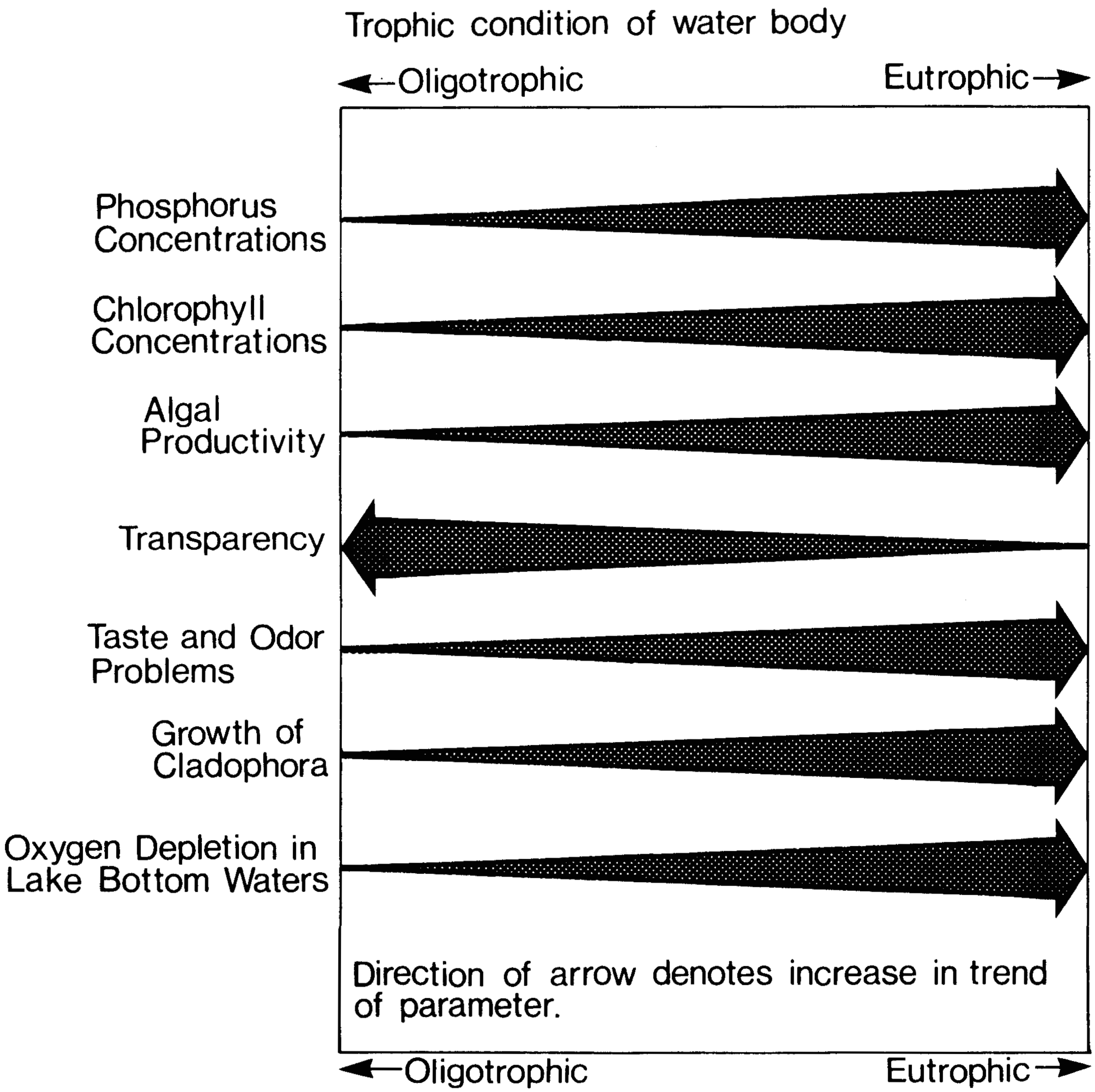


Figure 5: EUTROPHICATION RELATIONSHIPS IN LAKES

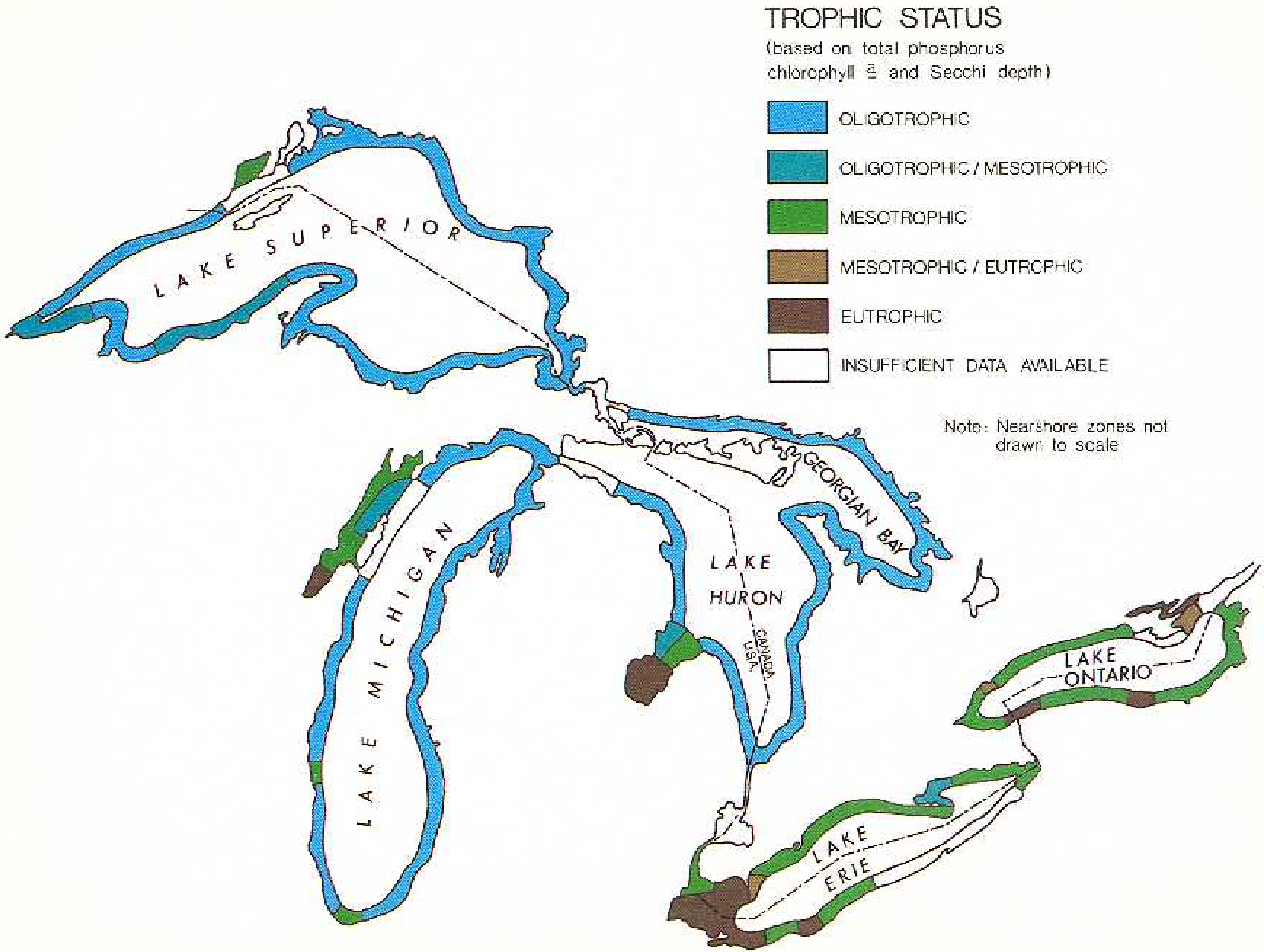


FIGURE 6. NEARSHORE TROPHIC CONDITION OF THE GREAT LAKES.

waters. Data for phosphorus, chlorophyll *a* and Secchi depth are particularly sparse for the U.S. nearshore areas of Lake Erie and Ontario, except in areas proximal to urban centers. This trophic state delineation must therefore be viewed in light of some deficiencies of nearshore data. However, it is believed to be a reasonably accurate representation of trophic conditions in the nearshore zone of the Great Lakes as of the early 1970's. A similar analysis of more recent nearshore water quality data to assess temporal changes in trophic status, in light of the reductions in phosphorus loads to the lakes resulting from the 1972 Water Quality Agreement, has not yet been conducted. It is noted in Figure 6 that the nearshore zone proximal to the south shore red clay area of Lake Superior exhibits an oligotrophic/mesotrophic boundary condition. In actuality, this region is one of low aquatic productivity, this anomaly is likely due to the high turbidity values exhibited in the data for this region of the lake, which would tend to produce an anomalous trophic characterization, based on the above three parameters used to classify the nearshore zone.

Loadings to the Great Lakes

A summary of the 1976 total phosphorus loads for the Great Lakes, as determined by PLUARG, is presented in Table 3. A comparison of the point and nonpoint portions of the total phosphorus load can be made upon examination of this table. Diffuse tributary inputs of phosphorus comprise a large proportion of the total phosphorus loads to the lakes, accounting for 53 percent in Lake Superior, 30 percent in Lake Michigan and 50 percent in Lake Huron. In the lower lakes, where the total phosphorus loads are higher, diffuse tributary sources remain substantial, accounting for 28 and 48 percent of the total load to Lakes Ontario and Erie, respectively.

Phosphorus from shoreline erosion was not included in the lake phosphorus loading estimates. PLUARG studies indicated that shoreline phosphorus consisted primarily of apatite phosphorus, which is not biologically available under the pH conditions normally existing in the lakes. Internal phosphorus loading from lake bottom sediments, highly variable, was also not included in the total load estimates.

RECOMMENDED TARGET LOADS

The relative magnitudes of phosphorus loads from point sources, diffuse sources, the atmosphere and upstream lakes to each of the Great Lakes are illustrated in Figure 7. Loads from shoreline erosion and from bottom sediments are not included for the reasons indicated above. Recommended target loads[a] are also indicated for each lake.

The target loads established for Lakes Superior, Michigan and Huron (exclusive of Saginaw Bay) are based on a philosophy of nondegradation. Phosphorus load reductions are recommended for Saginaw Bay, Lake Erie and Lake Ontario to improve present water quality. In Saginaw Bay, the phosphorus objective was established to reduce taste, odor and filter clogging problems at water treatment plants. The objective for Lake Erie was based on reduction of approximately 90 percent of the anoxic area in the central basin, with an associated reduction in the release of phosphorus from the sediments. The Lake Ontario objective was established to reduce phosphorus concentrations to the objective level of 10 μg/L phosphorus.

The recommended target loads presented in Figure 7 for Lakes Superior, Michigan and Huron show small differences from those recommended by Task Group III.

These differences occur for the following reasons:

(a) the tributary and atmospheric loads used by PLUARG were more detailed than those available to Task Group III; and

(b) PLUARG used a phosphorus effluent concentration of 1.0 mg/L for sewage treatment plants with discharges of one million gallons per day or greater, whereas Task Group III used a 1.0 mg/L concentration applied to plants with the same discharge limits, as well as for some plants with discharges less than one million gallons per day.

Task Group III considered a phosphorus loading reduction to Saginaw Bay, separate from Lake Huron, to 440 metric tons/yr, based on an optimum solution of taste and odor problems in drinking water. However, the Task Group[51] stated that minimal compliance could be achieved with a target load of 620 metric tons/yr. As will be discussed in chapter 3.3, this latter target load appears to be a more reasonable value. The limnology of southern Lake Huron has been well described by the Upper Lakes Reference Group[37], which reported that this southern sector is being affected by eutrophication of Saginaw Bay. In addition, the transport of materials from southern Lake Huron through the St. Clair River has been verified on the basis of PCB studies[52]. The need for a southern Lake Huron phosphorus reduction program involving the Saginaw Bay basin is discussed in chapter 3.3.

BIOLOGICAL AVAILABILITY OF PARTICULATE PHOSPHORUS

The percentages of biologically available phosphorus vary between point and diffuse sources and between lake basins, as well as from stream to stream and from season to season. Also, some portion of the phosphorus associated with sediment may not be immediately available for use by algae, although available forms can be released gradually over time.

Overall, it appears a large percentage of phosphorus associated with sediments delivered to the Great Lakes is not available. Based on a limited number of river studies in the Basin, 40 percent or less of the suspended sediment phosphorus was estimated to be available. PLUARG rivermouth data indicated the available phosphorus fraction made up roughly 35 percent of the total phosphorus load to the Great Lakes, suggesting the majority of the tributary total phosphorus load to the lakes is in forms not immediately available for use by algae.

In Canadian stream studies, phosphorus forms in suspended solids were determined by chemical fractionation,

[a] In accordance with provisions in the 1972 Water Quality Agreement, a comprehensive review of the operation and effectiveness of the Agreement was required during the fifth year after its coming into effect. Consequently, a technical bilateral working group (Task Group III)[51], composed of U.S. and Canadian scientists, was charged with developing total phosphorus loading objectives for each of the Great Lakes as part of the re-negotiations of the Agreement. The general criterion used in establishing these target loads was the interference with man's use of Great Lakes' waters.

TABLE 3

SUMMARY OF 1976 TOTAL PHOSPHORUS LOADS TO THE GREAT LAKES[a]

	metric tons/yr							
	LAKE SUPERIOR				LAKE MICHIGAN			
SOURCE	CANADA	U.S.	TOTAL	[PERCENT]	CANADA	U.S.	TOTAL	[PERCENT]
Direct Municipal Sewage Treatment Plants[b]	29	39	68	[2]	—	1,040	1,040	[16]
Tributary Municipal Sewage Treatment[c] Plants	38	162	200	[5]	—	1,458	1,458	[23]
Direct Industrial[d]	102	0	102	[2]	—	32	32	[<1]
Tributary Industrial[d]	0	33	33	[<1]	—	247	247	[4]
Urban Nonpoint Direct[e]	16	*	16	[<1]	—	*	*	
Tributary Diffuse[f]	1,453	769	2,222	[53]	—	1,891	1,891	[30]
(Tributary Total)	(1,491)	(964)	(2,455)		—	(3,596)	(3,596)	
Sub-Total	1,638	1,003	2,641	[63]	—	4,668	4,668	[74]
Atmospheric[g]	—	—	1,566	[37]	—	—	1,682	[26]
Load From Upstream Lake[h]	—	—	—		—	—	—	
Total			4,207	[100]			6,350	[100]
Shoreline Erosion[i] (not Included in Total)	0	3,781	3,781		—	3,711	3,711	

TABLE 3 (continued)

SUMMARY OF 1976 TOTAL PHOSPHORUS LOADS TO THE GREAT LAKES[a]

	metric tons/yr							
	LAKE HURON				LAKE ERIE			
SOURCE	CANADA	U.S.	TOTAL	[PERCENT]	CANADA	U.S.	TOTAL	[PERCENT]
Direct Municipal Sewage Treatments Plants[b]	107	16	123	[3]	70	5,588	5,658	[32]
Tributary Municipal Sewage Treatment[c] Plants	83	309	392	[8]	185	985	1,170	[7]
Direct Industrial[d]	0	31	31	[<1]	164	111	275	[2]
Tributary Industrial[d]	0	81	81	[2]	0	72	72	[<1]
Urban Nonpoint Direct[e]	16	*	16	[<1]	44	*	44	[<1]
Tributary Diffuse[f] (Tributary Total)	864 (947)	1,564 (1,954)	2,428 (2,901)	[50]	1,726 (1,911)	6,675 (7,732)	8,401 (9,643)	[48]
Sub-Total	1,070	2,001	3,071	[63]	2,189	13,431	15,620	[89]
Atmospheric[g]	—	—	1,129	[23]	—	—	774	[4]
Load From Upstream Lake[h]	—	—	657	[14]	—	—	1,080	[6]
Total			4,857	[100]			17,474	[100]
Shoreline Erosion[i] (Not Included in Total)	131	295	426		5,912	1,024	6,936	

TABLE 3 (continued)

SUMMARY OF 1976 TOTAL PHOSPHORUS LOADS TO THE GREAT LAKES[a]

	metric tons/yr							
	LAKE ONTARIO				INTERNATIONAL SECTION OF ST. LAWRENCE RIVER			
SOURCE	CANADA	U.S.	TOTAL	[PERCENT]	CANADA	U.S.	TOTAL	[PERCENT]
Direct Municipal Sewage Treatment Plants[b]	1,079	968	2,047	[17]	84	9	93	[2]
Tributary Municipal Sewage Treatment[c] Plants	155	613	768	[7]	0	54	54	[<1]
Direct Industrial[d]	47	33	80	[<1]	42	0	42	[<1]
Tributary Industrial[d]	4	18	22	[<1]	0	0	0	
Urban Nonpoint Direct[e]	324	*	324	[3]	—	—	—	
Tributary Diffuse[f] (Tributary Total)	1,088 (1,247)	2,169 (2,800)	3,257 (4,047)	[28]	88 (88)	659 (713)	747 (801)	[14]
Sub-Total	2,697	3,801	6,498	[55]	214	722	936	[17]
Atmospheric[g]	—	—	488	[4]	—	—	—	
Load From Upstream Lake	—	—	4,769	[41]	—	—	4,545	[83]
Total			11,755	[100]			5,481	[100]
Shoreline Erosion[i] (Not Included in Total)	777	538	1,315		—	—	—	

Explanation of Table 3:

[ ] = percentage of total phosphorus load, excluding shoreline erosion

* = included with U.S. tributary diffuse loads

Dash (—) indicates data not available.

[a] Data are considered to be best available estimates for 1976, unless otherwise indicated.

[b] Direct municipal sewage treatment plant load estimates were generally taken from the 1976 Remedial Programs Subcommittee Report[48]. Minor discrepancies in these direct municipal loads and those reported by the Water Quality Board's Surveillance Subcommittee[49] occur because some sewage treatment plant outfalls (considered as direct discharges by the Surveillance Subcommittee) occur above PLUARG tributary river mouth sampling stations and because data from several major U.S. plants were not included in the Subcommittee Report.

[c] Loading information concerning indirect, or tributary, municipal inputs was also taken primarily from the 1976 Remedial Programs Subcommittee Report[48], with some additional information used for several major U.S. plants not included in the Subcommittee Report. Additional, but generally small, sewage treatment plant loads have been considered in the PLUARG U.S. studies of tributary loadings. However, they were not included in this table for consistency of data between both countries. These additional small plants would not significantly alter the load estimates to the Great Lakes.
(*note*: on the basis of footnotes b and c, direct and indirect municipal sewage treatment plant loads to the lakes are considered to be a conservative estimate, since a number of generally small plants in each lake basin are not included in the Remedial Programs Subcommittee Report[48]).

[d] Both direct and tributary industrial loads were taken from the 1976 Remedial Programs Subcommittee Report[48].

[e] Urban nonpoint direct loadings (date not specified) were taken from an unpublished manuscript by D.H. Waller[50]. Estimates include combined sewer overflows and surface runoff for Ontario municipalities with populations greater than 10,000. A portion of this urban runoff may be included in the tributary load estimates. However, since it was not possible to separate urban diffuse loads from total tributary loads, urban runoff has been assumed to be a direct input. Since these loads are a relatively small proportion of the total lake load, any errors resulting from this assumption are deemed to be small.

[f] Tributary loads for 1976 are those calculated in U.S. PLUARG studies and by the Ontario Ministry of the Environment. In order to estimate actual tributary mouth loads from only diffuse sources, known tributary point source loads (see note c) were subtracted from the tributary mouth loads, assuming 100 percent of the point source load to the tributary was transported to the lake. Thus, the proportion of the total tributary load derived from diffuse sources is a conservative estimate.

[g] From PLUARG studies on atmospheric loads[30].

[h] Interconnecting channel loads from upstream lakes are taken from the 1976 Surveillance Subcommittee Report[49], and from studies in progress at the Canada Centre for Inland Waters.

[i] Shoreline erosion loads are not included in the total lake loads since a large portion of this phosphorus fraction is not biologically available.

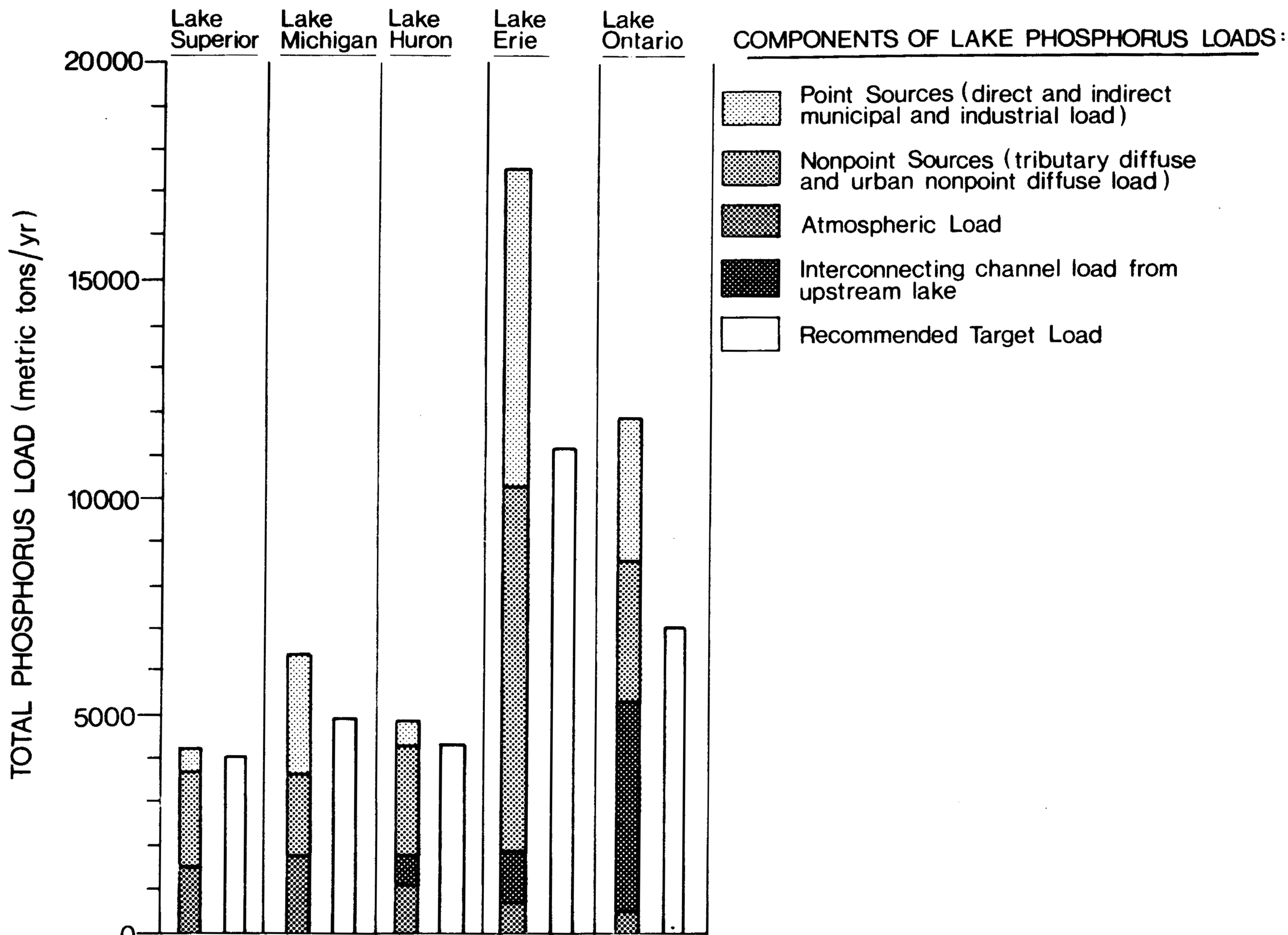


Figure 7: 1976 PHOSPHORUS LOADS AND RECOMMENDED TARGET LOADS FOR THE GREAT LAKES

which partitions sediment-bound phosphorus into three forms, designated apatite phosphorus, organic phosphorus and non-apatite inorganic phosphorus (NAIP). Only NAIP, among these three forms, is considered to be immediately available for algal growth, although a portion of the organic phosphorus form will be converted to available forms over time. The results of these studies are summarized in Table 4.

Considerable variation is noted in Table 4, especially for organic phosphorus and NAIP. Despite intersample variations, however, there is remarkable agreement, particularly for the NAIP fraction, in percentage composition between the monitor streams and lake sections. For the monitor streams, the composition varies from 27 to 40 percent, with a mean of 33.4 percent available phosphorus as a percentage of the particulate phosphorus. The Saugeen monitor NAIP value of 27 percent is similar to the Lake Huron (Bruce Peninsula drainage) value of 22.2 percent. Georgian Bay, North Channel and Lake Superior all show consistently lower percentages of available phosphorus, ranging from 13 percent (Lake Superior) to 26 percent (North Channel), consistent with Canadian Shield drainage.

The percentage compositional data, although they are specific to suspended solids, indicate sediment quality and do not account for total solids variation as a function of flow, appear to be sufficiently consistent for applying to estimates of suspended solids delivered to the lakes in routine agency monitoring programs.

1.3 TRACE ELEMENTS

Almost all the major elements in the earth's crust are detectable in Great Lakes' waters in at least trace amounts, derived mainly from natural sources.

With the coming of European settlement on a large scale in the mid 1800's, levels of metals entering the Great Lakes and ending up in sediments at the bottom of the lakes began to rise. This rise could be attributed to the clearing of the forests, resulting in increased erosion rates and increased inputs of geologically derived elements. In addition, the rapid growth of heavy industry in the Basin gave rise to elevated inputs of trace elements. Present inputs of two heavy metals of environmental concern, mercury and lead, can be traced to specific human activities (e.g., the chlor-alkali industry (mercury) and the advent of leaded fuels for automobiles).

Evaluation of the vertical distribution of trace elements in Great Lakes sediment cores has shown that modern surface sediment has been enriched in heavy metals[53].

PLUARG, in its study of trace element inputs to the lakes, determined that the following elements should be considered as present or potential pollutants requiring further close surveillance:

I mercury, lead

II arsenic, cadmium, selenium

III copper, zinc, chromium, vanadium

These elements have been ranked on the basis of their real or anticipated potential as an environmental hazard. Elements were included if they met either of the following criteria: (1) the potential for transformation of the element to a toxic methylated form; or (2) enrichment of sediments and organisms with the element. As mercury and lead are seen to be of greatest concern in the above ranking, they are discussed below in detail. Elements in categories II and III are discussed in chapter 1.7.

Methylation

The impetus for the study of methylation of trace elements was the discovery that microorganisms in lake sediments were able to convert inorganic mercury in sediments into a very potent human nerve poison, methyl mercury[54]. It has subsequently been shown that methylation is a common process in the aquatic environment.

Other studies have indicated there is a possibility that lead, selenium and arsenic may also undergo methylation[55,56].

Mercury

Sediments and fish, especially in Lakes Ontario, Erie and St. Clair, are presently contaminated with mercury. This mercury is derived from several sources, including past industrial discharges and present atmospheric deposition directly onto the Great Lakes and onto the land surface, with subsequent drainage to the lakes.

THE PROBLEM

A major input to the Great Lakes until 1970 was the industrial discharge of mercury into the St. Clair and Detroit rivers. The sediments and fish in Lake St. Clair became contaminated with mercury and the commercial fishery was closed. In addition, bans on fishing were issued for Lake Huron (pickerel), Lake Erie (pickerel and bass longer than 25 cm) and the extreme eastern end of Lake Ontario (perch). Numerous warnings about the consumption of Great Lakes fish contaminated with mercury have been issued. An indication of current levels of mercury in Great Lakes fish is presented in Table 5. As indicated earlier, mercury is a current problem because of its ability to be transformed into an organic, readily-bioaccumulated form, methyl mercury.

An indication of mercury levels in sediments of the Great Lakes[58] is given in Figure 8. This information is extremely useful in tracing the movement of mercury from its sources to its sinks. It is clear from Figure 8, for example, that Lake St. Clair is still a major source of mercury to Lake Erie, even seven years after closure of the point source discharge. The mercury-laden sediments of Lake St. Clair are being washed out through the Detroit River and deposited in the western basin of Lake Erie. Resuspension and continued transportation results in the sediment and associated contaminants being carried along the south shore of the lake and being deposited predominantly in the eastern basin. Significant levels of mercury in Lake Ontario sediments have also been noted, particularly in its deep basins. Distribution patterns show that the Niagara River is the predominant source, with wide dispersal particularly to the eastern basin of the lake.

TABLE 4

FORMS OF PARTICULATE PHOSPHORUS IN CANADIAN RIVER MOUTHS TRIBUTARY TO THE GREAT LAKES

	Apatite		Organic Phosphorus		NAIP		Total Particulate Phosphorus		As Percent Total Particulate Phosphorus		
	Mean (mg/kg)	Coefficient of variation (Percent)	Mean (mg/kg)	Coefficient of variation (percent)	Mean (mg/kg)	Coefficient of variation (percent)	Mean (mg/kg)	Coefficient of variation (percent)	Apatite (percent)	Organic (percent)	NAIP (percent)
MONITOR STREAMS											
Bronte Creek	391	18.0	633	52.0	447	52.6	1403	35.5	26.6	43.0	30.4
Humber River	491	5.3	680	69.3	669	40.7	1982	40.2	26.7	37.0	36.4
Credit River	450	7.8	461	88.9	481	45.5	1416	46.2	32.3	33.1	34.6
Niagara River	372	22.2	319	6.3	298	21.2	1012	5.7	37.6	32.3	30.1
Grand River	384	12.0	609	39.3	659	29.9	1620	27.3	23.2	36.9	40.0
Cedar Creek	288	39.7	588	31.0	489	27.6	1312	21.1	21.1	43.1	35.8
Thames River	329	29.0	671	56.0	620	35.4	1592	29.0	20.3	41.4	38.3
Saugeen River	366	22.8	348	41.5	259	46.2	966	25.0	37.6	35.8	26.6
Nottawasaga River	416	46.4	706	49.3	508	47.9	1597	29.8	25.5	43.3	31.2
ALL MONITOR SAMPLES	407	28.3	559	59.3	484	50.1	1460	37.3	28.1	38.6	33.4
LAKES AND LAKE SECTIONS											
Lake Ontario North	502	46.8	669	36.4	553	46.6	1742	29.5	29.1	38.8	32.1
Lake Ontario South	448	47.1	1107	111.1	706	91.1	2309	86.2	19.8	49.0	31.2
Lake Erie	392	30.8	433	75.1	492	92.6	1318	52.2	29.8	32.9	37.4
Lake Huron	348	21.7	356	54.2	201	41.8	901	27.6	38.5	39.3	22.2
Georgian Bay	456	17.3	342	41.0	211	46.0	958	22.6	45.2	33.9	20.9
North Channel	426	6.7	252	55.4	242	81.2	815	15.2	49.6	27.4	26.3
Lake Superior	458	12.3	86	38.6	89	67.4	629	16.6	72.4	13.6	14.1

[a] coefficient of variation = standard deviation expressed as a percent of the mean

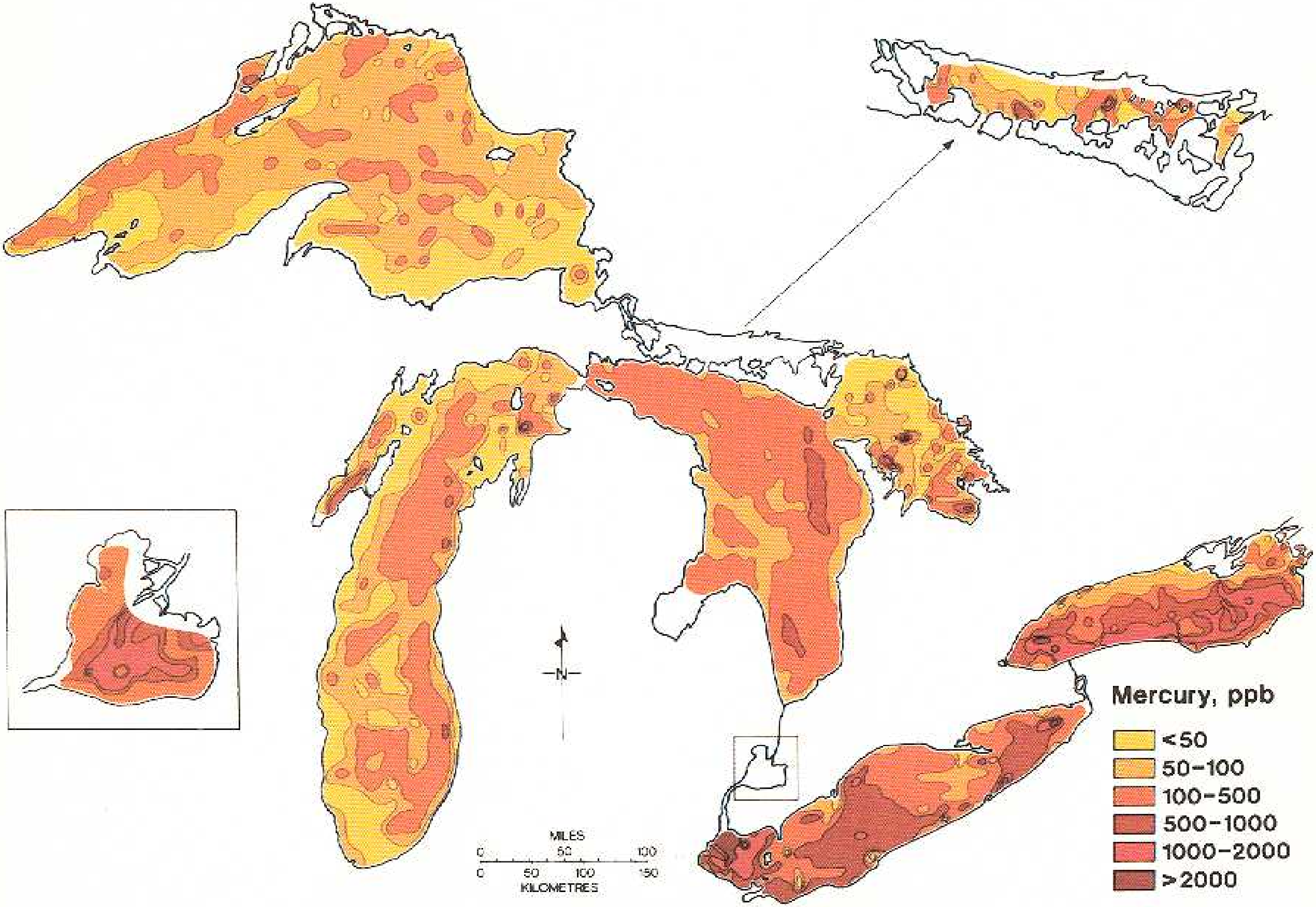


FIGURE 8: MERCURY CONCENTRATIONS IN SURFACE SEDIMENTS OF THE GREAT LAKES (ppb = μg/kg).

TABLE 5

CONCENTRATIONS OF MERCURY IN GREAT LAKES FISH

(wet weight)

Lake	Number of Fish Analyzed	Concentration[a] (mg/kg)
Superior	80	0.07 – 0.78
Michigan	20	0.22 – 0.54
Huron	50	*0.06 – 0.18
St. Clair	742	0.06 – 3.8[b]
Erie	3000	0.03 – 1.52[c]
Ontario	85	0.06 – 0.49

[a] the accepted guideline concentration is 0.5 mg/kg
[b] from 50 to 100 percent of individuals in the 14 species analyzed in 1976 still exceeded the guideline
[c] range of mean values
data taken from several sources[59-65].
* Value revised from first printing of this report.

Recent studies in the U.S. and Canada have shown an exponential decline in mercury levels in Lake St. Clair fish species between 1970 and 1977. Sediment studies in 1970, 1974 and 1976 showed mean mercury values of 1549, 568 and 535 μg/kg, respectively. This indicates a parallel decline in fish and sediment, suggesting slow recovery of this ecosystem[58, 59]. The initial point source on the St. Clair River has produced a dissemination of mercury in the Lake St. Clair delta, which is currently serving as a diffuse source of this element. The load from this source to Lake St. Clair appears to be in a semi-equilibrium condition with the output of contaminated sediment from Lake St. Clair to the Detroit River and Lake Erie.

LOADINGS TO THE GREAT LAKES

The major mercury loads to the lakes, as noted above, result from the redeposition of sediments contaminated by past industrial discharges, possibly from the continued use of small amounts of mercurial pesticides to combat bacterial and fungal infestations on turf and the current atmospheric deposition of mercury. Data on atmospheric and point source loads of mercury to the lakes are scarce. Consequently, no attempt was made to present a loading table. The present tributary loading of mercury to the Great Lakes is 2300 kg/yr. The loadings to each lake are as follows: Lake Superior, 86 kg/yr; Lake Michigan, 96 kg/yr; Lake Huron, 120 kg/yr; Lake St. Clair, 95 kg/yr; Lake Erie, 1530 kg/yr; and Lake Ontario, 370 kg/yr.

Information was available on soluble mercury loads to the lakes. However, this information was not useful because of biasing of the data toward high values. Present technology allowed PLUARG investigators to detect mercury in almost every stream draining into the Great Lakes. However, this technology did not allow accurate quantification of mercury levels in the streams. The mercury loads presented above are the sediment-associated loads.

Lead

At present, lead is not an environmental contaminant of concern in the Great Lakes, relative to current concentrations in fish. However, it has a potential for becoming a problem through chemical and biological methylation, if current loadings of lead to the lakes are not reduced. Major sources of lead are diffuse in nature.

THE PROBLEM

Levels of lead in Great Lakes fish[59-65] are below the accepted concentration of 10 mg/kg (Table 6). There are no recorded cases of lead levels in Great Lakes fish exceeding this guideline. However, the problem of methyl lead levels in fish is in an early stage of evaluation. It is conceivable that with further toxicological work, the guideline for lead in fish may ultimately be revised.

Figure 9 shows levels of lead in Great Lakes sediments[58,66]. As with mercury, major source areas of lead may be inferred on the basis of sediment concentration patterns. Figure 9 illustrates the effects of the large urban complexes in the Lake Erie and Ontario basin on concentrations of lead in sediment, particularly the influence of the Detroit River and Cleveland on the western and central basins of Lake Erie, respectively.

LOADINGS TO THE GREAT LAKES

Table 7 indicates the relative contributions of point and nonpoint sources to the total loading of lead to the Great Lakes. It is clear that nonpoint sources are by far the greatest component of the load. In this analysis, diffuse sources include the atmospheric component. This has been done because the substantial inputs of lead from automobile exhausts are considered a land use activity by PLUARG, and, thus, the atmosphere is acting as more than just a transport mechanism.

TABLE 6

CONCENTRATIONS OF LEAD IN GREAT LAKES FISH

Lake	No. of fish analyzed	Concentration[a] (mg/kg)
Superior	70	0.012 – 0.066
Michigan	23	N.D.[b] – 0.54
Huron	50	0.04 – 0.10
St. Clair	34	0.47 – 0.63[c]
Erie	49	0.04 – 0.12[c]
Ontario	219	<1.0

[a] the accepted guideline concentration is 10 mg/kg.
[b] not detected
[c] range of mean values
data from several sources[59-65]

TABLE 7

LOADINGS OF LEAD TO THE GREAT LAKES

Lake	metric tons/yr			Nonpoint Load as Percent of Total Load
	Point Sources	Nonpoint Sources	Total to Lake	
Superior	4.	975	979	99.6
Michigan	[190][a]	1670	[1860][a]	[90.0][a]
Huron	90	875	965	90.5
Erie[b]	340	1900	2240	84.7
Ontario[c]	8.0	620	628	98.7

[a] estimated values
[b] includes inputs to Lake St. Clair
[c] includes inputs to Niagara River

1.4 ORGANIC COMPOUNDS

Pesticides

THE PROBLEM

PLUARG studies have indicated that Great Lakes biota continue to show residual levels of DDT, aldrin-dieldrin and chlordane. Other pesticides monitored in the PLUARG studies were not found to be a current problem. These latter pesticides included heptachlor-heptachlor epoxide and atrazine, and are discussed in chapter 1.7.

Pesticides have been used in the Great Lakes Basin for over 50 years. The earliest pesticides, no longer in use, were arsenic-based. These materials have become bound to soil particles in old orchards (where they were predominantly used) and can pose an environmental threat only if the soils of these orchards are disturbed during construction activities for housing or industrial developments and carried into surface waters.

Organochlorine pesticides (e.g., DDT) were first used in the Basin after World War II. These compounds were easy to apply to crops and were very effective in controlling insect pests. However, environmental problems associated with these materials are related to three features: (1) persistence; (2) widespread use; and (3) the ability to bioaccumulate in aquatic organisms. Extensive monitoring, begun in the early 1960's, is continuing. PLUARG was initially concerned with DDT, aldrin-dieldrin, chlordane, heptachlor-heptachlor epoxide and atrazine in Great Lakes waters, biota and sediments.

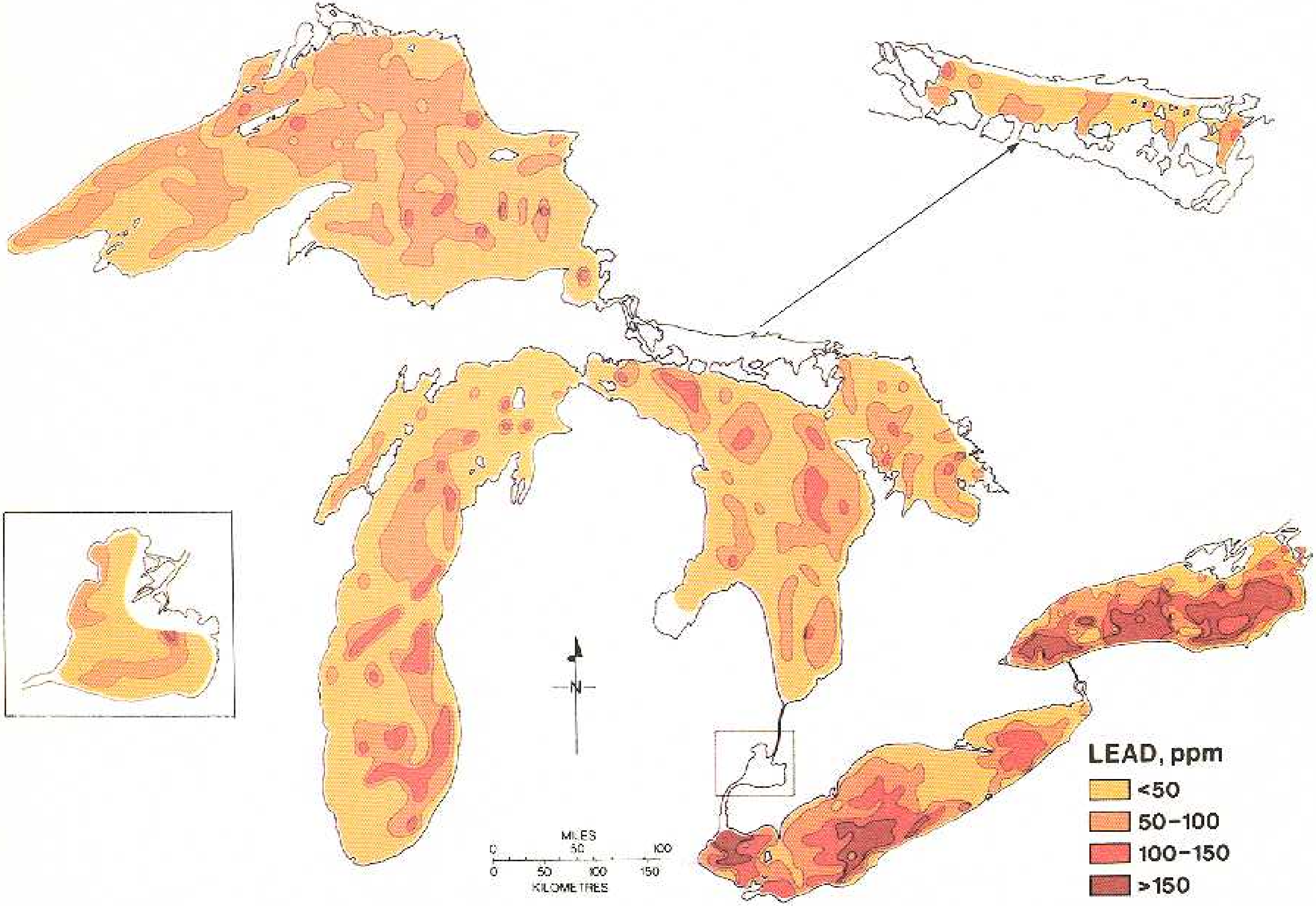


FIGURE 9: LEAD CONCENTRATIONS IN SURFACE SEDIMENTS OF THE GREAT LAKES (ppm = mg/kg)

TOTAL DDT[a]

Because of environmental concerns regarding organochlorine pesticide residues in fish and wildlife, DDT was banned from use in Ontario in 1972. In the United States, DDT was also generally banned in 1972. Current sampling results indicate that total DDT levels in fish are well below the U.S. and Canadian guideline of 5.0 mg/kg, with the exception of Lake Michigan, where 1976 lake trout DDT levels[49] still exceeded the guideline, although a continuing decline is in evidence.

Total DDT levels in Great Lakes sediments are elevated in some localities, reflecting past inputs. It is anticipated these sediments will not become further burdened with DDT because of the current restrictions on its use. The role of these sediments as a long-term potential source of DDT is probably minimal, due to their burial by fresh sediment with declining total DDT levels.

ALDRIN-DIELDRIN[b]

Aldrin-dieldrin has been in use nearly as long as DDT, but has never received the same publicity. It was a notable problem in Lake Michigan, where levels in fish from 1969 to 1974 were just at, or below, the U.S. Food and Drug Administration guideline of 0.3 mg/kg. The levels in lake trout and chub were found to exceed the guidelines in 1975 and 1976; no explanation has yet been offered for this occurrence. The ban on the use of aldrin in Ontario in 1969, and in the United States in 1974, should result in declining levels of dieldrin in Lake Michigan fish. Dieldrin was not a problem in any other Great Lakes fish, with the exception of bloaters caught in Lake Huron and Georgian Bay in 1975, where levels were at, or just below, the guideline. Because of the current ban, levels of dieldrin are expected to decline to even lower values in fish in the other lakes.

CHLORDANE

Chlordane levels were monitored during the PLUARG study in sediment and biota in the nearshore zones of Lakes Huron, St. Clair, Erie and Ontario. Chlordane was detected in all components of the ecosystem in Lakes Erie and Ontario in 1976 samples and was found to exceed established guidelines of 100 μg/kg for the protection of wildlife[67] in fish sampled at the mouth of the Niagara River in 1977. Increases in chlordane residues were also found[67] in fish sampled near Point Pelee (Lake Erie).

The use of chlordane is currently restricted. In Ontario, its use on corn was banned in 1978 and only very restricted use is allowed on turf and vegetables. In the U.S., it is proposed to totally phase out chlordane use by 1981. It is anticipated this ban should result in a decline in chlordane residues in the ecosystem, although a lag time of several years (as observed with DDT) is expected before a decline will be observed. Continued monitoring for chlordane is warranted.

[a] total DDT signifies parent DDT, plus its degradation metabolites DDE and TDE.

[b] aldrin is the parent compound, and degrades to dieldrin, the form usually detected in environmental samples.

PCBs

PLUARG has found that PCBs are a contaminant of the Great Lakes ecosystem (Table 2) and that diffuse sources, including atmospheric inputs, account for the major loadings of PCBs to the lakes.

THE PROBLEM

The class of compounds known as PCBs (polychlorinated biphenyls) has been manufactured since the late 1920's and has been in use in the Great Lakes Basin for more than 40 years. They have been recognized as an environmental pollutant for the past 20 years. PCBs are extremely stable compounds that are usually only destroyed by high temperature incineration. These compounds are only sparingly soluble in water, but are quite soluble in fat. It is this latter property which makes PCBs an environmental hazard, since PCBs readily accumulate in the fatty tissues of fish, birds and human beings. Even when levels of PCBs may barely be detectable in the water, PCB levels in fish tissue can exceed established guideline concentrations for human consumption.

Environmental concern with PCBs centers in their ability to cause gross deformities in primates used as test animals and reproductive failure in fish-eating birds (herring gulls)[68]. These birds, over the past few years, have exhibited a sharp decline in egg hatching. Young birds are often grossly deformed, particularly their bills, rendering them incapable of eating. There is, as yet, no toxicological data on the effects of PCBs on human beings, although various studies are underway in both Canada and the United States to monitor levels of PCBs in human milk and fat tissue. PCB levels found in human fat tissue in Ontario residents have not declined between 1969 and 1974. It was found that the subjects with the highest PCB contents in their fat tissue were also large consumers of fish from the Great Lakes[68].

Table 8 indicates PCB levels in Great Lakes fish[61, 69]. As this table is a summary of data of many fish species over several years, only an overall mean value for PCBs and a range of levels can be given. Levels vary considerably with fish size, species, fat content and geographical location of the fish sample. The Canadian Department of National Health and Welfare guideline for PCBs in fish tissue for human consumption is also indicated. For Lake Michigan, the U.S. Food and Drug Administration (FDA) guideline is presented.

PCB levels in fish tissue have not declined, nor have they shown a marked increase in the past 8–9 years. An indication is also given in Table 8 (where data permit) of the number of fish sampled in each lake which exceeded the established Canadian guideline of 2.0 mg/kg (5.0 mg/kg for Lake Michigan). Numerous warnings to fishermen have been issued over the past seven years concerning consumption of Great Lakes fish contaminated with PCBs. Several bans have also been issued, including commercial fishing bans on coho and chinook salmon in Lake Huron, Georgian Bay, North Channel, Lake Erie and Lake Ontario; catfish and eel in Lake Ontario; and salmon in Lake Michigan.

PCBs are barely detectable in the water component of the Great Lakes ecosystem and no data are presented here. High PCB levels in fish and sediments (see following discussion) emphasize the fact that PCBs can readily bio-

TABLE 8

SUMMARY OF PCB LEVELS IN GREAT LAKES FISH

Lake	Years of Sampling	Mean PCB Concentration All Samples (mg/kg)	Range (mg/kg)	Percentage of Major Species Exceeding Guidelines
Superior	1968-1975	0.61 (2.0)[a]	<0.1 – 3.7	75% – whitefish (1974) – Marathon 20% – chub (1975)
Michigan	1972-1974	10.2 (5.0)	2.1 – 18.9	13% – chubs 50% – *lake trout*
Huron	1968-1976	0.82 (2.0)	<0.1 – 7.0	50% – coho salmon (1971) 75% – rainbow trout (1974) – Douglas Point 33% – rainbow trout (1974) – Goderich 10% – rainbow trout (1974) – Nottawasaga River
Erie	1968-1976	0.88 (2.0)	<0.1 – 9.3	27% of all samples analyzed had, in the range of concentrations for a sample, an upper PCB concentration >2 mg/kg. Of these, 75% were from the western and central basins. Species with the largest number of individuals exceeding the guideline were coho salmon, fresh-water drum, white bass and channel catfish.
Ontario	1972-1977	2.37 (2.0)	<0.1 – 21.1	30% – carp (1972-74) 100% – coho salmon (1972-73) 27% – rock bass (1972-74) 88% – catfish (1972-74) 0% – sunfish (1972-74) 36% – white perch (1972-74) 42% – northern pike (1972-73) 0% – cisco 77% – smelt (1972-74) smelt, coho salmon and lake trout had PCB levels in whole fish ranging from 0.4 – 16.2 mg/kg. Mean concentrations in fish from the eastern basin were highest at 5.31 mg/kg (1977)

[a] (accepted guideline for fish)

accumulate or can go into storage in the sediments. It is not yet known whether PCBs can be released from sediments to water or biota. Work is currently underway to investigate this question.

Levels of PCBs[52,70,71] in Great Lakes surface sediments and their distribution are shown in Figure 10. It is obvious that the sediments, particularly in Lakes Ontario and Erie, are highly enriched with PCBs. An estimate of the total amount of PCBs present in Great Lakes sediments, from 1956 to the present, is given in Table 9. It can be inferred from the sediment enrichment pattern with PCBs (Figure 10), that large urban areas are major sources for PCBs. The widespread dispersion throughout the lake sediment system, however, indicates a major atmospheric source to the entire Basin.

LOADINGS TO THE GREAT LAKES

Because PCBs were used in a wide variety of industrial and commercial applications, their disposal over the years has resulted in an untold number of possible sources, including many hundreds of landfill sites. In addition, there are currently numerous point sources discharging PCB wastes into the lakes. Both industrial and municipal wastewaters have been found to contain PCBs. Wastewater PCB levels have been examined in some jurisdictions, and measured loads range from several to hundreds of kilograms per year. For example, 26 large sewage treatment plants in Ontario discharged a total of about 250 kg/yr of PCBs. One industry in Ontario was found to be discharging 7 kg/yr into Lake Ontario[72].

When compared to diffuse PCB loads, however, these wastewater values are less significant. PLUARG studies indicate that between 5 and 50 metric tons/yr of PCBs are deposited directly onto the water surface of the Great Lakes from the atmosphere[30]. The monitored total tributary PCB load to the Great Lakes is approximately 770 kg/yr. This value includes numerous tributaries with forested or agricultural watersheds, again implying atmospheric sources.

The loading of PCBs from urban areas is about 310 kg/yr for the Great Lakes Basin. While comprehensive PCB loading data are not readily available, this gross assessment of sources, coupled with the PCB distribution in sediments (Figure 10), indicates that urban areas represent a major PCB contribution to the lakes.

Other Industrial Organic Compounds

THE PROBLEM

Many synthetic organic compounds have been detected in the aquatic environment because of continuing improvements in analytical techniques and because of more intensive monitoring programs. At the beginning of the PLUARG study in late 1972, many materials were not suspected of being environmental pollutants. Consequently, land-based monitoring activities for most industrial organic compounds were not established as part of the PLUARG study.

However, two compounds that were studied during the PLUARG study were mirex and hexachlorobenzene (HCB).

MIREX

Mirex in Lake Ontario fish was first reported[73] in 1974. Analyses of Lake Ontario sediment revealed the widespread dispersion of mirex in the lake and identified point sources in the Niagara and Oswego Rivers in New York. Mirex levels in fish have not shown any decline to the present time. Analyses of suspended solids in Canadian rivers tributary to the Great Lakes did not reveal the presence of mirex in 1974 and 1975, other than in the Niagara River. Analyses of river mouth biota, however, indicated the presence of mirex in emerald shiners in Oakville Creek (Lake Ontario)[67]. Subsequent suspended solids analyses on Grand River samples in 1977 indicated mirex concentrations between 2 and 10 μg/kg. These data, when related to a potential industrial source in the Grand River basin, indicate an apparent lag time in fluvial transmission. This is probably related to detection limits of mirex on sediment particles.

HCB

At present, little is known about the sources or total usage of hexachlorobenzene in the Great Lakes Basin. Con-

TABLE 9

ESTIMATED TOTAL QUANTITY OF PCBs IN GREAT LAKES SEDIMENTS[a]

Lake	Average Concentration Range (μg/kg)	Estimated Total Quantity of PCBs in Sediment (kg)
Superior	30	4,000
Michigan[b]	38.2	17,000
Huron	9.0 – 33.0	11,000
Erie	74.0 – 252.0	35,600
Ontario	77.0 – 89.0	9,000

[a] 1956 to present
[b] using an average annual sedimentation rate of 1 mm/year in the depositional area for a period of 48 years (1930-1978). U.S. Environmental Protection Agency data.

tinued surveillance for HCB in nearshore zone sediments and biota in the lakes is warranted.

HCB is currently used in the plastics industry and in the manufacture of dyes. It readily bioaccumulates, is very stable in the environment and is easily volatilized. HCB has been shown to be carcinogenic in laboratory tests. Dispersal through the atmosphere appears to be the major pathway for the entry of HCB from point sources into the aquatic ecosystem.

PLUARG studies in Lake Ontario[67] showed that fish (emerald shiners) near Oakville Creek (Lake Ontario) contained HCB residues of about 10 μg/kg. Fish sampled at the mouth of the Niagara River also had HCB levels of about 25 μg/kg in their tissues. Lake-wide surveillance data indicate HCB levels in fish from Lakes Ontario and Erie to range from undetectable to 20 μg/kg. At present, there is no accepted guideline for HCB in fish for human consumption, although there is an interim U.S. Environmental Protection Agency HCB guideline of 500 μg/kg in food products for human consumption.

1.5 MICROORGANISMS

PLUARG studies indicate that bacteria represent a minor Great Lakes problem. Bacteria are primarily derived from combined sewer overflows and from urban stormwater runoff.

The Problem

For this discussion, pathogenic bacteria are those bacteria whose presence in Great Lakes waters is indicative of contamination by fecal matter, whether of human or animal origin. The bacteria generally considered indicative of fecal pollution are *Escherichia coli, Pseudomonas aeruginosa* and *Salmonella* species. Some diseases are transmitted through fecal contamination of water (e.g., swimmer's itch, ear infections and leptospirosis). Epidemic diseases such as cholera or typhoid are not present in the Great Lakes Basin. However, the impact of bacterial contamination of Great Lakes nearshore zones can be quite significant in terms of beach closings. From 1975–1977, eighteen recreational beaches on the Canadian Great Lakes shoreline were closed for periods ranging from three to 52 weeks (i.e., permanent closure). There were also numerous postings warning bathers of possible risk[74]. Whether these particular beaches were closed because of stormwater runoff or combined sewer overflows is not clear. While data from U.S. beaches are not readily available, it would be reasonable to assume a similar situation exists.

Pathogenic organisms can enter the Great Lakes through several sources, including direct sewage plant discharges, direct storm sewer discharges, combined storm and sanitary sewer overflows and septic tank failures. The impact of these discharges is generally restricted to the nearshore zone of the lakes. The presence of pathogenic organisms at, or near, municipal water intakes could necessitate increased vigilance.

It should be noted that a major component of the urban diffuse bacterial load to the lakes is of non-human origin. Pets and birds deposit significant quantities of excrement on city streets daily. It is this material, in the strict sense of PLUARG's mandate, that is of diffuse origin. Material (mostly human in origin) from combined sewer overflows, while considered in part a point source problem, is discussed in later chapters of this report.

Septic tanks may be a source of bacterial contamination to the Great Lakes when they are located on unsuitable soils on, or close to, the shoreline. The survival time of bacteria in soil, groundwater and, subsequently, surface water, is not sufficiently long to allow them to travel great distances from septic tank systems located far inland. Local bacterial contamination of streams and groundwater may occur inland.

Loadings to the Great Lakes

It is not possible to develop comprehensive loading estimates for bacteria. However, some examples of the bacterial content of storm sewers and combined sewers[6] are presented in Table 10.

The source of bacterial contamination can be inferred from examining the ratio of fecal coliforms to fecal streptococcus. Bacteria of a predominantly animal origin will give a ratio of <1, while those of a predominantly human origin will give a ratio of >4. In Table 10, the ratio from storm sewers is 0.6, while that from combined sewers is 4.6. Without this detailed assessment of a violation of the bacterial stan-

TABLE 10

BACTERIAL CHARACTERISTICS OF STORM AND COMBINED SEWER OVERFLOWS

Organism	Water Quality Agreement Objective (#/100 mL)	Storm Sewers (Allen Creek Drain, Ann Arbor)		Combined Sewers (Conner Creek, Detroit)	
		Range	Mean	Range	Mean
Total Coliform (#/100 mL)	1000	26,500 – 17,500,000	1,200,000	495,000 – 90,000,000	9,400,000
Fecal Coliform (#/100 mL)	200	7,500 – 1,115,000	82,000	200,000 – 17,000,000	2,700,000
Fecal Streptococcus (#/100 mL)	100	13,800 – 730,000	140,000	295,000 – 1,570,000	580,000

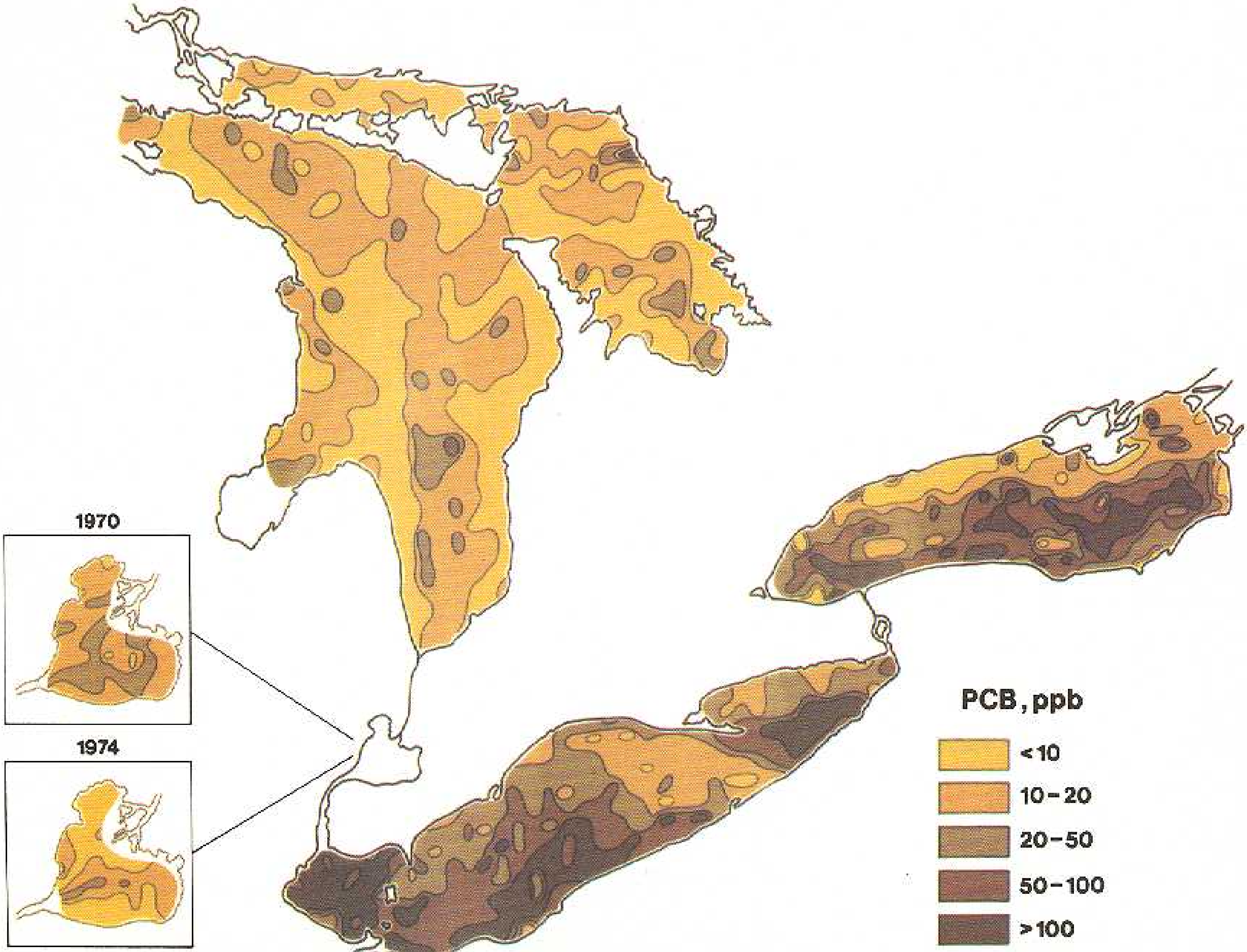


FIGURE 10: PCB CONCENTRATIONS IN SURFACE SEDIMENTS OF LAKES HURON, ERIE AND ONTARIO. (ppb = μg/kg)

dard at each site, no estimate can be made of the total impact of urban stormwater on the bacterial content of the lakes.

Evidence suggests some problems in the Great Lakes are caused by bacterial pollution from storm sewers. Bacterial pollution does, in any event, constitute a localized, short term problem. Lakewide nearshore surveys do not indicate any extensive, long term violations of bacterial water quality standards. Circulation patterns in the Great Lakes tend to dissipate bacterial populations rather quickly, except in areas of very restricted circulation.

1.6 SEDIMENT

The Problem

There has been a background input of sediment from shoreline erosion since the formation of the Great Lakes. With the clearing of forests for agricultural purposes, in the 19th century, sediment inputs from tributaries to the Great Lakes increased. The forests were previously an excellent protection for the soil. The leaf canopy dissipated the energy of rain and the thick litter of organic matter on the forest floor protected and bound together the parent soil material. However, with the removal of trees and the incorporation of the organic matter into deeper layers of soil, the exposed soil was subsequently subjected to erosion. This sediment input has been further augmented by construction activities in urban areas, where little or no effort is made in some jurisdictions to retain soil disturbed during excavation.

Sediment is considered to have a special role as a pollutant in the Great Lakes, particularly in the nearshore zones. It has been suggested that excessive sedimentation near fish spawning grounds could be detrimental to fish viability. More than $100 million are spent annually to dredge Great Lakes harbors so that shipping activities can continue unimpaired. High sediment levels in the lakes may pose aesthetic problems for recreational uses and may also present problems to drinking water treatment plants.

Sediment is primarily of concern, however, because of its ability to bind phosphorus, heavy metals, pesticides and other organic compounds (such as PCBs)[75]. PLUARG has determined that these materials can become bound to the clay size fraction of suspended solids ($< 2\ \mu m$ particle size) and move easily with water. These particles settle out only very slowly when they reach the open lakes. Their large surface area and slow settling rate can expose the clay-particle-associated pollutant to the lake water for an extended period of time. This may allow the pollutant to be released into the water column and become available for biological uptake. For example, in terms of tributary phosphorus loads, PLUARG studies have shown that between 40 and 80 percent of the total phosphorus load is associated with sediment. Thus, sediment can act as both a pollutant and as a carrier of pollutants. Sediment may also act as a sink for some pollutants under some conditions, with deposition in specific areas of sediment accumulation in each lake.

Loadings to the Great Lakes

Sediment sources in the Great Lakes include runoff from agricultural land, urban areas, forests and other land uses, as well as shoreline erosion. Data on tributary and shoreline erosion inputs of sediment[24,28,76,77] are presented in Table 11.

The absolute loads of sediment to the lakes should, however, be interpreted with caution when considering lake impacts. The sediment from shoreline erosion does not contain any man-made substances or anthropogenic elements prior to erosion. Sediments derived from agriculture have been found to contain elevated levels of phosphorus and some organic compounds. Sediments derived from urban construction activities have also been found to contain elevated levels of these substances, as well as trace elements. These pollutants become adsorbed onto the sediment particles, either while part of the parent soil material or in transport to the lakes.

Table 12 gives an indication of the percentage of the tributary pollutant loads to the lakes that are associated with sediments. In terms of an overall lake load, the sidement-associated fraction of many pollutants constitutes a substantial proportion of the total loading of that pollutant.

TABLE 11

LOADINGS OF SUSPENDED SOLIDS AND SEDIMENTS FROM SHORELINE EROSION TO THE GREAT LAKES BASIN

	metric tons/yr		
	Source		
Lake	Tributary (suspended solids)	Shoreline Erosion (total sediments)	Total
Superior	1,378,260	11,279,000	12,657,260
Michigan	706,540	21,778,000	22,484,540
Huron	1,052,960	1,763,000	2,815,960
Erie	6,531,800	11,131,000	17,662,800
Ontario	1,597,000	3,206,000	4,803,000
Total Great Lakes	11,266,560	49,157,000	60,423,560

TABLE 12

TRIBUTARY POLLUTANT LOADINGS ASSOCIATED WITH SEDIMENT

	metric tons/yr			
Lake	Phosphorus	Lead	PCBs	Mercury
Superior	2,419 (79.9)[a]	81 (7.1)	0.033 (—)	0.086 (>95)
Michigan	3,596 (—)	73 (4.0)	0.061 (—)	0.895 (>95)
Huron	3,025 (67.2)	51 (5.0)	0.013 (—)	0.120 (>95)
Erie	11,883 (35.7)	896 (40)	0.53 (26)	1.530 (>95)
Ontario	4,905 (51.3)	209 (33)	0.14 (20)	0.370 (>95)

Dash (—) indicates data not available
[a] (percent of total tributary load to lake for phosphorus; percent of load to tributary for lead, PCB's and mercury)*

*Footnote revised from first printing of this report.

INTERNAL SEDIMENT TRANSPORT

Many studies have been conducted on the dispersal and deposition of sediments in the Great Lakes System. Point source discharges of such materials as PCBs, mirex and mercury have served as sediment-bound tracers of industrial origin, and have provided an insight into the mode of transport of sediment in the Great Lakes by identifying dispersal pathways and areas of sediment sink.

Sediment entering the individual lakes, from their many tributaries and interconnecting channels, diffuses in a plume-like fashion, together with its transporting waters, into the nearshore zones, where particles commence settling at rates determined by particle size and density. Settling in the nearshore zone is intermittent. Physical processes, associated with turbulent mixing by wave action, result in resuspension and onward transportation of the sediment. With calm conditions, resettling occurs, but again of intermittent nature, until such particles are moved to depths where they are able to settle undisturbed. This produces deep water concentrations of fine particles and associated contaminants, as observed in Lakes Superior, Michigan, Huron and Ontario and the eastern basin of Lake Erie. The deep water basins of these lakes serve as sediment sink regions. In Lake St. Clair and the relatively shallow western and central basins of Lake Erie, sediments are not able to go to permanent sinks. This results in much fine grain sediment in Lake Erie moving to, and being deposited in, the eastern basin. Lake St. Clair remains in a state of perpetual perturbation by sediment resuspension and constitutes a nondepositing lake system. Thus, most of the sediment entering Lake St. Clair, from its tributaries and upstream Lake Huron, ultimately moves to Lake Erie. As an example of these phenomena, mercury derived from industrial sources in the St. Clair River is in the process of partial entrainment to a final sink in the eastern basin of Lake Erie.

In summary, some general statements may be made regarding the physical transport of sediment in the Great Lakes:

(a) contaminated sediment will settle temporarily in nearshore zones and will be transported until it arrives at a locality or depth where energy levels are insufficient to reinitiate particle motion;

(b) the general movements, when averaged, tend to be toward the east along the southern shores, with an anticlockwise component resulting in the spreading into deeper water basins, as displayed by mirex in Lake Ontario; and

(c) contaminated sediment may be physically transported long distances before coming to a sink. With highly active contaminants, this factor will invalidate a mixing zone concept, since it may well result in virtual whole lake contamination.

1.7 IDENTIFICATION OF POLLUTANTS OF LOCAL CONCERN OR FOR WHICH INSUFFICIENT DATA EXIST

In addition to the pollutants discussed above, several parameters were determined not to cause Great Lakes water quality problems from land use activities, or were identified only as a local problem (i.e., a water quality problem in tributaries or lakes draining to the Great Lakes). This is not meant to dismiss local water quality problems related to land use activities as unimportant, but rather to focus on Great Lakes concerns, as manifested in PLUARG's Terms of Reference. Information on pollutants of local concern is presented in many of the PLUARG documents listed in Appendix 3. In several cases, insufficient information was currently available for assessing the relationship between land use activities and Great Lakes water quality.

Trace Elements

Trace element concentrations in Great Lakes waters are presented in Table 13. The current International Joint Commission water quality objectives are also shown. In terms of water quality, there appears to be no environmental concern regarding these trace elements. It should be noted, however, that the objectives are based on total element content, rather than on particular chemical forms of the element (e.g., methylated form). Thus, a current water quality assessment alone may be misleading. In addition, the additive, synergistic and/or antagonistic effects of a mixture of heavy metals, for example, as might be found near an industrial outfall,

TABLE 13

CONCENTRATIONS OF TRACE ELEMENTS IN THE OFFSHORE WATERS OF THE GREAT LAKES

LAKE	μg/L							
	Mercury (0.2)[a]	Lead (10 – 25)[b]	Chromium (50)[b]	Cadmium (0.2)[b]	Copper (5.0)[b]	Zinc (30)[b]	Selenium (10)[b]	Arsenic (50)[b]
Superior	0.10 – 0.15	≤ 1.0	≤0.2	≤ 0.2	2.0 – 2.5	3.0 – 5.0	—	0.6 – 1.0
Michigan[c]	—	7.2[d]	6.8[e]	<2.0[f]	1.8[g]	—	—	<2.0[h]
Huron (open water)	≤ 0.05[i]	≤ 1.0	≤ 0.2	≤ 0.2	≤ 2.0	≤ 7.0	≤ 0.1	≤ 0.6
Erie	≤ 0.5	<1.0 – 3.0	—	<0.2	1.0 – 2.5	2.0 – 9.0	≤ 0.1	0.3 – 0.6
Ontario	0.12	0.7	—	≤ 0.2	1.2	2.2	—	—

[a] objective for mercury is for a filtered sample; all other objectives are for total element concentration
[b] International Joint Commission objectives (μg/L)
[c] all samples taken in 1977; sample locations vary from nearshore to a maximum of 30 km outward from the shore
[d] mean of 101 samples; probably high as most samples were below 6.0 μg/L detection limit
[e] mean of 103 samples; probably high as most samples were below 3.0 μg/L detection limit
[f] mean of 102 samples; probably high as most samples were below 2.0 μg/L detection limit
[g] mean of 99 samples; probably high as most samples were below 1.0 μg/L detection limit
[h] mean of 11 samples; probably high as most samples were below 2.0 μg/L detection limit
[i] value for Georgian Bay
Dash (—) indicates data not available
Lake Michigan data from U.S. Environmental Protection Agency; other data from other sources[37,81].

have not been considered in formulating these objectives. To illustrate this point, a mixture of all the trace elements listed in the International Joint Commission's revised Water Quality Objectives[78], proved highly toxic to algae at concentrations given in the objectives, as well as at 50 and at 10 percent of the proposed objective concentrations[79].

The single metal objectives may also be too high. The currently proposed objective of 25 μg/L total lead in Lake Ontario could prove harmful to aquatic life. Current studies in Canada indicated that symptoms of lead toxicity to fish and snails occurred at 22 and 17 μg/L concentrations, respectively[80]. These levels are below the proposed International Joint Commission objective for lead.

Concentrations of trace elements in Great Lakes fish, with the exception of mercury, are currently well below any accepted guideline. This situation could change, however, given the potential for methylation in the lakes, (e.g., lead, as discussed previously). The trace elements indicated in Table 13 do not contravene Great Lakes water quality objectives. This is not to say that they should be ignored, especially since knowledge concerning the effects of these elements on the behavior, growth and reproduction of fish and other aquatic organisms in the lakes is sparse.

Nitrogen

Nitrogen, an aquatic plant nutrient, is not a limiting nutrient in the Great Lakes, except in some nearshor and embayment areas of restricted circulation. It is a concern in the Great Lakes Basin mainly as it contributes to contamination of potable ground water supplies. As such, nitrogen is primarily a local water quality problem. In the form of nitrate, nitrogen is extremely mobile and can move readily through the soil profile to ground water supplies. This potential problem may be of concern from a health viewpoint, in areas where ground water constitutes the major source of water for human and livestock consumption.

Chlorides

Extensive use of sodium chloride deicing salt in the Basin began in the early 1950's, with the expansion of the highway system and the growth of urban areas. Governments adopted a "bare pavement" policy for major arterial roads, with salt use increasing steadily as a result.

Chloride levels in the Great Lakes, except Lake Superior, have been steadily increasing since the turn of the century. However, deicing salts alone have not accounted for this total increase. Industrial sources of chlorides to the lakes account for 57 – 93 percent, depending on the lake, of the total chloride load at present.

In the nearshore zones, and in some harbors and embayments of the lakes, typical mean spring chloride concentrations are higher than lakewide average concentrations. However, these elevated levels have not been proven to be deleterious to any use of the water. Spring chloride levels were used in this evaluation in an attempt to assess the elevation of chloride as correlated with the melting and subsequent runoff of salt-laden snow in urban areas[81].

Most Great Lakes jurisdictions have a drinking water standard of 200 mg/L, or higher. By contrast, the levels of chloride regarded as safe for aquatic life are measured in thousands of milligrams per liter[82]. There has been a suggestion that shifts in phytoplankton species to more salt-tolerant species may occur at concentrations around 10 mg/L, but this has not yet been proven.

A reduction in the application of road deicing salts may be desirable for a variety of other reasons, including local water quality problems, automobile corrosion, damage to terrestrial vegetation, etc. However, in terms of Great Lakes water quality, diffuse loadings of chloride have not been identified as an environmental concern. It is predicted that current levels of road deicing salt use will increase by the year 2020 to 10–15 percent above current levels[2]. It seems unlikely that this increase will have any significant impact on the environmental health of the Great Lakes. As such, chlorides are primarily a local water quality problem in the Basin.

Asbestos

Asbestos in the aquatic environment has received considerable attention in the past, particularly in regard to its potential health hazards in the Lake Superior basin. In 1975, the Research Advisory Board of the International Joint Commission reported its findings[83] concerning asbestos in the Great Lakes, including sources and efficiency of current treatment procedures. The Upper Lakes Reference Group[37] has also examined the asbestos problem in Lakes Superior and Huron. For these reasons, PLUARG did not address the topic of asbestos. Asbestos is primarily a nearshore problem and, other than from natural weathering of rock, from redistribution within the lakes and from atmospheric inputs from vehicular brake linings, is derived mainly from point sources.

Viruses

PLUARG did not address the question of whether the Great Lakes are being polluted by viruses from land use activities or the atmosphere. Data on in-lake levels and sources are too sparse to allow a reliable analysis to be conducted. However, there could be a threat to human health from waterborne viruses, particularly if past immunization practices (e.g., polio vaccinations, etc.) become relaxed.

Pesticides

In addition to the pesticides discussed in chapter 1.4, numerous other pesticides were studied in the pilot watersheds. These latter pesticides, discussed below, were generally not found to affect Great Lakes water quality.

ATRAZINE

PLUARG studies included rivermouth monitoring for atrazine, a herbicide associated with corn growing. Atrazine was detected in virtually every rivermouth sample taken in southern Ontario. However, in terms of an impact on Great Lakes water quality, atrazine is not regarded as a problem at this time. Residues of atrazine were not found in fish. This may be because atrazine is water soluble, with a bioaccumulation factor of only a few hundred fold (as compared to one million fold for PCBs).

HEPTACHLOR-HEPTACHLOR EPOXIDE

PLUARG data indicate this compound is not presently a Great Lakes water quality problem. Heptachlor was banned in Ontario in 1969 and is scheduled to be banned in the United States in 1978. With these restrictions, no future problems with this pesticide are anticipated for the Great Lakes.

OTHER PESTICIDES

There are a variety of new pesticides (e.g., organophosphates, carbamates) currently in use in the Basin. These pesticides generally possess chemical characteristics making them less environmentally hazardous. They either rapidly degrade in the environment or else they do not bioaccumulate. PLUARG rivermouth monitoring and data on Great Lakes biota did not reveal the presence of any of these new pesticides, although future periodic monitoring should be conducted.

Acid Precipitation

Acid precipitation refers to acid rainfall produced by the absorption of oxidized sulfur and nitrogen compounds by moisture in the air. The resulting rainwater is a weak acid and can have a pH value as low as 3. This problem has received considerable attention in the literature and was discussed in the 1977 Annual Report of PLUARG[66]. Acid precipitation is a local water quality problem, particularly in some of the inland lakes of upstate New York and in the Canadian Shield lakes of Ontario.

In terms of Great Lakes water quality, however, acid precipitation has no measurable effect at present, except in two isolated embayments in Georgian Bay, and is not likely to in future years. The volume of water in the Great Lakes is great, and their buffering capacity substantial. Calculations indicate that if all the buffering in the inflow waters to Lake Superior were instantly removed, it would take Lake Superior many centuries to have its pH substantially reduced. Obviously, such a situation is unlikely to arise. In addition, the other Great Lakes are even more strongly buffered, and the likelihood of their pH changing because of acid rain is even more remote.

1.8 CONCLUSIONS FROM LAKE STUDIES

In response to the first reference question (Appendix 1), pollution of the Great Lakes is now occurring due to diffuse source inputs of phosphorus, sediment, mercury, PCBs and to a minor extent, microorganisms. Inputs of lead from land use activities, while not currently a Great Lakes environmental problem, warrant continued monitoring. Residues of DDT and dieldrin, derived from past pesticide usage in the Basin, were found in Lake Michigan fish. Chlordane was found in fish in Lakes Ontario and Erie. Contamination of Lake Ontario fish by mirex and HCB has also been detected.

In addition to these above materials, which are currently, or could become water quality problems in the lakes, there are also materials which have the potential to become pollutants from land use activities, or whose roles as pollutants will intensify because of projected increases in their usage[2-4] between now and the year 2020. These projected increases may occur as a result either of population increases or of changes in land usage or increases in intensity of use, especially for aquatic plant nutrients and sediments.

The input of phosphorus to the Great Lakes is strongly linked to man and his activities. The current influence of man's activities on Great Lakes eutrophication will be alleviated to some degree through completion of present point source control activities. Some degree of nonpoint source control will have to be initiated in Lake Huron, Erie and Ontario jurisdictions in order to achieve the proposed target loads for these water bodies (Figure 7). However, because there is a relatively constant phosphorus contribution per person in municipal wastes, these reductions in current phosphorus inputs will be countered by projected increases in the current Great Lakes Basin population, from about 36 million to 54 million in the year 2020. A 37 percent increase in urban land area is forecast for this same time period. Since the unit load for most pollutants is higher for urban lands than for forested or agricultural lands, this would suggest an increase in the phosphorus load to the Great Lakes under current conditions of phosphorus control. Projected increases in nonsewered residential areas and recreational areas will also likely result in increased phosphorus loads to the Great Lakes. The majority of this increase is forecast for the Lake Erie and Ontario basins, already the basins most influenced by phosphorus inputs.

There is also a projected increase in most specialized land uses in the Great Lakes Basin. Disposal sites of all kinds offer a potential for impacting Great Lakes water quality. Potential pollutants from disposal sites include trace elements, nitrogen, phosphorus, toxic organic compounds, suspended solids and pathogens. The amounts of wastes to be disposed of are projected to increase in the future in response to projected population and economic changes in the Great Lakes Basin.

Attention is focused in the remaining chapters of this report on the identification of nonpoint pollutant sources to the Great Lakes and the quantification of inputs from these sources, as well as on remedial measure options for their control.

In response to the mandate given PLUARG, discussion in subsequent chapters will generally be limited to materials determined to be a Great Lakes water quality problem (either in the open waters or nearshore areas), which have been derived largely from land use activities in the Great Lakes Basin.

2. SOURCES OF DIFFUSE POLLUTANTS

2.1 INTRODUCTION

Chapter 1 established that phosphorus, sediment, PCBs and mercury, and to a minor extent, bacteria, as derived from land use activities, are currently affecting Great Lakes environmental quality. This chapter identifies the general sources of these pollutants and discusses their relative importance.

PLUARG pilot watershed study data, integrated with land use, materials usage and rivermouth loading data, forms the basis for this chapter. The major land uses and land management practices represented by the pilot watersheds described in the introduction are presented in greater detail in the appropriate PLUARG technical reports[12–20].

2.2 POLLUTANT CONTRIBUTIONS FROM MAJOR LAND USES AS DETERMINED BY PILOT WATERSHED STUDIES

Unit Area Loads

Unit area loads are calculated by dividing total pollutant contributions from a given land area by the size of the land area. Unit area loads help compare nonpoint pollutant contributions between different land uses. Pilot watershed investigations determined a large number of pollutant unit area loads for areas with a single dominant land use. These data, generally based on two years of intensive monitoring, are presented in Table 14, which shows the ranges of unit area loads for several pollutants.

The wide ranges in unit area loads for each land use category in Table 14 result from variations in soil type, physiography, watershed area and land use. In a few instances, climatic extremes encountered in the watersheds during the period of record caused wide variability. For example, a one-in-a-hundred year frequency storm in a portion of the Maumee basin in 1975 caused as much as a one hundred fold greater sediment yield for 1975, as compared to 1976. The importance of watershed characteristics and climatic variations is also discussed in this chapter.

Comparison of Unit Area Loads from Different Land Uses

Comparisons and ranges of unit area loads by dominant land use from the pilot watershed studies are presented in Tables 14 and 15.

Information specific for predominantly rural and urban land use is presented. More general combinations of these uses are also presented for comparative purposes under the headings "general agriculture" and "general urban". Because the general agriculture category includes the range of agricultural land uses, its range of unit area loads is generally greater than the unit area load for any single agricultural land use. A similar situation exists for the general urban category.

Unit area load ranges presented in Table 15 indicate that unit area loads of suspended sediment, phosphorus and nitrogen from intensive agricultural (i.e., cropland) and urban land uses are approximately the same order of magnitude. Unit area loads from both categories are 10 to 100 times greater than those of forested and/or idle land. Forested and idle land unit area loads are at or near background levels. Unit area loads for improved pasture overlap the upper range of forested and/or idle land categories and the lower range of the cropland category. Unit area loads of lead from general urban lands are about 10 times greater than the upper range of general agriculture and cropland. Phosphorus unit area loads for wastewater spray irrigation approximate the loads from general agriculture, cropland and urban categories, while nitrogen unit area loads from wastewater spray irrigation are up to 10 times greater than those from other land uses.

Factors Affecting Pollution from Land

PLUARG studies indicate that land use is not the only land-associated factor influencing Great Lakes water quality. Consequently, PLUARG has identified additional factors contributing to the variances in unit area loads observed for single dominant land uses.

The most important factors influencing the magnitude of pollution from land use activities are the physical, chemical and hydrological characteristics of the land, land use intensity and materials usage. Meteorological conditions also affect annual and seasonal variations in pollutant contributions from land use activities. An understanding of these factors and the way they influence nonpoint source pollution is essential. The evaluation of these factors leads to the identification of those portions of a watershed which are more hydrologically active than other areas of the same watershed. A hydrologically active area is an area within a watershed which produces significant amounts of runoff, even during relatively minor rainfall and snowmelt events. Areas with predominantly flat slopes and poorly-drained soils and which are located near enough to a water body that runoff waters are delivered very efficiently, are particularly active under conditions when the soil moisture content is at a level which reduces the infiltration of additional water. Under these conditions, less hydrologically active areas may become more hydrologically active. In rural areas, pilot watershed studies have presented examples in which 15–20 percent of the land surface contributed up to 90 percent of the total sediment load from the watershed. In urban areas, the amount of connected impervious surface can be used to identify hydrologically active areas. Generally, connected impervious surface area is correlated with population density and land use intensity.

Remote sensing techniques sensitive to soil moisture and impervious surface areas can be used to rapidly identify hydrologically active areas. Several remote sensing techniques were evaluated during the PLUARG study and, although further refinement is necessary, these techniques show great potential for rapid and accurate identification of land characteristics now requiring time-consuming field investigation. Because soil moisture content and land use management often vary with season, the size of the hydrologically active area and the importance of land management will vary

TABLE 14

UNIT AREA LOADS OF SELECTED MATERIALS BY LAND USE FROM PILOT WATERSHED STUDIES

Land Uses[a]	ANNUAL UNIT AREA LOADS (kg/ha/yr)							
	Suspended Sediment	Total Phosphorus	Filtered Reactive Phosphorus	Total Nitrogen	Lead	Copper	Zinc	Chloride
I. RURAL								
General Agriculture								
Genesee	30 – 900	0.1 – 1.1	0.01 – 0.16	4 – 22	—	—	—	—
Grand/Saugeen	3 – 2,200	0.1 – 2.3	0.01 – 0.5	0.6 – 24	0.002 – 0.08	0.002 – 0.09	0.005 – 0.3	10 – 120
Maumee	500 – 5,600	1.4 – 9.1	0.2 – 0.5	—	—	—	—	—
Menomonee	230 – 410	0.3 – 0.6	0.2	14	0.1	0.06	0.1	90
Agricultural watersheds	30 – 800	0.1 – 1.5	0.02 – 0.6	3.2 – 42	0.004 – 0.015	0.013 – 0.064	0.019 – 0.189	—
Cropland								
Maumee	80 – 5,100	0.8 – 4.6	0.05 – 0.3	—	—	—	—	—
Mill Creek	20 – 70	0.2 – 0.6	0.1 – 0.3	4.3 – 10	—	—	—	10 – 50
Agricultural watersheds	400 – 800	0.9 – 1.5	0.3 – 0.4	16 – 31	0.005 – 0.006	0.014 – 0.064	0.026 – 0.083	—
Improved Pasture								
Agricultural watersheds	30 – 80	0.1 – 0.5	0.02 – 0.2	3.2 – 14	0.004 – 0.015	0.021 – 0.038	0.019 – 0.172	—
Forested/Wooded								
Genesee	7 – 820	0.02 – 0.67	0.01 – 0.03	1 – 6	—	—	—	—
Grand/Saugeen	30 – 50	0.1	0.01	4.8 – 5.6	0.01 – 0.03	0.02 – 0.03	0.01 – 0.03	20
Forested watersheds	1 – 5	0.04 – 0.2	0.03 – 0.1[b]	1.7 – 6.3	—	—	—	2 – 10
Idle/Perennial								
Felton-Herron	10 – 30	0.1 – 0.2	0.02 – 0.07	0.5 – 1.5	—	—	—	35
Genesee	7 – 820	0.02 – 0.67	0.01 – 0.03	1 – 6	—	—	—	—
Grand/Saugeen	30 – 50	0.1	0.01	4.8 – 5.6	0.01 – 0.03	0.02 – 0.03	0.01 – 0.03	20
Sewage Sludge								
Grand/Saugeen	—	0.2	0.01	11	0.01	0.005	0.2	10
Wastewater Spray Irrigation								
Felton-Herron	—	0.4 – 1.4	0.1 – 1.3	2.2 – 5.6	—	—	—	40 – 160
Grand/Saugeen	—	0.2	—	370	—	—	—	—

II. URBAN:								
General Urban								
Grand/Saugeen	400 – 1750	0.7 – 2.1	0.05 – 0.12	6.7 – 10	0.3 – 0.5	0.05 – 0.13	0.3 – 0.6	130 – 270
Memomonee	210 – 280	0.3 – 0.9	0.3	6.2	0.14	0.07	0.3	380
Residential								
Grand/Saugeen	620[c]	0.4[c]	—	5.0[c]	—	—	—	—
Menomonee	830 – 2,300	0.9 – 1.3	0.2	7.3	0.06	0.03	0.02	1,050
Commercial								
Grand/Saugeen	830[c]	0.9[c]	—	11[c]	—	—	—	—
Menomonee	50 – 660	0.1 – 0.4	0.02 – 0.08	1.9 – 2.2	0.17 – 1.10	0.07 – 0.13	0.25 – 0.43	10 – 150
Industrial								
Grand/Saugeen	1.080[c]	0.9[c]	—	14[c]	—	—	—	—
Menomonee	400 – 1,700	1.1 – 4.1	0.3	1.9	2.2 – 7.0	0.29 – 1.3	3.5 – 12.0	—
Developing Urban								
Menomonee	27,500	23	0.1	63.0	—	—	—	75 – 160

Dash (—) indicates data not available.
[a]Dominant land uses, as defined in pilot watershed study reports[11].
[b]Total dissolved phosphorus.
[c]Data obtained from Canada/Ontario Agreement Studies.

TABLE 15

SUMMARY OF RANGES OF UNIT AREA LOADS OF SELECTED MATERIALS BY LAND USE FROM PILOT WATERSHED STUDIES

	ANNUAL UNIT AREA LOADS (kg/ha/yr)							
Land Uses[a]	Suspended Solids	Total Phosphorus	Filtered Reactive Phosphorus	Total Nitrogen	Lead	Copper	Zinc	Chloride
I. **RURAL:**								
General Agriculture	3 - 5,600	0.1 - 9.1	0.01 - 0.6	0.6 - 42	0.002 - 0.08	0.002 - 0.09	0.005 - 0.3	10 - 120
Cropland	20 - 5,100	0.2 - 4.6	0.05 - 0.4	4.3 - 31	0.005 - 0.006	0.014 - 0.064	0.026 - 0.083	10 - 50
Improved Pasture	30 - 80	0.1 - 0.5	0.02 - 0.2	3.2 - 14	0.004 - 0.015	0.021 - 0.038	0.019 - 0.172	—
Forest/Wooded	1 - 820	0.02 - 0.67	0.01 - 0.10[b]	1 - 6.3	0.01 - 0.03	0.02 - 0.03	0.01 - 0.03	2 - 20
Idle/Perennial	7 - 820	0.02 - 0.67	0.01 - 0.07	0.5 - 6.0	0.01 - 0.03	0.02 - 0.03	0.01 - 0.03	20 - 35
Sewage Sludge	—	.02	0.01	11	0.01	0.005	0.2	10
Wastewater Spray Irrigation	—	0.2 - 1.4	0.1 - 1.3	2.2 - 370	—	—	—	40 - 160
II. **URBAN:**								
General Urban	210 - 1750	0.3 - 2.1	0.05 - 0.3	6.2 - 10	0.14 - 0.5	0.05 - 0.13	0.3 - 0.6	130 - 380
Residential	620[c] - 2,300	0.4[c] - 1.3	0.2	5[c] - 7.3	0.06	0.03	0.02	1,050
Commercial	50 - 830	0.1 - 0.9[c]	0.02 - 0.08	1.9 - 11[c]	0.17 - 1.10	0.07 - 0.13	0.25 - 0.43	10 - 150
Industrial	400 - 1,700	0.9[c] - 4.1	0.3	1.9 - 14[c]	2.2 - 7.0	0.29 - 1.3	3.5 - 12.0	—
Developing Urban	27,500	23	0.1	63.0	—	—	—	75 - 160

Dash (—) indicates data not available.
[a]Dominant land uses, as defined in pilot watershed study reports[11].
[b]Total dissolved phosphorus.
[c]Data obtained from Canada/Ontario Agreement Studies.

with the season of the year. The factors which affect the amount of pollutant produced by various land use activities are discussed below in greater detail.

LAND CHARACTERISTICS

Land characteristics include soil type, surficial geology, geomorphology and soil chemistry. These characteristics are, in many cases, interrelated but generally describe the nature or "form" of the land. While most sites have certain unique characteristics, generalizations concerning the importance of basic land characteristics have emerged for the Basin.

The most important land characteristic is soil type, indicated by differences in soil texture or particle size. Runoff is greater from fine-grained, low permeability soils such as clay, compared to coarser-grained sandy soils, having higher infiltration rates. Pollutants tend to associate with clay-sized soil particles. Since these particles are suspended readily by rainfall impact and runoff and settle out only in very slowly flowing water, there is a high possibility of clay-sized particles being transported to the lakes.

Further evidence of the influence of soil type on pollutant loadings is seen in the better water quality (with respect to sediment and phosphorus) observed in areas with sandy soils (e.g., the upper Lake Michigan basin), indicating higher infiltration rates and coarse-sized particles than areas with clay soils (e.g., Lake Erie basin), having similar land use, but poorer water quality.

Surface soil and vegetation affect the amount of precipitation infiltrating to ground water. In areas where rapid infiltration occurs, certain pollutants may be carried into ground water, while others will be retained by sorption in the soil profile.

In cases where discharge to the ground water system is direct, as with a poorly designed sanitary landfill, the less mobile pollutants will rapidly decline due to adsorption as water moves through the porous substrate. In general, the pollutants moving into ground water are anions, such as chloride and nitrate.

In agricultural areas, movement of these ions to surface waters and away from ground waters may be facilitated by drain tiles.

Physiographic characteristics, such as slope and drainage density, are important and explain problems associated with specific sites. For example, assuming a constant clay content, a clay soil on a steep slope represents a greater pollution problem than a clay soil on flat land. Also, the potential for the movement of pollutants to receiving waters increases with greater drainage density.

Surficial geology is an important land characteristic related to soil chemistry. Natural soil fertility affects nutrient losses. For example, natural phosphorus, contrasted with fertilizer phosphorus, accounts for a large percentage of the phosphorus loss from agricultural lands. Calcareous soils in the Basin contribute higher unit loads of dissolved phosphorus than other soil types with similar land uses.

LAND USE INTENSITY

The intensity with which land is used may have a major impact on its pollutant contribution. For example, how land is farmed, or the degree of industrialization, are major characteristics affecting potential pollutant contributions from land areas.

Any land practice which exposes soil to the erosive forces of wind, rainfall and runoff increases the pollutant contribution from the land. In general, the greater the canopy and ground cover protection, the lower the erosion potential. Following is a list of rural land uses, illustrating progressively greater erosion potential: permanent pasture; small grains; corn in rotation; continuous corn; white beans and similar cash crops; some horticultural crops; and bare land.

Of the cultivated lands in the Basin, widely spaced row crops contribute the greatest quantities of sediments and associated pollutants. Studies indicate that developing areas, with soil-exposing construction sites, are one of the major urban land use concerns, in terms of unit area pollutant loads.

Phosphorus loads also originate on feedlots, barnyards, manure storage areas and on farm land receiving winter-spread manure. In a number of agricultural watersheds, these sources contribute about 20 percent of the total agricultural phosphorus load. However, the range of values are wide, since livestock density, location of buildings vis-a-vis streams and the presence or absence of vegetative buffer strips near streams all markedly affect loads from these sources. Among the various animal enterprises, cattle operations, either dairy or beef, were found to exert the greatest influence on water quality, since the animals are frequently fed in "outside lots" or are assembled frequently in outside yards.

In some intensely farmed areas, such as parts of the Lake Erie basin, artificial drainage (e.g., tile drains) is practiced to increase crop production. More than 50 percent of the cropland in the Maumee River basin is tile drained. Although tile drainage has not been generally used as a soil erosion control practice, it can reduce soil loss and associated pollution by reducing runoff on poorly drained soils. These soils are often clay soils, which have high unit area yields of fine-grained pollutant-bearing soil particles.

Cultivation practices also affect pollutant contributions from farm land. For example, the type and timing of tillage practices affect the amount of soil exposed to possible erosion. Many soils in the Great Lakes Basin are wet, and difficult to till during early spring, causing many farmers to plow during the fall. Although fall plowing generally increases crop yields, it also exposes the soil for a long period, increasing erosion potential. Larger, more continuous row cropping systems lead to higher sediment loads. Farming close to streams reduces the vegetative buffer, increasing the chances for soil transport to the watercourse or drainage system.

Soils rich in organic matter, such as peat or muck, can be a source of nutrients and other materials (e.g., trace metals) when they are drained and heavily cultivated. Such soils can yield large quantities of nutrients, due to high decomposition rates and excessive fertilizer applications. However, intensively-farmed organic soils are not widespread in the Basin.

In forested ecosystems, clearcutting and scarification result in exposure of soil. While these practices can cause increased pollutant loads, these increases are generally small. Since re-vegetation is usually rapid following harvest (two to five years), the effects are short term.

Atmospheric fallout from vehicular exhausts, a source of lead to all land surfaces, is particularly important around intensive transportation corridors. In addition, these corridors, particularly in urban areas, are an intensive land use, producing unusual accumulations of chloride, pesticides, oil, grease and heavy metals.

In urban areas, the amount of connected impervious cover, industralization, and factors such as tree density and animal population, can also affect pollutant contributions. In urban drainage studies, a high correlation was found between the amount of runoff and the amount of associated pollutants. In the Menomonee basin, it was found that the pollutant concentrations in urban drainage did not vary much with flow. Residential areas with a high tree density can contribute leaf litter and seed/pollen which, when leached by rainwater, contributes to the phosphorus load.

The design of urban stormwater management systems was found to be related to the level of development and the intensity of the land use. Typically, lower density developments do not have well developed storm sewer systems. Thus, the amount of water which runs off these areas is less than that from high density areas. The way in which stormwater is handled may affect water quality, since the larger flows resulting from high density urban areas can carry significantly greater quantities of pollutants and sediments and can increase stream bank erosion. Proper design of urban stormwater systems will provide for more nearly natural hydrologic conditions and reduce the amount of connected impervious surfaces.

MATERIALS USAGE

Materials applied to land, combined with land characteristics and land use intensity factors, influence the quality of drainage water. These materials include commercial fertilizers, manure, pesticides and road salts.

Commercial fertilizer applications on both agricultural and urban land may increase nutrient loads above normal levels. PLUARG studies indicate that fertilizer application is not a major cause of nonpoint phosphorus pollution in the Basin. However, a large portion of the nutrients lost from agricultural land is accounted for by the high natural nutrient content in most soils used for intensive agriculture.

Failure to incorporate fertilizers into the soil exposes the fertilizer to wind and runoff. This runoff contains increased levels of soluble phosphorus and nitrate. Furthermore, excessive fertilizer application produces increased phosphorus loads.

Manure applications can contribute to the pollutant load in runoff. As with commercial fertilizers, failure to incorporate manure into the soil leads to higher soluble phosphorus and nitrogen concentrations in runoff waters. For example, spreading manure on frozen soil leaves the manure exposed and produces increased levels of soluble nutrients in runoff. Manure storage or livestock feeding areas may also cause problems. However, like commercial fertilizers, manure applications were not found to be the major cause of pollution from agricultural land.

Storage of farm products other than manure may also cause water quality problems. For example, farm silos can cause pollution when drainage liquor from the silos flows into a stream or drainage system. Barnyard and milk house drainage can also contaminate sub-surface drainage systems.

Pesticides are widely used in the Basin and, if persistent (i.e., not rapidly degraded in the environment), can be carried off the land. They can continue to contaminate drainage water long after their use is discontinued. Contamination of aquatic organisms in the lakes has resulted from the runoff of DDT (now banned) and its derivatives. Pesticide use is now closely controlled, and, with present pesticides, persistence or carryover is essentially eliminated. Pesticide problems sometimes result from careless handling or accidental spills.

Orchards often have high pesticide application rates. Guthion, an example of a current organophosphate broad spectrum pesticide, is commonly used on fruit orchards in many parts of the Basin. Although sometimes found in orchard drainage waters, Guthion and similar materials degrade rapidly and do not pose a threat to Great Lakes water quality. However, residues of organochlorine pesticides, such as DDT, are still found in orchard drainage.

Elevated chloride levels in ground and surface waters at highway study sites were often found. Although salt use as a de-icing agent appears to have greatly increased in recent years, no deleterious effects on the lakes are apparent.

Small increases in the future are anticipated in the use of pesticides, manures, fertilizers and road salts in the Basin. This projection assumes no major shifts in agricultural production practices, either in technology or crop type, in the next 10 to 15 years.

Fertilizer increases are expected to be greatest for nitrogen, with phosphorus use remaining the same or declining. However, if there is a shift toward more intensive cultivation, phosphorus may be applied at higher rates in certain areas of the Basin and could lead to increased phosphorus in drainage waters. The greatest use of fertilizers, manures and pesticides occurs in the Lake Erie basin.

METEOROLOGY

Annual unit area loads can vary significantly, depending on the precipitation. Meteorological factors affecting runoff and associated erosion include rainfall intensity, duration and frequency and snow cover. Annual variations occur even when land characteristics, land use intensity and materials usage remain unchanged. Unit area loads generally increase in proportion to increases in stream flow or runoff.

Most study data were collected during 1975 and 1976. Tributary flows during this period were higher than long term averages. The Lake Michigan basin, as well as the U.S. portions of the Lakes Ontario and Huron basins, had higher flows in 1976. This was particularly true for Lake Ontario. Unit area loads measured at rivermouths were also higher for the tributaries of these lakes in 1976. Since the Great Lakes Basin covers a large geographical area, annual climatic variations are considerable across the Basin. Thus, tributary flows must be considered when evaluating unit area loads for a given year.

Annual loads from a unit of land are not evenly distributed, with large portions of the annual load occurring during major runoff events. The most critical period for runoff events from agricultural land occurs between the time of snowmelt and the establishment of vegetative cover. Some erosion occurs during the summer growing season as a result of intense thunderstorms.

2.3 POLLUTANT CONTRIBUTIONS FROM OTHER SOURCES

Combined sewer overflows, nonsewered waste disposal, transportation corridors, streambank erosion, microorganisms, pesticides and toxic organic compounds do not lend themselves to strict unit area load calculations. Major regional differences, management considerations, density effects and the fact that some loadings are independent of land area, require a more generalized reporting method for these sources.

Combined Sewer Overflow

Combined sewer overflows are a problem specific to certain urban centers, particularly older urban areas. When overflows occur, wastes containing phosphorus, microorganisms and other pollutants are discharged directly to streams or lakes. In certain large cities, combined sewer overflows, although quite variable, often increase the total phosphorus load from urban areas by up to 10 percent.

Nonsewered Waste Disposal

Small scale, private waste disposal systems (i.e., septic systems) are not a major source of Great Lakes pollution. The only pollutants found from this source were phosphorus and, to a lesser extent, nitrogen, from improperly designed or maintained systems. Bacterial contamination may also occur as a result of faulty private waste disposal systems. In areas where large urban and rural populations use private waste disposal systems, some local impact on water quality was found.

The control of water quality problems related to septic system failure is carried out on a sporadic basis. In many cases, failing systems are not identified until they become completely inoperative. Adequate resources for routine inspection are not generally available in the Basin.

Sanitary Landfills

Sanitary landfills are not a major source of pollutants to the lakes. Increased levels of chlorides, heavy metals and some toxic organic compounds, from poorly designed or mismanaged sanitary landfills, occur. Some persistent toxic organic compounds, such as PCBs, may be partially derived from landfills, although the relative importance of this source, as compared to other sources affecting the Great Lakes, is not yet known. However, properly designed, well-managed landfills, using the soil's natural removal capacity, accompanied by leachate treatment where necessary, minimize potential impacts and present no threat to Great Lakes water quality at present.

Pesticides and Other Toxic Organic Substances

Of the variety of pesticides monitored, only a limited number were occasionally detected in drainage waters. Levels were too low to calculate precise pesticide load estimates. Among the pesticides detected were atrazine, derivatives of DDT, dieldrin, lindane, endrin, heptachlor and endosulfan. Mirex was not detected in the pilot watershed studies. Of the pesticides currently used, only atrazine was frequently identified in stream samples. Atrazine is used widely in corn-producing areas, but its use has probably peaked, as there is currently some shifting to other herbicides. Despite its widespread use, atrazine does not appear to be a hazard since it degrades rapidly in the environment.

PCBs were detected in several pilot watershed studies. Calculated PCB unit loads from urban drainage areas range from 0.003 to 0.26 g/ha/yr. Agricultural watershed loads of PCBs ranged from 0.08 to 0.22 g/ha/yr. Unfortunately, information is lacking on PCB contributions from other sources. Thus, it is difficult to assess the importance of land-derived PCB sources. It appears, however, that the atmospheric inputs constitute a major portion of the PCB load.

Microorganisms

Monitoring in several watersheds indicated that microbiological quality at some sites exceeded standards for recreational quality. Urban and agricultural areas contribute fecal indicator bacteria and, in some cases, pathogenic *Salmonella* and *Pseudomonas aeruginosa*. The source of these organisms in urban areas is thought to be fecal material from domestic animals, wildlife and combined sewer overflows.

In agricultural areas, livestock wastes contribute significantly to microbial water quality, although it is not possible to show a direct relationship between livestock numbers and water quality.

No estimates could be made of the transmission of pathogenic microorganisms to the lakes. However, previous work suggests that bacterial die-off is likely to be rapid, particularly during the summer when microbial inputs appear to be greatest. It is likely that bacterial contamination may be locally hazardous where surface waters are used for contact recreational purposes and/or as a water supply. Bacterial contamination from runoff does not appear to be a serious water quality problem.

Streambank Erosion

Streambank erosion is not a major pollutant source to the lakes. The total annual streambank sediment contribution of 827,000 metric tons accounts for only about seven percent of the estimated total tributary sediment load. The estimated phosphorus load from streambank erosion, 426 metric tons, accounts for only about two percent of the total tributary phosphorus load.

Streambank erosion contributes only a small quantity of pollutants, relative to sheet and rill erosion. Areas having a low intensity use, such as forestry and permanent grassland, and low or moderately erodible soils, have low sediment unit loads (e.g., 10 kg/ha/yr) attributable to bank erosion. Areas with a high intensity use, such as cash cropping and highly erodible soils, may have bank erosion unit loads in excess of 200 kg/ha/yr.

Groundwater Inputs

Groundwater discharge (i.e., base flow) is a significant portion of the dry weather flow of Great Lakes tributaries. Base flow is a large portion of the tributary nonpoint pollutant load to Lakes Superior, Michigan, Huron and Ontario. Base flow inputs of materials are generally representative of near natural conditions, except where groundwater contamination (e.g., nitrate and chloride) occurs.

Miscellaneous Specialized Land Uses

PLUARG considered several specialized land uses, including mine tailings land disposal areas, sludge disposal on land, liquid and solid waste disposal areas, deepwell disposal areas, mineral extractive areas and recreational land. In general, these specialized land uses do not appear to cause significant water quality problems. Mismanagement, however, may lead to pollutant inputs from these sources.

Sewage sludge disposal on land is a nutrient source similar to contributions from farmyard manure. Unlike manure, however, it is generally contaminated with high levels of heavy metals and organic contaminants.

2.4 TRANSMISSION OF POLLUTANTS BY TRIBUTARIES TO THE GREAT LAKES

When evaluating the extent of nonpoint pollution, as well as measures to reduce this pollution, it is important to understand the transmission (delivery) of sediment and associated pollutants from their origin to the Great Lakes. The sediment delivery ratio is the ratio of gross erosion to sediment actually delivered to some point downstream. Gross erosion, an empirical measurement based on very small plot studies, is an estimate of the potential for soil to be dislodged and moved from its place of origin. It does not necessarily indicate the amount of material which actually enters drainage water. Gross erosion should not be confused with unit area loads, which, as used in this report, indicate the amount of material actually entering streams or lakes.

Lands with low gross erosion rates may have high unit area loads and vice versa. For example, although certain agricultural areas of the Maumee River basin have low gross erosion rates, they have high unit area loads of sediment and phosphorus, due to the clay soils in the watershed. Conversely, areas with high gross erosion rates may have larger-sized particles eroded, resulting in low unit area loads.

Transport of Pollutants in Streams

Since a large fraction of sediment-related pollutants are associated with clay-sized particles that do not settle readily, the stream delivery ratio for sediment-associated pollutants is probably close to 1.0. Unfortunately, the stream delivery ratio is difficult, if not impossible, to measure in the field, and must be determined through indirect evidence. It is likely, however, that a stream delivery ratio of 1.0 will often be obtained in the very long term (i.e., 10 to 50 years) as a result of scour and intermittent transport. Exceptions to long term 100 percent delivery may occur when very large lakes or impoundments are present upstream of the Great Lakes (e.g., the Kawartha Lakes of southern Ontario and the Finger Lakes of New York).

Sediment-associated pollutants, such as phosphorus, may become soluble during stream transport. Conversely, soluble ions may also become fixed onto particulate material. For example, phosphate may react with fine particulate solids in suspension, or at the sediment surface, to produce insoluble phosphorus complexes which may precipitate. Certain pesticides which are relatively insoluble and associated with sediment may decompose in temporary sinks in streams.

The fate of soluble ions in stream transport depends upon biological activity, as well as physical processes. Aquatic plants may retain phosphorus as a result of biological uptake and may serve as significant sinks during late spring and early summer. This is only a temporary sink, however, since dead plant material is transported downstream, and phosphorus can be mineralized or carried to the lakes as particulate phosphorus.

Nitrogen transformations occur in streams, particularly at the sediment/water interface. Organic nitrogen may be mineralized, producing nitrate, which is subsequently denitrified, resulting in a permanent nitrogen loss during transport. Temporary sinks also occur in plant uptake and in immobilization during decomposition of nitrogen-poor organic residues.

In most urban areas, stream channels have been modified to allow rapid transfer of water to the lakes, in order to decrease flood hazards. Hence, it is likely that a delivery ratio of 1.0 occurs in these areas, even over the short term.

Bedload, consisting of larger-sized particles moved along the stream bottom, was not studied extensively since it usually comprises a small fraction of the total sediment load. It is also less contaminated with pollutants, compared to the smaller-sized suspended particles. In one stream studied, bedload contributed approximately 10 percent of the total sediment load.

In-stream pollutant transport is greatly affected by tributary flow. It is well known that, for many streams, 80 percent or more of the total load of certain pollutants can be transported during runoff events, when tributary flow is greatest. Sediment-associated pollutants which have entered a temporary sink may be re-mobilized during runoff events and moved toward the lakes.

During runoff events, concentrations of phosphorus and suspended solids often increase dramatically. However, it is important to note that the degree of increase in concentration is not the same for all streams in the Basin. Tributaries influenced by runoff events are referred to as "event response" tributaries. "Stable response" tributaries are not dominated by runoff events since their concentrations of materials do not vary greatly with the tributary flow and because their flow is less erratic. Event response tributaries (e.g., many of the Lake Erie tributaries) tend to have high annual diffuse rivermouth unit area loads for phosphorus and suspended solids. Stable response tributaries (e.g., Lake Michigan's Grand River and many other eastern Lake Michigan tributaries) tend to have relatively small annual diffuse rivermouth unit area loads.

Although many factors influence whether a stream fits either an event response or stable response classification, the type of soil in the watershed is perhaps the most important factor.

2.5 POTENTIAL CONTRIBUTING AREAS IN THE GREAT LAKES BASIN

Basinwide Distribution of Source Areas

PLUARG data has been used to identify and locate general areas within the Great Lakes Basin which yield the highest phosphorus loads. One method used was the extrapolation of pilot watershed data to a range of land use activities in different physiographic areas.

Figures 11, 12 and 13 indicate the primary sources of phosphorus from the main contributing land use activities: general agriculture, livestock operations and urban development. Figure 11 is based on row crop density (mainly corn, soybeans, tobacco and vegetables) and soil clay content. The agricultural contribution of total phosphorus to streams is highest on the intensively farmed clay soils of northwestern Ohio and southwestern Ontario. Additional moderate loading areas include southeastern Wisconsin, the Niagara peninsula of Ontario and the lowlands of New York at the eastern end of Lake Ontario.

Figure 12 prov, es an estimate of phosphorus from livestock operations. The extrapolation is based on a livestock contribution of 0.2 kg P/ha/yr per animal unit, a figure representative of PLUARG study results. Values are smaller than those from general agriculture, of which they are a component, and illustrate the small quantities of phosphorus involved, compared to other sources. However, intense livestock production in central southwestern Ontario is noticeable, as is the next highest livestock source area, southeastern Wisconsin.

Figure 13 gives an estimate of diffuse phosphorus and lead loads from urban land. The phosphorus contributions were determined by multiplying the percent of urban area in a watershed by a fixed urban unit area load of 2 kg P/ha/yr. Thus, areas of the Basin with large urban concentrations, including the Detroit, Toledo, Cleveland and Toronto-Hamilton areas, are easily distinguished as having the highest urban diffuse loadings.

Information extrapolated from pilot watershed studies[12–20] provided an overview of phosphorus loads delivered to streams. Closer examination of areas, based on specific land characterizations, may result in different interpretations for some areas. Nonpoint tributary loads expressed on a unit area load basis are highest for tributaries draining into Lake Erie, southern Lake Huron, southern Lake Michigan and parts of Lake Ontario. Thus, the correlation is good between predicted values and values from areas monitored for phosphorus contributions based on land characteristics.

Rivermouth loads are a homogenization of point and nonpoint sources throughout the watershed. As such, it is difficult to separate the effects of any particular combination of land use and watershed characteristics for any given watershed from rivermouth data. Nevertheless, a comparison of land use and rivermouth loads shows clearly that watersheds with large amounts of agricultural and urban land contribute more phosphorus than forested or idle land watersheds.

Urban land comprises only about three percent of the basin (Table 1). Although it often contributes more phosphorus and other contaminants on a unit area basis than other land uses, the overall phosphorus load from urban land is relatively small. Table 16 presents the proportional inputs of phosphorus from major land types, estimated from a model based on the Universal Soil Loss Equation and calibrated using rivermouth loading data[84]. Although the diffuse loadings in Table 16 are only approximate, and subject to the limitations of the model, it is thought that the relative differences are representative of the basin.

Specific Problem Areas

Nonpoint pollution does not arise uniformly from whole watersheds, or even sub-watersheds. Some areas contributing large loads may represent only small portions of basin source areas. For example, in a given agricultural basin, 80 to 90 percent of the sediment load may be derived from only 15 to 20 percent of the basin. Similarly, urban construction sites, although small in land area, may contribute a large fraction of the total urban sediment load. This is because certain areas within watersheds are hydrologically active. Hydrologically active areas (HAA) are discussed further in chapter 3.

2.6 MANAGEMENT INFORMATION BASE AND OVERVIEW MODELLING

To gain a more complete understanding of the relative importance of diffuse pollutant loads, PLUARG developed a process called "overview modelling". This process provides a broad overview of combinations of factors shown to most directly affect diffuse tributary loads. Overview modelling allows a clearer understanding of problem area locations, defines why they are problem areas and provides the means to determine the most cost-effective control.

The primary objective of overview modelling was to illustrate how PLUARG and allied findings can be utilized in decision-making processes at various levels of management.

PLUARG has assembled information on pollutant unit inputs and the effectiveness and costs of selected measures to reduce these inputs. Using the overview modelling technique, rural and urban point and nonpoint sources can be compared, in terms of total pollutant inputs, potential reductions and costs (per unit and total) for pollutant reductions.

This section describes the rationale and methodology of overview modelling, provides examples of the types of data required in the management information base and the types

TABLE 16

ESTIMATED RELATIVE DIFFUSE TRIBUTARY PHOSPHORUS LOADS FROM MAJOR LAND USE CATEGORIES[a,b]

Major Land Use	Lake Superior percent phosphorus load	Lake Michigan percent phosphorus load	Lake Huron percent phosphorus load	Lake Erie percent phosphorus load	Lake Ontario percent phosphorus load
Urban	7 (<1)[c]	12 (3)	12 (2)	21 (9)	19 (4)
Cropland	4 (<1)	64 (12)	61 (9)	61 (39)	55 (11)
Pasture	3 (1)	7 (11)	7 (13)	5 (20)	11 (21)
Forest	74 (94)	3 (50)	11 (66)	1 (17)	3 (56)
Other	12 (4)	14 (23)	9 (10)	12 (15)	12 (8)

[a] estimated from a model based on the Universal Soil Loss Equation[84].
[b] diffuse tributary loads comprise approximately 50 percent of the total phosphorus load to the Great Lakes, excluding shoreline erosion and internal loading from the sediments.
[c] (percent of lake basin in particular land use).

of output available. This account is meant to describe the overview modelling process to those agencies and personnel involved in developing implementation plans. It is essential to emphasize that *the remedial measures employed in these analyses are presented as management options and examples of the intensity, variety and type of measures which may be employed.*

Predicted Phosphorus Unit Area Loads for Different Combinations of Land Factors

The initial step in this exercise is to determine the probable unit area loads for combinations of land characteristics and use intensity (Tables 17 and 18). The phosphorus unit area loads in these tables represent integration of considerable data, and are best estimates of typical conditions. From a management perspective, the relative differences of numbers are more important than the absolute values. Unique characteristics of individual land areas may result in significantly different unit area loads. For example, forested areas in portions of the red clay region of the Lake Superior basin have unit area loads several times higher than most other forested areas in the Basin, which tend to be on sandy or rocky soils.

Table 17 indicates that while unit area loads for a given land use may vary by a factor of ten or more, knowledge of certain watershed characteristics permits a more refined estimate of a representative value. For example, row crops grown in high clay content soils produce high unit area phosphorus loads.

Phosphorus unit area loads rise with increasing industrialization (Table 18). Some urban unit area loads are significantly higher than those for rural areas. The unit area load for urbanizing land (i.e., construction sites) is particularly high. If construction occurred on sandy soil, the phosphorus unit area load would likely be less than that shown in Table 18. Most large urban areas in the Basin, however, are located on clay plains.

Watershed Characterization

The next step in overview modelling is to divide the area into relatively homogeneous sub-basins, based on two specific criteria: (1) land use and intensity; and (2) land characteristics. Each sub-basin is then further characterized according to a set of requisite input variables (e.g., appropriate unit area loads, area population, growth rate, density, sewerage system and per capita inputs of specified pollutants), as well as point and nonpoint source load control costs and efficiencies.

Finally, information on pollutant transmission characteristics in different reaches of the tributary is integrated into the data base. For example, if a reservoir between two points on a river traps approximately 60 percent of the suspended solids, a value of 0.4 can be applied as the stream delivery ratio for suspended solids in this portion of the river.

Schematic representation of a small watershed (Figure 14) illustrates how the system is characterized by the input data. The geographic schema at the left characterizes a "real-world" situation showing a watershed containing several municipalities and a reservoir. This watershed, as portrayed for overview modelling, is presented on the right side of Figure 14. The real world situation is treated as 10 separate phosphorus contributing units whose individual outputs are summed, except as reduced by transmission coefficients (t) of less than 1.0. The transmission coefficients simulate the effects of reservoirs and other variables on the downstream transport of materials. The paired numbers within the circles and the municipality symbols refer to land use and land characteristics, respectively. These numbers, in turn, key the model to specific unit area loads for given combinations of land uses and characteristics. Additional details concerning the overview modelling technique are presented elsewhere[85].

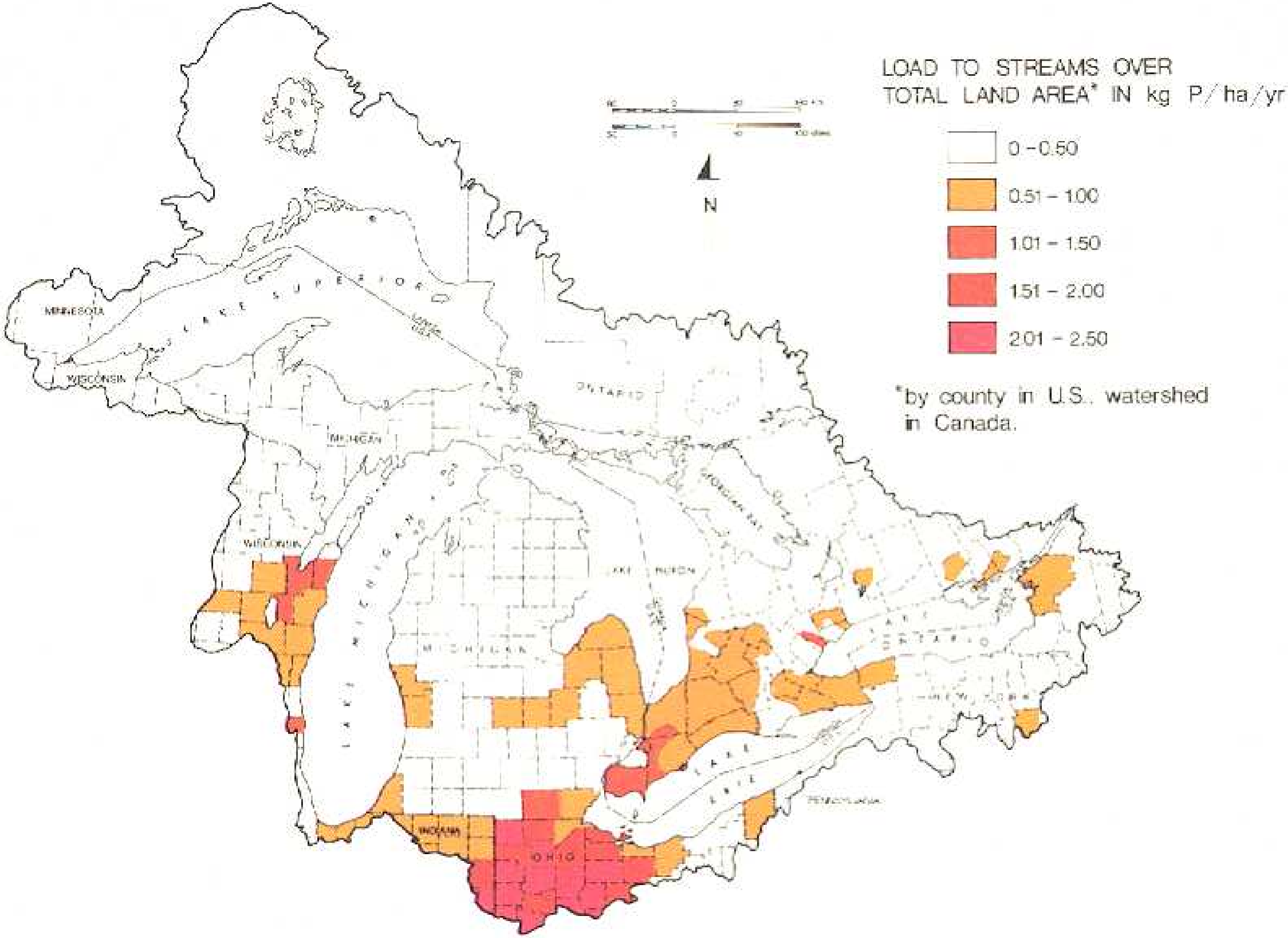


FIGURE 11. LOCATIONS OF ESTIMATED AGRICULTURAL CONTRIBUTIONS OF TOTAL PHOSPHORUS TO STREAM LOADINGS (by extrapolation, 1976 data).

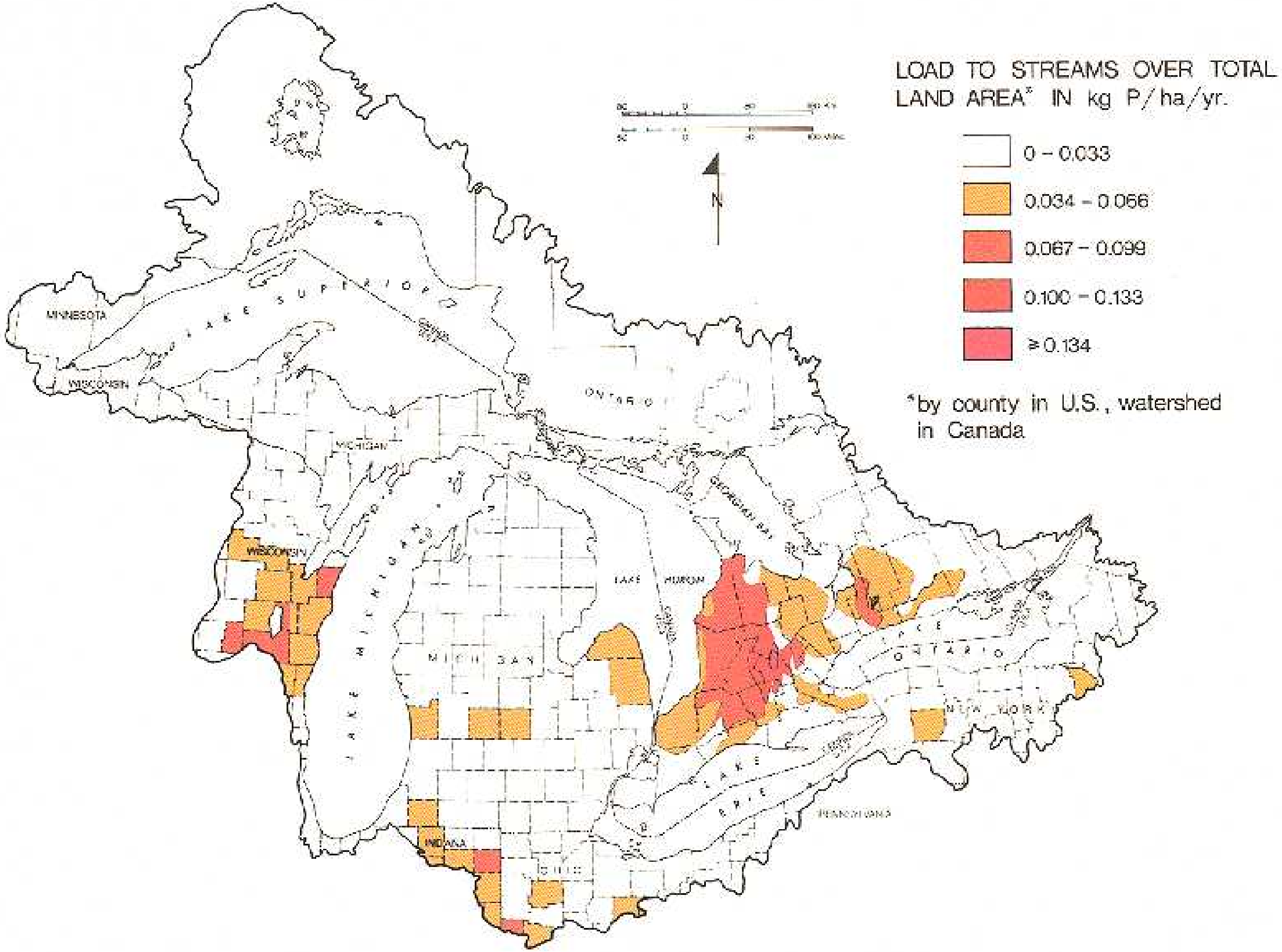


FIGURE 12: LOCATIONS OF LIVESTOCK ESTIMATED PHOSPHORUS LOADINGS TO STREAMS (by extrapolation, 1976 data).

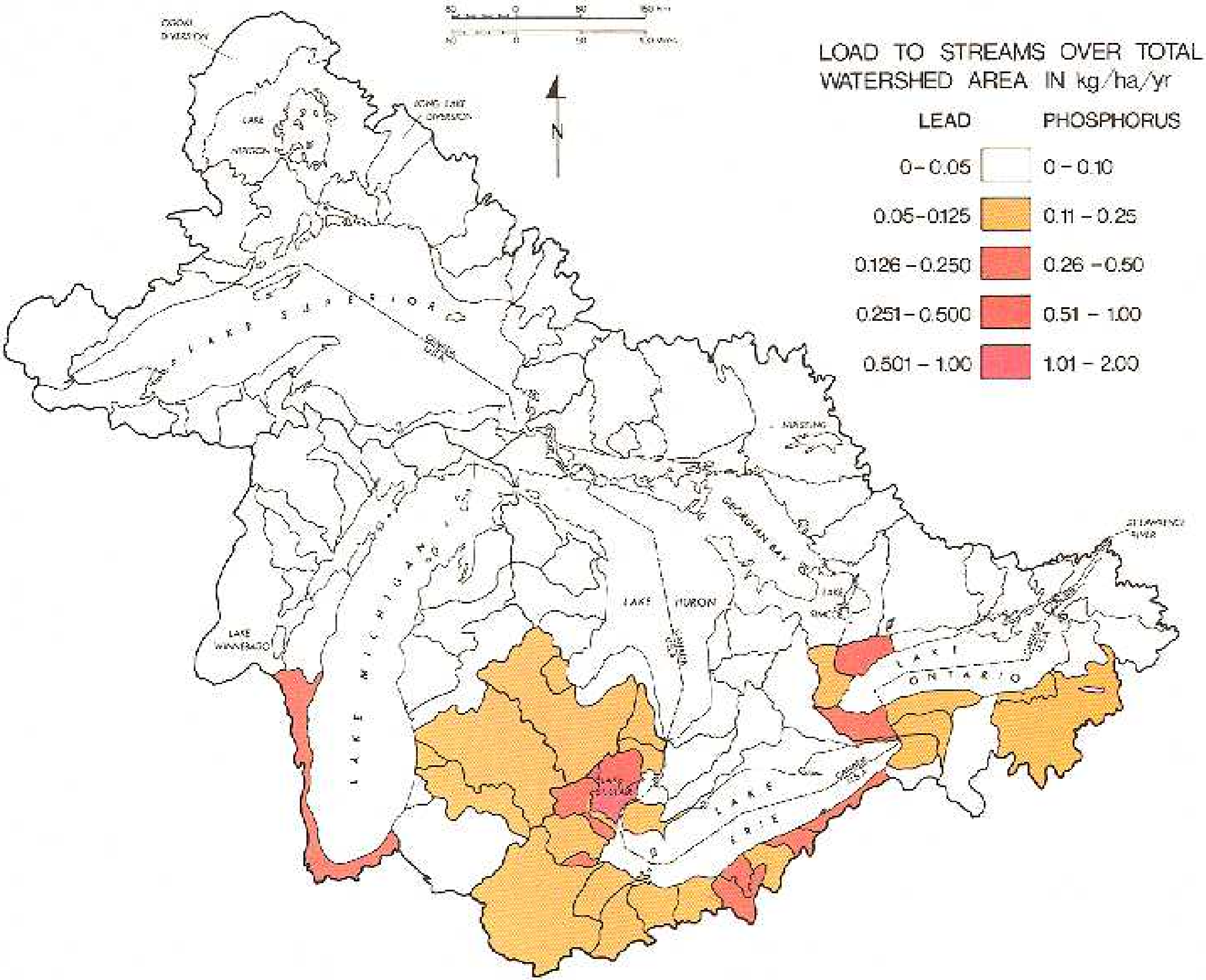


FIGURE 13. LOCATIONS OF ESTIMATED URBAN CONTRIBUTIONS OF TOTAL PHOSPHORUS AND LEAD TO STREAM LOADINGS (by extrapolation, 1976 data).

By comparing unit area loads associated with the various pollutant sources (Table 15), the relative importance of sub-basins, on a unit area basis, can be determined. Additionally, the pollutant contribution of each sub-basin, in terms of river-mouth loads, can be determined on the basis of location (i.e., distance upstream of mouth) and total land area.

Municipal Point Sources

Municipal point source inputs have been calculated as per capita inputs, with applied treatment efficiencies. Population, extent of sewered and nonsewered areas, growth rates and expansion densities are used to determine the transfer of lands from rural to urban categories. Developing land is held in a separate category for one year, during which time accelerated erosion losses may be simulated. Industrial inputs are considered separately.

Transmission

Pollutant transmission from sources to boundary waters may be incomplete because of losses in overland transport and retention in impoundments, lakes, flood plains, estuaries and other wetlands. Overland transmission, about which

TABLE 17

PREDICTED TOTAL PHOSPHORUS UNIT AREA LOADS FOR RURAL LAND, FORESTED LAND AND WETLANDS[a]

	kg/ha/yr					
	Type of Soil					
Land Use Intensity	Sand	Coarse Loam	Medium Loam	Fine Loam	Clay	Organic
Rural						
Row Cropping (> 50 percent row crops)	0.25	0.65	0.85	1.05	1.25[b]	—
Mixed Farming (25 –50 percent row crops)	0.10	0.20	0.30	0.55	0.85	—
Forage (< 25 percent row crops)	0.05	0.05	0.10	0.40	0.60	—
Grassland	0.05	0.05	0.10	0.15	0.25	—
Forest	0.05	—	—	—	0.10[c]	—
Wetlands						
Natural areas	—	—	—	—	—	0
Cultivated Organic Soils	—	—	—	—	—	2.20

[a] data above are arranged for use in the U.S. portion of the Basin. Soil characteristics and loads are arranged differently in the Canadian analysis. The end results are comparable.
[b] unit area loads may be higher when soil has an unusually high clay content. Values up to 2.5 kg/ha/yr were used in portions of the U.S. Lake Erie basin.
[c] unit area loads may be higher in certain unique forested areas with clay soils (e.g., the Nemadji River basin, which flows into Lake Superior, contributes about 1.0 kg/ha/yr).

TABLE 18

PREDICTED TOTAL PHOSPHORUS URBAN UNIT AREA LOADS

	kg/ha/yr		
	Degree of Industrialization		
Urban	Low	Medium	High
Combined Sewered Areas	9	10	11
Separate Sewered Areas	1.25	2.5	3.0
Unsewered Areas	1.25	—	—
Small Urban Areas (Sewer System Not Differentiated)	2.5	2.5	2.5
Urbanizing Land	25	25	25

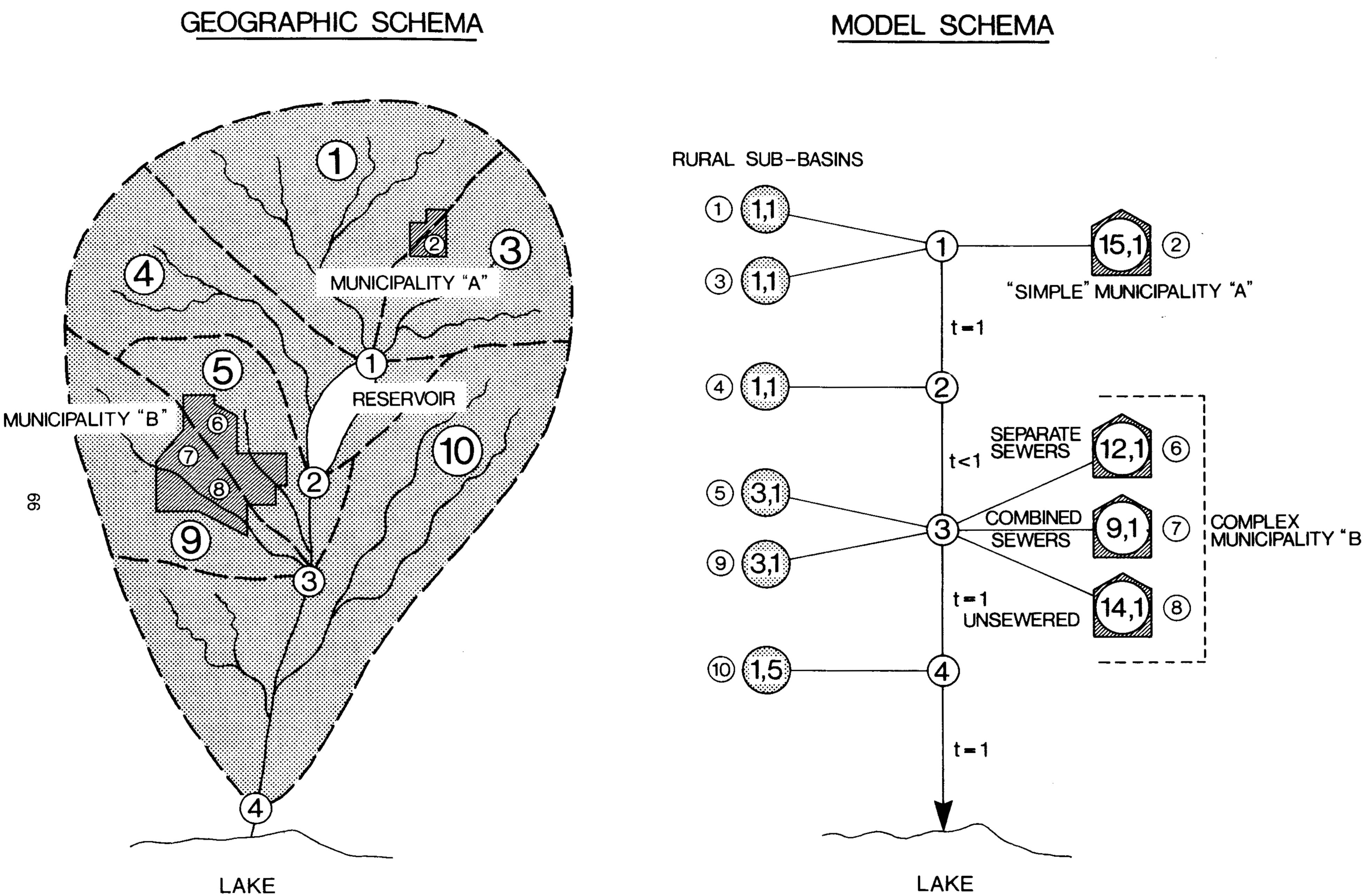


Figure 14: SCHEMATIC REPRESENTATION OF WATERSHED FOR OVERVIEW MODELLING

there is sparse empirical data, does not need to be considered separately, as it is implicitly included in subwatershed unit loads. Some data are available on main stream transmission. Where available, these data have been applied in this model to provide better resolution on the relative pollutant loads from various parts of the Basin and to improve estimates of load reductions to boundary waters.

The sums of the lake loads from rural and urban lands and point sources, including the effects of main stream transmission, have been compared with independent data from PLUARG rivermouth monitoring studies to verify and further adjust unit load tables. Agreement between the overview modelling and rivermouth monitoring results has been excellent[86].

Simulation of Remedial Measures

Estimated incremental costs of reducing phosphorus loads from municipal point sources were derived from PLUARG and other studies[87, 88]. Municipal sewage treatment plant (discharging one million gallons per day or greater) phosphorus effluent reductions to 1.0, 0.5, and 0.3 mg/L are considered. The effect of population growth on future phosphorus loads is also considered, since increased wastewater flow over time will increase loads, even if effluent concentrations are held constant. For many urban centers, the initial reduction in phosphorus achieved in moving from 1.0 to 0.5 mg/L phosphorus effluent concentrations would be partially offset by future population growth.

Urban nonpoint remedial measures and associated costs have been based primarily on information from the American Public Works Association[89] and the Canada/Ontario Urban Drainage Subcommittee[90]. The levels of effort are incremental and may be summarized as: (1) pollutant source reduction (primarily street cleaning); (2) detention of stormwater through watershed storage, downstream storage and treatment of runoff by settling; and (3) the preceding measures, augmented by advanced treatment of runoff. The programs are extremely expensive per metric ton of phosphorus removed. The first level program may cost $50,000-100,000 per metric ton of phosphorus removed. Second and third level cumulative programs are estimated to have unit costs of $125,000 and $250,000, respectively, per metric ton phosphorus removed.

Information on rural remedial programs was derived primarily from PLUARG pilot watershed studies[20]. Once it is determined that a remedial program is required for reducing rural phosphorus and sediment loads from a given sub-basin, the program must then be examined from two perspectives: (1) location and degree of effort; and (2) necessary expenditures. All agricultural areas and types of farming, as well as the lakes, can benefit from sound soil and nutrient conservation practices (level 1). These practices include using soil test results in fertilizer application, incorporation of manures into the soil, avoiding spreading manures and fertilizers on frozen or sloping land near streams, using crop residues to build organic matter and a protective mulch, cross-slope tillage and minimizing tillage for reducing erosion and obtaining optimum yield. An estimated 10 percent reduction in phosphorus and sediment loss should result from applying such management practices where they are not used currently. The cost of this level has not been estimated, but it is likely to be minor compared with level 2 programs (described below).

Further reductions (level 2) may be obtained through implementation of additional field and structural measures on fine-textured soils. In some rural areas, the level 2 program includes, in addition to sound management practices, improved drainage practices, including buffer strips along drains and natural watercourses. For certain other lands, a level 2 effort might include the preceding sound management practices, as well as field rearrangement to fit the contours of the land and strip-cropping.

Regionally, it is readily apparent that row crop production on fine-textured soils offers the most reasonable potential for load reductions. Regions with row crop production on medium-textured soils where the land is sloping, also offer potential for significant load reduction. Management of these lands would also be of great benefit from the point of view of field husbandry and soil conservation. Areas of coarse-textured soils (sandy), and most areas of medium-textured soils, offer very little potential for reduction of phosphorus and sediment loadings to the lakes.

The Canadian basin of Lake Erie serves as an example of an analysis of the degrees of effort and pollutant reductions in various farming regions (Table 19). The levels of effort, as numbered, are not necessarily identical among regions in terms of measures and efforts. However, they are grouped and ranked in order of declining cost-effectiveness and overall feasibility. Unit costs vary widely, from $5,000 – 6,000 per metric ton reduction in the phosphorus load attributable to strip-cropping programs in certain regions, to in excess of $100,000 per metric ton for other measures.

Lake Erie is also used to illustrate the analysis of further point source and new nonpoint source phosphorus control programs (Table 20). The reduction necessary to achieve the recommended annual phosphorus target load of 11,000 metric tons is 2,400 metric tons. Point source control programs to reach a 0.5 mg/L effluent phosphorus concentration could achieve 1,300 of the necessary 2,400 metric tons reduction. However, this reduction would diminish to 900 metric tons by the turn of the century. The remaining 1,100 metric tons of the reduction required at this time could be achieved by various combinations of nonpoint programs and by possible implementation of further point source controls corresponding to reduction of phosphorus effluent concentrations from 0.5 to 0.3 mg/L. Table 20 illustrates the various load reductions obtainable.

Additional information on the overview modelling process is provided in the PLUARG technical report series[85].

2.7 MAJOR CONCLUSIONS FROM WATERSHED AND RELATED STUDIES, AND OVERVIEW MODELLING

The results of the PLUARG pilot watershed studies, agricultural watershed studies and specialized land use studies have shown that, in terms of impact on the Great Lakes, agricultural and urban land uses are the major sources of nonpoint pollutant. Unit area loads of phosphorus and sediment derived from agricultural and urban lands have been mapped and calculated for the entire Basin.

PLUARG identified soil type, land use intensity and materials usage as the most important factors in determining pollutant generation from the land. It is not necessarily the individual factors, but rather the combinations of these factors, that are critical. For example, in the southwestern Ontario/northwestern Ohio portion of the Lake Erie basin, it is a combination of fine clay soils, coupled with intensive agricultural activities, that result in the high unit area loads shown in Figures 11, 12 and 13.

Overview modelling, in addition to quantifying outputs from potential contributing areas, enabled PLUARG to present various options for the removal of phosphorus from nonpoint sources (taking also point source removal into consideration) and to give approximate costs for this removal. In addition to present day remedial measure strategies, overview modelling allows prediction of future phosphorus loads and management strategies that will be required.

TABLE 19

RURAL LAND PHOSPHORUS REMOVAL OPTIONS IN THE CANADIAN LAKE ERIE BASIN

Treatment (percent of basin)	Cumulative Load Reduction (Percent)	Total Cost/ Metric Ton Reduced Load (Dollars)	Reduction from 1975 in 1980 (Metric Ton)	Annual Cost of Program (Millions of Dollars)
All land				
Sound management practices	5 – 10	Minimal	90	N.D.[a]
Cash cropping – St. Clair plain (14 percent)				
1) Sound management practices;	5	Minimal	26	N.D.
2) Plus buffers and better drain construction;	27	57,000	125	4.6
3) Plus winter cover crop;	33	71,000	150	7.0
4) Plus forage in rotation.	40	103,000	180	12.3
Mixed farming, fine textured soils (33 percent)				
1) Sound management practices;	10	Minimal	43	N.D.
2) Plus strip cropping;	14.5	5,000	60	0.25
3) Plus buffers and better drain construction;	23	26,000	95	1.9
4) Plus winter cover and forage.	38	59,000	155	7.4
Forage, fine textured soils (10.2 percent)				
1) Sound management practices;	10	Minimal	9	N.D.
2) Plus strip cropping;	19	17,000	14	0.13
3) Plus buffer & better drain construction;	40	100,000	20	1.5
4) Plus delay plowing until spring.	40	153,000	28	2.5
Mixed farming, medium textured sloping soils (9.4 percent)				
1) Sound management practices;	10	Minimal	10	N.D.
2) Plus strip cropping;	19	12,000	15	0.1
3) Plus delay plowing until spring;	38.5	73,000	30	1.3
4) Plus buffer and better drain construction.	47.5	104,000	35	2.2

[a] not determined (likely minimal); would include cost of augmented extension program.

TABLE 20

LAKE ERIE
PHOSPHORUS LOAD REDUCTION IN 1980 AND 2000[a]

Reduction Source	metric tons/yr					
	United States		Canada		Total	
	1980	2000	1980	2000	1980	2000
Municipal Point Sources:						
1.0 to 0.5 mg/L effluent concentration	1180	820	125	80	1305	900
1.0 to 0.3 mg/L effluent concentration	1760	1540	190	160	1950	1700
Urban Diffuse Sources:						
Level 1	425	195	20	−20	445	175
Level 2	1000	815	60	15	1060	830
Rural Diffuse Sources:						
Level 1	350	500	100	115	450	615
Level 2	550	675	250	255	800	930
Level 3	730	830	375	380	1105	1210

[a] based on 1976 datum.

3. MANAGEMENT STRATEGY

INTRODUCTION

Management of nonpoint sources will require a dramatic departure from the traditional approach followed for the control of point sources. PLUARG does not favor across-the-board measures for nonpoint source pollution control, but recommends a comprehensive strategy for management of the Great Lakes ecosystem and a methodology to identify priority management areas to be treated.

Chapter 1 clearly indicates that the Great Lakes are still being polluted by a variety of contaminants, restricting society's use of these lakes. Continuing eutrophication of the lower lakes, particularly the western and central portions of Lake Erie and the present problem of PCBs, mirex and mercury, may be the forerunners of future environmental problems. If further action is not taken now, the future use of the Great Lakes will be jeopardized.

Point sources, with their odorous pollutant discharges, were the first sources identified in the effort to reverse the trend of declining Great Lakes water quality. To date, governments and industries of Canada and the United States have demonstrated serious dedication to controlling many point sources. For example, since the signing of the Great Lakes Water Quality Agreement in 1972, more than $3 billion has been committed by governments to the task of upgrading municipal sewage treatment plants, including effluent phosphorus concentration reductions. Completion of projects under this commitment will produce a greater than 80 percent reduction in phosphorus loadings from these plants.

Despite these efforts, much remains to be done. Further control of point sources will not meet the needs of a society demanding improved Great Lakes water quality. PLUARG studies have concluded that nonpoint source pollutants represent a significant part of the total loading to the Great Lakes. Between 32 and 90 percent of the total phosphorus load, depending on the individual lake, comes from nonpoint sources (i.e., land drainage and atmospheric inputs), as well as significant loads of sediments and toxic substances; all impact on Great Lakes water quality.

Unlike point source discharges, nonpoint pollution is characterized by:

(a) a wider variety of sources;

(b) the seemingly insignificant nature of individual contributions;

(c) the intermittent nature of inputs;

(d) natural processes which modify inputs; and

(e) the variety of social and economic factors which affect these sources and inputs.

These complex interactions create difficulties in finding simple solutions to these problems. Agencies with environmental responsibilities will have to involve other agencies in solutions to these problems and individual members of society will have to take the initiative to insure the success of the program.

All of PLUARG's recommendations are directed to the International Joint Commission for its consideration and subsequent transmittal to the governments of Canada and the United States.

PLUARG presents, as a primary recommendation, the preparation of comprehensive management plans by the respective jurisdictions, as an essential part of an effective nonpoint source pollution control program. Further recommendations outlining essential elements of the plan provide the necessary guidance for individual jurisdictions to design their own specific plans. Remedial measure options are presented in this chapter, as well as their probable costs. Finally, recommendations are made concerning the review and evaluation of management plans.

3.1 DEVELOPMENT OF MANAGEMENT PLANS

3.1.1 PLUARG RECOMMENDS MANAGEMENT PLANS, STRESSING SITE-SPECIFIC APPROACHES, TO REDUCE LOADINGS OF PHOSPHORUS, SEDIMENTS AND TOXIC SUBSTANCES DERIVED FROM AGRICULTURAL AND URBAN AREAS, BE PREPARED BY THE APPROPRIATE JURISDICTIONS WITHIN ONE YEAR AFTER THE INTERNATIONAL JOINT COMMISSION'S RECOMMENDATIONS ARE TRANSMITTED TO THE GOVERNMENTS. PLUARG FURTHER RECOMMENDS THAT A MUTUALLY SATISFACTORY SCHEDULE FOR THE REDUCTION OF NONPOINT SOURCE LOADINGS BE ANNEXED TO THE REVISED GREAT LAKES WATER QUALITY AGREEMENT.

MANAGEMENT PLANS SHOULD INCLUDE:

(i) A TIMETABLE INDICATING PROGRAM PRIORITIES FOR THE IMPLEMENTATION OF THE RECOMMENDATIONS;

(ii) AGENCIES RESPONSIBLE FOR THE ULTIMATE IMPLEMENTATION OF PROGRAMS DESIGNED TO SATISFY THE RECOMMENDATIONS;

(iii) FORMAL ARRANGEMENTS THAT HAVE BEEN MADE TO INSURE INTER- AND INTRA-GOVERNMENTAL COOPERATION;

(iv) THE PROGRAMS THROUGH WHICH THE RECOMMENDATIONS WILL BE IMPLEMENTED BY FEDERAL, STATE AND PROVINCIAL LEVELS OF GOVERNMENT;

(v) SOURCES OF FUNDING;

(vi) ESTIMATED REDUCTION IN LOADINGS TO BE ACHIEVED;

(vii) ESTIMATED COSTS OF THESE REDUCTIONS; AND

(viii) PROVISION FOR PUBLIC REVIEW.

An important part of developing an effective management strategy is to perceive the Great Lakes and the land draining into them as a complete system. From this perspective, it is apparent that activities in one area may have repercussions on another. Ultimately, the cumulative impact of land drainage on the Great Lakes must be considered. Because nonpoint sources are so closely tied to the hydrologic system, this perspective must also be reflected in the management framework developed for this problem.

The control of nonpoint pollution associated with distinct land use activities will require increased involvement by existing agencies in the management of these problems. For example, in both countries, many government agencies are aligned by separate land use categories. This will undoubtedly result in problems in achieving overall coordination during both the design and implementation phases of nonpoint pollution control programs. It is important to note, however, that PLUARG public consultation panels[32, 33] strongly opposed additional layers of government. Most of PLUARG's consultation panels were concerned about too much existing government, with poor or non-existent coordination, both within and between levels of government. The consultation panels also expressed the belief that *a concerted effort will be required to minimize the overlap of programs and jurisdictions and to align government goals and objectives.*

There are obvious requirements to involve local, state and provincial levels of government and to establish an overall management responsibility. The role of municipal and county governments in the implementation of programs is often insufficiently considered during the development of international programs. Many local authorities are not aware of the activities and expectations of the International Joint Commission and the Water Quality Agreement between the two federal governments to protect and improve Great Lakes water quality. The potential for supportive and pragmatic involvement by local government should not be overlooked. The challenge is to encourage local decision-making in favor of common causes, without overriding local prerogatives and authority.

In the United States, point source control programs required extensive intergovernmental cooperation, primarily through fiscal arrangements. In Canada, even to achieve this level of collaboration, numerous special agreements have been necessary. In most cases, only a few agencies were involved in these agreements and their implementation.

In the United States, the Section 208 (Public Law 92-500, as amended) Areawide Waste Treatment Management planning process provides a vehicle for examining the relative importance of nonpoint source problems and developing management plans for them. Generally, there has not been a consideration of how these sources affect the Great Lakes. Such a consideration must be a part of the continuing activities that are part of this process.

To achieve effective coordination between agencies and all levels of government, all available means must be utilized to the fullest extent. *The International Joint Commission, acting as an international forum, has a key role to play in promoting coordination between the United States and Canada. Government agencies in both countries should develop formal mechanisms to achieve extended coordination.*

There is an opportunity to approach the management of nonpoint pollution from a new perspective. For instance, many nonpoint problems are amenable to nonstructural solutions and control of inputs, as opposed to controlling only the outputs at the end of a pipe, a commonly accepted practice in point source control.

Many improvements can be effected through changes in the present management practices of individual enterprises and institutions involved in determining how land is used. Basic decisions which lead to changes in the focus of economic activity must be made with an understanding of the potential effects on Great Lakes water quality, if future problems are to be avoided. In many cases, these management measures can be implemented with little or no capital costs.

Moreover, PLUARG found many measures presently available to control problems such as soil erosion have been developed over long periods and achieved proven efficiencies. Few of these measures were developed specifically to reduce water quality impacts and their efficiencies in this regard remain relatively untested.

"Real world" situations will often require the application of several practices in combination to provide a comprehensive control system. In these cases, the total system may be more effective than the sum of its component parts. *It must be kept in mind that it is not the land use, per se, that affects water quality, but rather how the land is managed.*

Essential Elements of a Management Plan

The development of management plans to control pollution from nonpoint sources must emphasize the following essential elements: (1) planning; (2) fiscal arrangements; (3) information, education and technical assistance; and (4) regulation.

PLANNING

3.1.2 PLUARG RECOMMENDS THAT GOVERNMENTS MAKE BETTER USE OF EXISTING PLANNING MECHANISMS IN IMPLEMENTING NONPOINT SOURCE CONTROL PROGRAMS BY:

(i) INSURING THAT DEVELOPMENTS AFFECTING LAND ARE PLANNED TO MINIMIZE THE INPUTS OF POLLUTANTS TO THE GREAT LAKES; AND

(ii) INSURING THAT PLANNERS ARE AWARE OF AND CONSIDER PLUARG FINDINGS IN THE DEVELOPMENT AND REVIEW OF LAND USE PLANS.

Water quality problems related to nonpoint sources are the result of a complex mix of land use, climate, hydrologic and biologic processes. Therefore, remedial programs must be carefully designed and implemented to insure that the full range of alternatives are considered and that the selected strategies are those best suited to the solution of the problem. This planning must integrate the various aspects of a problem in developing a proposed solution.

Planning is presently being carried out at all levels of government for many purposes. Most of this planning has been directed primarily to fulfilling the social and economic expectations of Basin residents. However, this approach does not recognize the implications that changing development patterns have on Great Lakes water quality and, conversely, the implications that changes in water quality have for continued development in the Basin.

Recently, however, several Ontario municipalities have taken the initiative to designate environmentally sensitive areas in their official plans. While these actions are local in nature and aimed at protecting local water resources and other environmentally sensitive features, they provide a sound starting point for developing improved awareness of the impact of continued development on the environment and Great Lakes water quality. In Ontario, the Planning Act is the basis for securing input from environmental agencies in the planning process. Additionally, comprehensive drainage basin water management studies provide another input to planning decisions.

In the United States, preparation of Section 208 water quality management plans provide a firm basis upon which to develop solutions.

To complete this awareness, planning agencies must have PLUARG findings and recommendations available to them and incorporate these findings into their planning process. In addition, federal, state and provincial governments should consider PLUARG results in their review of plans prepared under their guidance.

FISCAL ARRANGEMENTS

3.1.3 PLUARG RECOMMENDS THAT A REVIEW OF FISCAL ARRANGEMENTS BE UNDERTAKEN TO DETERMINE WHETHER PRESENT ARRANGEMENTS ARE ADEQUATE TO INSURE EFFECTIVE AND RAPID IMPLEMENTATION OF PROGRAMS TO CONTROL NONPOINT POLLUTION. SUCH A REVIEW SHOULD INCLUDE:

(i) DETERMINATION OF THE AVAILABILITY OF GRANTS, LOANS, TAX INCENTIVES, COST-SHARING ARRANGEMENTS AND OTHER FISCAL MEASURES;

(ii) DETERMINATION OF WHETHER OR NOT THE TERMS OF FINANCIAL ASSISTANCE PROGRAMS ARE SUFFICIENT TO ENCOURAGE WIDESPREAD PARTICIPATION; AND

(iii) DETERMINATION OF THE EXTENT TO WHICH VARIOUS FINANCIAL ASSISTANCE PROGRAMS ARE CONDITIONAL UPON THE IMPLEMENTATION OF NONPOINT SOURCE REMEDIAL MEASURES.

Many of the remedial measure costs discussed in this report may be viewed as additional costs of production in agriculture and in servicing urban developments. The benefits associated with these costs may not accrue directly to the individual or agency paying for them. In these cases, governments must consider some form of cost-sharing to help defray the cost of implementing these measures. This is especially important in agriculture, where the increased costs of production are not easily passed on in the price of the product at the farm gate. In Canada and the United States 60 percent of the farmers responding to the PLUARG agricultural survey[34, 35] stated they should not have to pay the entire cost of controlling water pollution created by their operations.

It is important that all government agencies review the adequacy of their present and planned cost-sharing and other economic incentive programs to determine if they are sufficient to encourage rapid implementation of nonpoint remedial measures. This review should include programs aimed at assisting local government agencies as well as agricultural operators. Economic incentives should be available to encourage farmers to adopt pollution control measures. Consideration should be given to making financial assistance for existing agricultural programs conditional upon implementing these pollution control measures.

INFORMATION, EDUCATION AND TECHNICAL ASSISTANCE

3.1.4 PLUARG RECOMMENDS THAT GREATER EMPHASIS BE GIVEN TO THE DEVELOPMENT AND IMPLEMENTATION OF INFORMATION, EDUCATION AND TECHNICAL ASSISTANCE PROGRAMS TO MEET THE GOALS OF THE GREAT LAKES WATER QUALITY AGREEMENT. THIS EMPHASIS SHOULD INCLUDE:

(i) DEVELOPMENT OF BROAD PROGRAMS, THROUGH SCHOOL SYSTEMS, THE MEDIA AND OTHER PUBLIC INFORMATION SOURCES, DESCRIBING THE ORIGINS AND IMPACTS OF POLLUTANTS ON THE GREAT LAKES AND ALTERNATIVE STRATEGIES THAT SHOULD BE FOLLOWED BY THE PUBLIC AND GOVERNMENT AGENCIES TO PREVENT WATER QUALITY DEGRADATION;

(ii) INITIATION OF MORE SPECIFIC PROGRAMS TO IMPROVE THE AWARENESS OF IMPLEMENTORS AND THOSE WORKING IN AND FOR GOVERNMENT, EMPHASIZING THE NEED FOR THE FURTHER CONTROL AND ABATEMENT OF NONPOINT POLLUTION; AND

(iii) STRENGTHENING AND EXPANDING EXISTING TECHNICAL ASSISTANCE AND EXTENSION PROGRAMS DEALING WITH THE PROTECTION OF WATER QUALITY, INCLUDING RURAL AND URBAN LAND MANAGEMENT PRACTICES.

The public is not adequately informed of potential Great Lakes nonpoint pollution problems. It is PLUARG's opinion that greater emphasis on public information, education and participation is required to achieve Great Lakes water quality goals. This is reinforced by PLUARG's public consultation panels which were unanimous concerning the need for improved information and public education programs, beginning at the primary school level, through the various technical assistance and extension programs of government.

Point source control has required agreement between government and industry to implement management programs. Even in these cases, adoption, monitoring and enforcement of point source remedial measures are complicated and expensive. The adoption and successful implementation of remedial measures for nonpoint source pollution programs will have to rely heavily on the interest and concern of individual members of society. Therefore, Basin residents must be involved in, and convinced of, the need and utility of proposed remedial measure programs before adoption and implementation take place.

For example, in the PLUARG Canadian agricultural survey[35], 80 percent of the farmers responding indicated that farming activities only contributed to water pollution to a minor extent, or not at all, and 90 percent felt their present management practices were adequate for controlling water pollution. However, 72 percent of the respondents did indicate a desire for more information related to control of water pollution from farming activities. In the U.S. agricultural survey[34], 77 percent of the farmers indicated the need for more information on how to control water pollution.

There is a demonstrated need for broad education programs on nonpoint problems. Personnel working in government agencies whose policies and programs have an impact on nonpoint pollution should be made aware of the implications their decisions may have on Great Lakes water quality. They must also learn how their technical assistance and extension programs can be used as a part of a comprehensive remedial program. Information gathered by the International Joint Commission, through its Boards and Reference Groups, provides a valuable resource to be used by the agencies involved with developing environmental management programs and those responsible for the development of public education curricula. *PLUARG is concerned that this information be actively disseminated to all those who need and should use it.*

REGULATION

3.1.5 PLUARG RECOMMENDS:

(i) THAT THE ADEQUACY OF EXISTING AND PROPOSED LEGISLATION BE ASSESSED TO INSURE THERE IS A SUITABLE LEGAL BASIS FOR THE ENFORCEMENT OF NONPOINT POLLUTION REMEDIAL MEASURES IN THE EVENT THAT VOLUNTARY APPROACHES ARE INEFFECTIVE; AND

(ii) THAT GREATER EMPHASIS BE PLACED ON THE PREVENTIVE ASPECTS OF LAWS AND REGULATIONS DIRECTED TOWARD CONTROL OF NONPOINT POLLUTION.

Nonpoint management programs must include voluntary and regulatory components. Regulations can be used when voluntary approaches do not achieve desired results. In a complex world, where the environment is often subject to competing and conflicting uses, *total* reliance on voluntary approaches is debatable and, thus, there may be a need for regulatory actions in specific cases.

Traditionally, an individual's agricultural or urban activities have not been subjected to regulations for water pollution control, with the exception of requirements related to the purchase and use of pesticides. The voluntary approach was supported to some extent by the PLUARG agricultural survey. In Canada, 56 percent of the farmers indicated that the best policy for reducing water pollution was to rely solely on the good will of farmers[35], while in the U.S., 71 percent indicated that it is best to rely on voluntary cooperation[34]. In Canada, the response to an additional question as to whether or not governments should strictly enforce regulations was divided, with 46 percent in favor and 44 percent opposed.

All levels of government must therefore review the adequacy of their present voluntary programs and consider other inducements or regulation alternatives where these programs are found lacking. There must also be a review of the conduct of government programs affecting water quality programs, and the Great Lakes in particular, to determine if more specific guidelines are needed. *Wherever possible, governments should maximize the utility of existing programs rather than creating new ones.*

3.2 IMPLEMENTATION OF MANAGEMENT PLANS

The next series of recommendations are provided to assist governments in the successful implementation of nonpoint pollution control programs. First, a rationale for dealing with regional priorities is presented, followed by a discussion of the management aspects of principal land uses of concern.

Regional Priorities

3.2.1 PLUARG RECOMMENDS THAT REGIONAL PRIORITIES FOR IMPLEMENTING MANAGEMENT PLANS DEVELOPED BY THE JURISDICTIONS BE BASED UPON:

(i) THE WATER QUALITY CONDITIONS WITHIN EACH LAKE;

(ii) THE POTENTIAL CONTRIBUTING AREAS (PCA) IDENTIFIED BY PLUARG; AND

(iii) THE MOST HYDROLOGICALLY ACTIVE AREAS (HAA) FOUND WITHIN THESE POTENTIAL CONTRIBUTING AREAS.

This recommendation provides basic strategy for the most cost-effective implementation of nonpoint source remedial programs using the management plans recommended in the previous section. Although the techniques developed by PLUARG are most immediately applicable to phosphorus control, other nonpoint pollutants, such as sediments, can also be managed by identifying potential contributing areas in the Basin.

Variations in water quality among and within lakes requires that different levels of management be developed. The basic water quality variations among the Great Lakes are discussed in chapter 1. Within a given lake basin, there are also factors which indicate a need for different levels of management for different portions of the lake basin.

Variations in nearshore water quality, especially in areas where circulation with offshore lake waters is restricted (e.g., Saginaw Bay, Green Bay, Bay of Quinte, Hamilton Harbour), or areas where point and/or nonpoint loadings are high (e.g., western basin of Lake Erie), will require a flexible management approach. Nonpoint source pollutants reaching these areas require more rigorous control than those transported to areas where water quality is not as degraded.

Because of these variations, uniform remedial programs for correcting Great Lakes water quality problems are not desirable. Instead, an approach which identifies the most severe problem areas must be adopted. Concentration of remedial resources in the most critical areas will achieve the greatest progress. *Since technical and financial resources are not likely to be sufficient for complete treatment of all problem areas, a prioritized approach is necessary to achieve maximum improvements in water quality in the shortest time.* Potential contributing areas have been identified through the pilot watershed studies and overview modelling (chapter 2). Soil type, land use intensity and materials usage are the most important factors affecting nonpoint pollution. The most critical problem areas are row crops on fine-textured soils, some concentrated livestock operations, developing urban areas and highly impervious portions of major urban centers.

It should be noted that identification of these areas does not necessarily reflect the actual presence or quantification of water quality problems, since the way these lands are managed is also important and cannot be included in these regional assessments. Potential contributing areas for phosphorus from various land uses have been determined by PLUARG (Figures 11, 12 and 13). *These are areas where jurisdictions and institutions responsible for carrying out nonpoint source remedial programs should concentrate their initial efforts.*

Not all the land within the potential contributing areas contributes equally to water quality problems. By applying further evaluation, smaller areas (possibly sub-watersheds of approximately 250-750 km^2) can be identified. Sub-watershed assessments can be made using the unit area loads found in chapter 2 and information on soil characteristics, land use, livestock densities, water quality, or information from other descriptive inventories. These sub-watershed assessments will result in a prioritization of those land uses within a potential contributing area.

A basic tool for estimating the location and level of management required for these prioritized land uses is the identification of the most hydrologically active areas (HAA). These are areas which contribute directly to ground and surface water, even during minor precipitation and snowmelt events. Areas contributing to surface waters are normally located close to rivers, lakes and streams. Those contributing to groundwater are in the recharge areas of aquifers, which commonly are in upland regions or undulating plains and often have coarser-grained soils. All areas of a watershed are potentially active. However, some areas will contribute runoff more often than others and in greater quantities than others and, thus, have the highest potential for pollutant delivery to receiving waters. The size of the most hydrologically active areas is determined by soil texture, slope, land use and management, and infiltration rates.

Within these most hydrologically active areas, proper land management has the most immediate benefit. Not all land areas within the most hydrologically active areas will need to be treated. Some areas will already be used or managed in a way which does not produce a water quality problem. It is essential that detailed assessment of the types and locations of management practices be made by local agencies familiar with the areas involved. *It is only at this level of problem identification that accurate inventories of practices needed and costs involved can be made.* Examples in the pilot watershed studies illustrated situations where 15-20 percent of the land area within a small sub-watershed produced up to 90 percent of the sediment load to receiving streams. Thus, with this tool, significant efficiencies in reducing nonpoint pollutants can be achieved.

Developed urban areas, because of their connected, highly impervious nature and extensive alteration of natural hydrology, have large hydrologically active areas. Many developing urban areas are either within a hydrologically active area or tributary to one, and special attention must be given to these areas to insure control of sediment and associated pollutants. Proper hydrologic design of developing areas, and management practices which decrease impervious areas, will reduce the size of hydrologically active areas and can result in decreased urban nonpoint pollutant loads.

In agricultural areas, many soil conservation techniques control runoff from these hydrologically active areas by reducing the intensity and quantity of runoff. Since the size of hydrologically active areas fluctuates seasonally, elimination of winter spreading of manures and sludges is particularly important. According to PLUARG's agricultural survey[35], approximately 35 percent of Ontario livestock farmers do spread manures during the winter and 33 percent spread manure within 50 feet of stream banks.

Soil conservation techniques also present the farmer with benefits related to improved productivity and the assurance that crop yields can be sustained over the long term. From a water quality perspective, the establishment of many of these same soil conservation techniques within the most hydrologically active areas will result in control of nonpoint pollutants. It was found, however, that approximately 50 percent of the Canadian respondents[35] to PLUARG's agricultural survey, who had clearly defined streams or drainage ditches alongside or within their cultivated fields, indicated they cultivated within ten feet of the bank. In the U.S., 23 percent of the respondents[34] cultivated to within ten feet of a defined drainage channel.

Locations of the most hydrologically active areas must be considered in siting solid and liquid waste disposal facilities and industrial storage and other facilities. This pertains to surface as well as groundwater contamination. Similar concerns are important when locating disposal areas for mine tailings and contaminated dredge spoil.

Historically, most agency programs have been developed with standard requirements and/or conditions for compliance across the entire area of their jurisdiction. For example, in Ontario, the Planning Act, Environmental Protection Act and Ontario Water Resources Act, establish uniform criteria across the province. In the United States, Environmental Protection Agency guidelines and requirements establish uniform criteria for regulation of discharges from municipal and industrial sources for all states in the Basin.

Adoption of the priority area approach may raise criticism concerning an apparent disregard for locally-perceived water quality problems and the creation of areas where less attention is paid to nonpoint pollution. Although problem areas have been identified as priority locations where programs would be most effective, their identification is not meant to restrict the implementation of programs in other areas. Rather, they are intended to act as the initial focal point for implementation of these programs. Once successful management programs are underway in these priority areas, the governments should be encouraged to expand programs into other areas of the Basin.

There are several examples in which different program emphasis has been directed to meet the needs of particular local situations. In the United States, the existence of local Soil and Water Conservation Districts is a direct result of this local desire for implementation of programs. Also, the Small Watershed Program (Public Law 566) directs resources into critical management areas, primarily for flood prevention.

The Rural Clean Water Program (Section 35 of the 1977 Clean Water Act) authorized by the U.S. federal government and recent legislation in the state of Wisconsin have directed that a prioritized approach be used to share the cost of nonpoint remedial measures recommended by Section 208 planning. These programs direct cost-sharing funds into areas where problems have been identified and where the potential for water quality improvement is greater.

In Ontario, the establishment of the Conservation Authorities, as local autonomous bodies under provincial-enabling legislation, similarly reflects the need for local involvement in program design and implementation. Recent decentralization of provincial agencies has allowed for improved regional program implementation.

Control of Phosphorus

3.2.2 PLUARG RECOMMENDS THAT PHOSPHORUS LOADS TO THE GREAT LAKES BE REDUCED BY IMPLEMENTATION OF POINT AND NONPOINT PROGRAMS NECESSARY TO ACHIEVE THE INDIVIDUAL LAKE TARGET LOADS SPECIFIED BY PLUARG.

IT IS FURTHER RECOMMENDED THAT ADDITIONAL REDUCTIONS OF PHOSPHORUS TO PORTIONS OF EACH OF THE FIVE GREAT LAKES BE IMPLEMENTED TO REDUCE LOCAL NEARSHORE WATER QUALITY PROBLEMS AND TO PREVENT FUTURE DEGRADATION.

Phosphorus has been identified as the principal nutrient of concern in developing a remedial program for controlling eutrophication in the Great Lakes. Recommended phosphorus target loads, as cited in Table 21, have been used to define phosphorus load reductions necessary for each lake. These target loadings, however, may not be sufficient to correct all nearshore water quality problems, such as those identified in Figure 6. Further reductions may be required locally in order to improve degraded areas.

The total phosphorus load to each lake results from several sources. The degree to which each of these sources may be controlled, and the relative costs to achieve this control, must be considered before making recommendations for nonpoint control. Therefore, a review of the potential for taking further action at municipal sewage treatment plants and industrial sources has been included in the PLUARG evaluation process.

Attention was also given to the significance of phosphorus from the atmosphere, from shoreline erosion and from upstream Great Lakes to the total load for a given lake. The result is that municipal point sources remain the most significant controllable source of phosphorus at this time, although some nonpoint sources are amenable to further control. There is a potential for further reduction at municipal sewage treatment plants to a 0.5 mg/L phosphorus effluent level, although many plants still have not attained the agreed-upon 1.0 mg/L concentration[1].

Figure 15 shows the 1976 phosphorus loads for the individual lakes under three municipal sewage treatment plant reduction scenarios: 1.0 mg/L and 0.5 mg/L phosphorus effluent levels in all lakes, and 0.3 mg/L in Lakes Erie and Ontario. These loads are compared to the recommended target loads. The basis of these target loads (i.e., nondegradation in Lakes Superior, Michigan and Huron (excluding Saginaw Bay); and improvement of water quality in Saginaw Bay and Lakes Erie and Ontario was discussed in chapter 1.2.

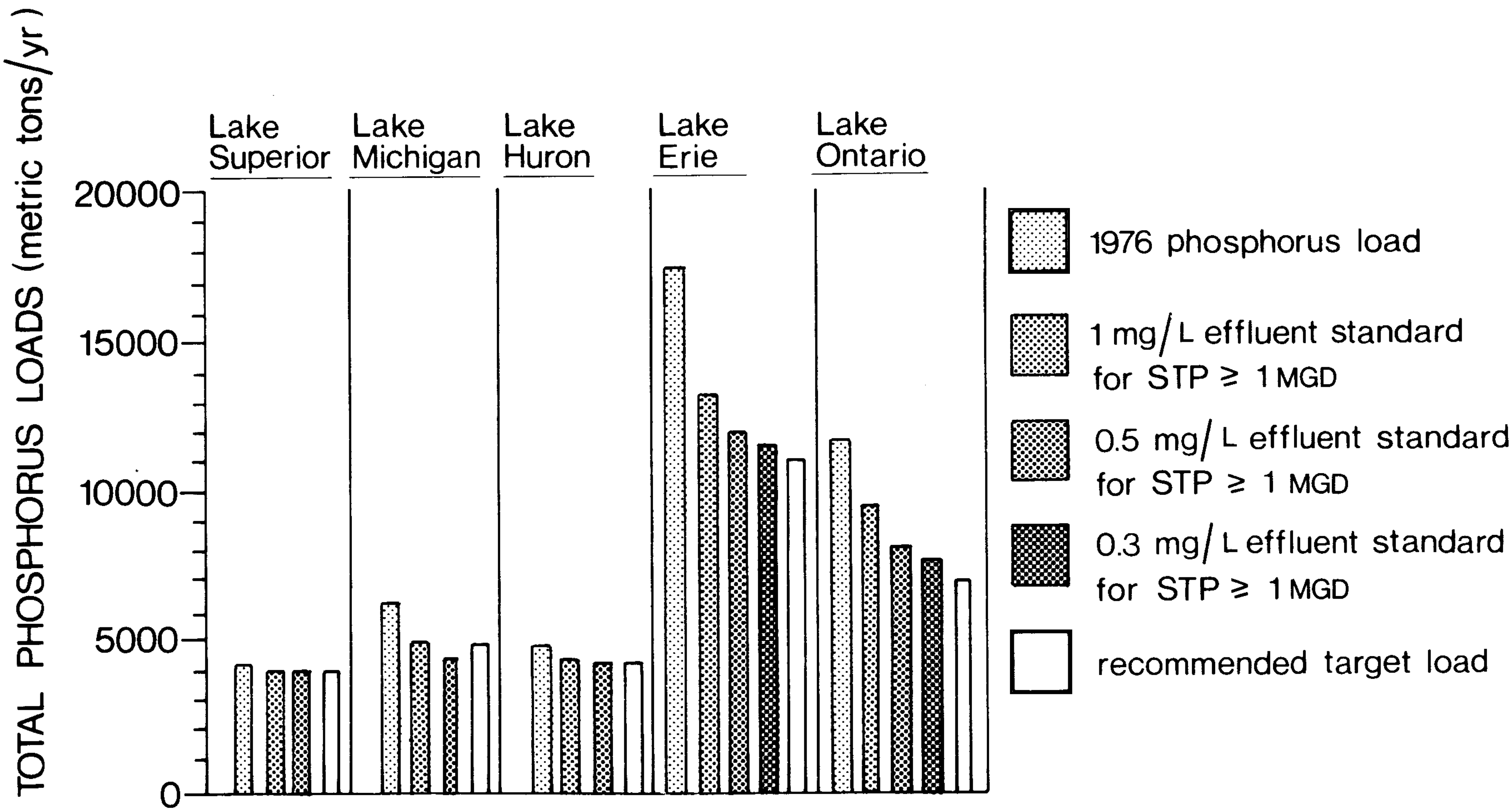
In Lakes Erie and Ontario, with maximum attainable point source reduction to the 0.3 mg/L phosphorus effluent guideline, target loads would still not be achieved. This emphasizes the need for a comprehensive program of nonpoint

TABLE 21

1976 PHOSPHORUS LOADS AND REDUCTIONS NECESSARY TO MEET RECOMMENDED TARGET LOADS

Canada/United States	metric tons/yr				
	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Baseload with municipal STPs at 1 mg/L[a]	4,000	4,900	4,500	13,400	9,400
Recommended Target Loads[b]	4,000	4,900	4,400	11,000	7,000
Reduction required to meet target loads	0	0	100[c]	2,400	2,400

[a] baseload reductions to the 1 mg/L municipal treatment plant (STP) effluent concentration have not yet been fully achieved in Lake Ontario and Lake Erie and no formal agreement has been made by the two federal governments to undertake reductions in Lake Huron, Lake Michigan and Lake Superior.
[b] based on loads recommended by Task Group III in the Fifth Year Review of the Great Lakes Water Quality Agreement, as modified on the basis of PLUARG study results (see chapter 1.2 for basis of target loads).
[c] see further discussion of Saginaw Bay in chapter 3.3



(shoreline erosion phosphorus loads not considered in graph)

Figure 15: GREAT LAKES 1976 PHOSPHORUS LOADS UNDER POINT SOURCE REDUCTION SCENARIOS

source reductions, especially in the Lake Erie basin. However, if Lake Erie target loads can be achieved, by a combination of point and nonpoint source controls, the target load for Lake Ontario could be met with point source controls at the 0.5 mg/L phosphorus effluent level along with some urban and rural nonpoint source programs. This results from reduced phosphorus input from Lake Erie through the Niagara River, the interconnecting channel to Lake Ontario. Nonpoint source reductions, achievable at low cost, should be implemented in the Lake Ontario basin to compensate for phosphorus inputs from increasing population and development. In Lake Huron, some nonpoint control is necessary to achieve the target loads. In Lakes Michigan and Superior, the whole lake target load can be achieved through point source control, although local and nearshore problems may continue to exist.

Throughout the Basin, there will be increases in point source loads, even as sewage treatment plant effluent concentrations decrease. This will occur in conjunction with increasing economic activity and population growth, as projected in Table 22. Loadings to the lakes are dynamic; therefore, continued effective management will require ongoing revision in management strategies if Great Lakes water quality is to continue to improve.

Control of Sediment

3.2.3 PLUARG RECOMMENDS THAT EROSION AND SEDIMENT CONTROL PROGRAMS BE IMPROVED AND EXPANDED TO REDUCE THE MOVEMENT OF FINE-GRAINED SEDIMENT FROM LAND SURFACES TO THE GREAT LAKES SYSTEM.

Management of major nonpoint sources of phosphorus will require the control of soil erosion and subsequent sediment delivery to streams and lakes. The deposition of sediment in harbors, channels and drainage ditches results in expensive dredging and maintenance and the necessity for contained disposal of dredge spoil. Sediment can also affect fish spawning areas and cause local turbidity problems.

The role of sediment as a carrier of phosphorus and toxic substances has been discussed in preceding sections of this report. This underlines the need for an effective program of sediment reduction as an important part of an overall nonpoint management strategy. Practicable means to accomplish reductions in sediment loadings will involve provincial, state and local efforts as follows:

(a) accelerate and focus existing information and education efforts in the problem areas identified by PLUARG as a first priority;

(b) conduct monitoring and research efforts to improve erosion and sediment control programs in the priority areas;

(c) through local initiatives, institute ordinances and/or bylaws requiring erosion and sediment control plans for land-disturbing activities;

(d) accelerate technical assistance programs for erosion and sediment control; and

(e) institute reasonable and equitable cost-sharing programs within priority areas.

Control of Toxic Substances

3.2.4 PLUARG RECOMMENDS THE FOLLOWING ACTIONS BE TAKEN TO REDUCE INPUTS OF TOXIC SUBSTANCES TO THE GREAT LAKES:

(i) CONTROL OF TOXIC SUBSTANCES AT THEIR SOURCE;

(ii) CLOSER COOPERATION OF BOTH COUNTRIES IN THE IMPLEMENTATION OF TOXIC SUBSTANCES CONTROL LEGISLATION AND PROGRAMS;

(iii) PROPER MANAGEMENT AND ULTIMATE DISPOSAL OF TOXIC SUBSTANCES PRESENTLY IN USE;

(iv) IDENTIFICATION AND MONITORING OF HISTORIC AND EXISTING SOLID WASTE DISPOSAL SITES WHERE THERE IS AN EXISTING OR POTENTIAL DISCHARGE OF TOXIC SUBSTANCES, AND THE IMPLEMENTATION OF CONTROL PROGRAMS AT THOSE SITES AS NEEDED; AND

(v) JOINT EXPANSION OF EFFORTS TO ASSESS THE CUMULATIVE AND SYNERGISTIC EFFECTS OF INCREASING LEVELS OF THESE CONTAMINANTS ON ENVIRONMENTAL HEALTH AND THE RAPID TRANSLATION OF THESE ASSESSMENTS INTO REFINED WATER QUALITY OBJECTIVES, OTHER ENVIRONMENTAL OBJECTIVES AND, WHEREVER POSSIBLE, TOLERABLE LOADS. FOR CERTAIN TOXIC SUBSTANCES, A ZERO LOAD WILL BE NECESSARY.

Substances that are toxic, have widespread use, bioaccumulate and which are environmentally persistent are now restricting multiple use of the Great Lakes. There are existing restrictions on the use of Great Lakes fisheries because of contamination from toxic substances such as PCBs, mirex and mercury. Concern regarding the health effects of using the lakes as sources of drinking water is increasing.

PLUARG has found that major existing problems are caused by past point source discharges and urban runoff from which toxic substances have accumulated in lake sediments, as well as atmospheric inputs and past use of persistent pesticides. Inputs of toxic substances to the Great Lakes from rural land use activities are minimal, except for potential inputs from spills and poorly designed and/or operated landfills.

Current legislation, and the required controls when fully implemented in both countries, should be sufficient for prevention of most future Great Lakes problems concerning toxic substances. PLUARG recognizes, however, that because of the complexity of these contaminants, including methods for the detection of their environmental health effects and their control, full implementation of legislation will be slow. In the interim, immediate coordinated action in assessing impacts and implementing control programs in the Great Lakes Basin is warranted.

TABLE 22

PRESENT AND FUTURE GREAT LAKES PHOSPHORUS LOADS UNDER SEVERAL PHOSPHORUS REDUCTION SCENARIOS

	metric tons/yr									
	Lake Superior		Lake Michigan		Lake Huron		Lake Erie		Lake Ontario	
Existing 1976 Total Load (excluding shoreline erosion)	4,207		6,350		4,857		17,474		11,755	
Existing 1976 Nonpoint Load[a]	2,238		1,891		2,444		8,445		3,581	
Recommended Target Loads[b]	4,000		4,900		4,400		11,000		7,000	
Reduction Scenarios[c]:	Present (1976)	Future[d] (2020)	Present (1976)	Future[d] (2020)	Present (1976)	Future[d] (2020)	Present (1976)	Future[d] (2020)	Present (1976)	Future[d] (2020)
Scenario 1:(STPs at 1 mg/L)Total Load	4,000	4,000	4,900	5,300	4,500[e]	4,700[e]	13,400	14,700	9,400	11,000
Additional Reduction Required to Meet Target Load	0	0	0	300	100	300	2,400	3,700	2,400	4,000
Percent of Existing Nonpoint Load	0	0	0	16	4	12	28	44	67	112
Scenario 2: (STPs at 0.5 mg/L) Total Load	4,000	4,000	4,400	4,700	4,400[e]	4,500[e]	12,000	12,600	8,200	9,000
Additional Reduction Required to Meet Target Load	0	0	0	0	0	100	1,000	1,600	1,200	2,000
Percent of Existing Nonpoint Load	0	0	0	0	0	4	12	19	34	56
Scenario 3: (STPs at 0.3 mg/L) Total Load							11,500[f]	11,900[f]	7,800[g]	8,300[g]
Additional Reduction Required to Meet Target Load	← Not considered Because Target Loads are Achieved in Either Scenario 1 or 2 above →						500	900	800	1,300
Percent of Existing Nonpoint Load							6	11	22	36

Explanation of Table 22:

[a] includes tributary diffuse and municipal nonpoint direct phosphorus loads; *does not include direct atmospheric and upstream lake loads.*
[b] modified from Task Group III recommended phosphorus loads for Great Lakes (see chapter 1.2 for rationale of recommended loads).
[c] only sewage treatment plants with flows ≥one million gallons per day are reduced to the indicated effluent standards.
[d] sewage treatment plants and upstram lake loads have been projected on the basis of population trends. All other lake inputs were kept constant in these scenarios.
[e] loading reduction may be applied to Saginaw Bay.
[f] based on assumption that phosphorus concentrations in Lake Huron sewage treatment plant effluent (> one million gallons per day) are reduced to 0.5 mg/L.
[g] based on assumption that phosphorus concentrations in Lake Erie sewage treatment plant effluents (> one million gallons per day) are reduced to 0.3 mg/L.

The present lack of technology to deal with in-place contaminants, and the likely cost of implementation of such technology, if it could be developed, makes source control imperative.

In attempting to assess this problem, PLUARG has found that there are insufficient monitoring data to adequately determine trends in sources, loads and ambient concentrations of these contaminants. Such data are necessary for present and future management of this problem.

Control of Microorganisms

3.2.5 PLUARG RECOMMENDS THAT EPIDEMIOLOGICAL EVIDENCE BE EVALUATED TO ESTABLISH APPLICABLE MICROBIOLOGICAL CRITERIA FOR BODY CONTACT RECREATIONAL USE OF WATERS RECEIVING RUNOFF FROM URBAN AND AGRICULTURAL SOURCES.

PLUARG watershed monitoring results and other studies show that indicator bacteria and/or pathogenic bacteria are discharged in runoff water from storm or combined sewers and agricultural activities. Birds and animals are the sources of much of this contamination.

Elevated microbiological levels in nearshore waters can curtail recreational use, including swimming. Current bacteriological criteria were developed primarily for assessing waters affected by human waste. The present practice of evaluating bacteriological results in relation to existing criteria and potential health hazards, and closing beaches to swimming as necessary, should continue until new criteria applicable specifically to waters affected by land drainage are available.

In a long term context, other actions to be considered in relation to the incidence of beach closings include changing the locations of storm sewer outfalls and reducing discharges from combined sewer overflows. Because the potential health hazard from combined sewer overflows is more serious than that from storm sewers and agricultural runoff, *special emphasis should be given to reducing untreated overflows from combined sewers when sewage systems are being expanded or improved.*

Principal Land Uses of Concern

There are a number of land use/land characteristic combinations which contribute to pollution of the Great Lakes. The following recommendations and discussions are concerned with a number of important management alternatives which should be considered in the development of management plans.

AGRICULTURAL LAND USE

3.2.6 PLUARG RECOMMENDS THAT AGENCIES WHICH ASSIST FARMERS ADOPT A GENERAL PROGRAM TO HELP FARMERS DEVELOP AND IMPLEMENT WATER QUALITY PLANS.

THIS PROGRAM SHOULD INCLUDE:

(i) A SINGLE PLAN DEVELOPED FOR EACH FARM, WHERE NEEDED;

(ii) CONSIDERATION OF ALL POTENTIAL NONPOINT SOURCE PROBLEMS RELATED TO AGRICULTURAL PRACTICES, INCLUDING EROSION, FERTILIZER AND PESTICIDE USE, LIVESTOCK OPERATIONS AND DRAINAGE; AND

(iii) A PLAN COMMENSURATE WITH THE FARMERS' ABILITY TO SUSTAIN AN ECONOMICALLY VIABLE OPERATION.

Agricultural pollution problems are often dealt with by separate programs and agencies. Because problems are interrelated, more efficient results may be achieved through a unified approach. This would also reduce the burden on farmers of dealing with a plethora of government agencies and programs. Three major agricultural areas of concern, and a discussion of the adequacy of present programs to deal with these concerns, is presented in this section. PLUARG's position is that these programs should be combined into a single farm planning approach.

Most "normal farming practices" in both countries are exempt from present regulations governing water pollution. Governments, however, do offer advisory services regarding many potentially polluting activities. Pesticide sales and applications are regulated in both countries. In Ontario, permits are required to add pesticides to water. Unauthorized deposition of pesticides in water is a prosecutable offense under The Pesticides Act and if it kills fish, under the Canada Fisheries Act.

Soil Erosion

In the past, the more obvious forms of soil erosion characterized by the formation of rills and gullies have received widespread attention. PLUARG studies, however, have noted that the less visible transport of fine soil particles, associated with sheet and rill erosion, is the prime mechanism for the movement of phosphorus from agricultural lands. Thus, programs directed towards improving Great Lakes water quality must necessarily incorporate this finding in their design.

Control of soil erosion has been a national program in the U.S. for more than 40 years. Major efforts have been undertaken at all levels of government to deal with it. The single most important of these programs is conducted by the U.S. Department of Agriculture (USDA), through the Soil Conservation Service (SCS), whereby technical assistance is made available to the individual farm operator.

An extensive network of technical expertise and erosion control information has been developed leading from SCS to farmers through local Conservation Districts. By placing a strong emphasis at the local level, SCS helps farmers develop conservation plans geared toward specific problems. State and local units of government are closely tied to the programs administered by the SCS. This assistance to individuals and local units of government is based on priorities established by local Conservation Districts, which are subdivisions of state government.

In the Great Lakes states, operators obtain SCS services on a completely voluntary basis. However, New York and Pennsylvania have statewide requirements for erosion control plans, as will Ohio, if pending legislation is enacted. Very significant progress has been made, but there is no guarantee the most serious erosion problems are controlled by soil conservation programs.

Historically, conservation plans developed with SCS assistance have been directed toward maintaining soil and water resources for future use. The effectiveness of these plans for improving water quality varies according to land characteristics, as well as the nature of downstream water quality problems. As Section 208 water quality management plans are developed and approved, required measures will be incorporated into long term water quality plans in identified nonpoint source problem areas. Because there has been a close link established between the planning agencies and the local SCS offices in many cases, the connection between improved conservation practices and water quality has been made. A recent development of significance to the reduction of agricultural erosion is the provision of technical and financial assistance for implementing long term measures for water quality improvement in Section 35 of the 1977 Federal Clean Water Act. Funding is limited to those measures identified in state and areawide Section 208 plans.

Numerous other state and federal programs also provide fiscal assistance and information/education support to the farm community. The most notable is the Agricultural Conservation Program which makes available federal cost-sharing funds for conservation practices.

Other U.S. Department of Agriculture agencies also administer programs that can help water quality management efforts. The Farmers Home Administration makes loans to rural residents and small businesses for pollution abatement. The Science and Education Administration (SEA) – Federal Research, and Cooperative Research, conducts and supports water quality research aimed at the development of effective and practical remedial measures. SEA-Extension supports education programs through State Cooperative Extension Services. The Economics, Statistics, and Cooperatives Service makes economic evaluations of remedial measures.

The Small Business Administration, an independent U.S. agency, has authority to make reasonable cost loans to small business firms, including farmers, for water pollution control measures.

The same level of assistance for soil conservation has not been evident in Canada, where emphasis has been placed more on productivity and profitability. Some presently accepted agricultural practices, such as fence row removal, the monoculture of row crops and a widespread dependency on inorganic fertilizers, has resulted in reduced organic matter in soils, and higher levels of soil erosion in some areas of the Basin, which contributes to Basin water quality problems. During the 1950's and early 60's, the Ontario Ministry of Agriculture and Food (OMAF) did operate a program of developing conservation plans for Ontario farmers. There is evidence, however, that this attitude is changing both in the Ontario Ministry of Agriculture and Food, and in many Conservation Authorities. Today, OMAF extension personnel provide technical assistance on request concerning soil erosion.

The Conservation Authorities in Ontario also provide advice to farmers on soil erosion control. This program is far from being uniform, however, since local authorities have considerable autonomy in determining program priorities.

Federal and provincial governments, through the Agricultural Rehabilitation and Development Act (ARDA), have in the past also entered into cost-sharing programs for the purpose of soil improvement and conservation of agricultural lands. This was discontinued in the last ARDA agreement, although the potential remains for their reconsideration.

Several avenues presently exist for the Canadian government to provide financial assistance to farmers undertaking soil conservation measures. Under the Farm Credit and Farm Syndicates Acts, funds are available for purchasing equipment or erecting structures to conserve soil. The accelerated Capital Cost Allowance Programme allows farmers to amortize the cost of equipment and processes installed for controlling water pollution. Existing cost-sharing programs, either between government agencies and/or between government and farmers, are not actively encouraging farmers to implement soil conservation planning.

Although agricultural soil losses have, in most cases, not reached the level where reduced yields are experienced, many farmers use erosion control techniques. PLUARG's agricultural survey[34,35] showed farmers did not generally feel they were contributing to water pollution, although soil losses in some watersheds are high enough to warrant concern for water quality. Therefore, agencies responsible for soil conservation programs will have to realize that these programs required to improve water quality will often be directed more for the benefit of society than for the individual farm operator. For this reason, these *programs must also involve a heavy reliance on education and voluntary persuasion in the initial phases to demonstrate the need for improved erosion control and build on the stewardship ethic.* A flexible cost-sharing component would be of great benefit in providing an extra inducement in those instances where little individual benefit may be realized.

In both countries, *implementation of soil conservation measures should make maximum use of existing federal, state, provincial and local agencies, broadening authorities and increasing resources to the extent necessary.*

Livestock and Poultry Manures

Since 1970, several revisions of the Ontario Agricultural Code of Practices have been issued jointly by the Ontario Ministries of Agriculture and Food, Environment and, recently, Housing. The original intent of this Code was to provide farmers contemplating expansion with the necessary guidance to avoid air/odour problems affecting nearby residences. The most recent version encompasses formulae for calculating separation distances between farm buildings and nearby residences to avoid air/odour problems, manure management plans, and methods for controlling water pollution caused by livestock watering at streams, ponds or lakes. Local municipalities are also encouraged to incorporate the present version of the Code into their municipal zoning by-laws. *The Code has been singularly successful in reducing odour problems from livestock operations on a voluntary basis. It requires strengthening, however, in the areas of reducing water pollution problems. Specific information related to the design and construction of proper manure management systems is also needed by farmers.*

In PLUARG's agricultural survey[35], only 31 percent of Ontario's livestock operators were familiar with the general guidelines of the Code of Practice and/or the attendant Certificate of Compliance program. This situation underlines the need for the adoption of a more intensive extension program of informing all livestock operators of the intent of the Code, if a measurable reduction in the water pollution from livestock operations is to be achieved. To this end, *more resources should be made available to the implementing agencies to insure that all livestock farmers become aware of the suggested Code of Practice.*

Periodic evaluation of the effectiveness of this program should also be undertaken in order to determine the level of awareness of Ontario livestock farmers and the level of implementation of measures designed to improve the management of livestock wastes.

The Ontario Farm Pollution Advisory Committee has also played an important role in coordinating the concerns of both pollution control and agricultural production interests. A strong emphasis on this type of coordinating role will be required in the future.

The National Pollutant Discharge Elimination System (NPDES) permit regulations cover only about five percent of the feedlots in the U.S. portion of the Basin, with control of the remainder varying from state to state. Although each state has the authority to go beyond the federal NPDES requirements, not all have done so. Indiana, New York and Ohio have developed guidelines for dealing with smaller feedlots. *The states should develop programs to deal with animal feedlot operations not covered by the NPDES regulations. Sufficient funds should be made available to the appropriate agencies to insure that requirements of those programs can be met.*

Commercial Fertilizers

Through a network of extension offices, annual publications and periodic news releases, agricultural extension agencies in the Basin provide information and guidance to farm operators concerning the types and quantities of fertilizers needed for optimum crop production. Farmers are also encouraged to have their soil tested prior to fertilizer application. Regulations pertaining to fertilizers have been limited to manufacture, distribution and labelling, primarily for consumer protection.

The PLUARG agricultural survey indicated that, while approximately 90 percent of Ontario farmers were aware of soil testing services, only 60 percent had their soil tested for fertilizer needs. Some farmers in the agricultural watersheds monitored by PLUARG were found to use twice the amount of phosphorus fertilizer, on the average, as the recommended county requirements. Phosphorus application exceeding that needed for optimal plant growth, especially in the HAA, increases the hazard of water pollution from this source.

By decreasing the use of fertilizer phosphorus to recommended levels, there should be a mutual benefit of decreasing the farmers' fertilizer costs, while decreasing the risk of water pollution. *Both countries should place greater emphasis on improving fertilizer application practices, especially within the HAA, and farmers should be encouraged to make greater use of soil testing services and to fertilize in accordance with these tests.*

URBAN LAND USE

3.2.7 PLUARG RECOMMENDS THE DEVELOPMENT OF MANAGEMENT PLANS FOR CONTROLLING URBAN STORMWATER RUNOFF. THESE PLANS SHOULD INCLUDE:

(i) PROPER DESIGN OF URBAN STORMWATER SYSTEMS IN DEVELOPING AREAS SUCH THAT THE NATURAL STREAM FLOW CHARACTERISTICS ARE MAINTAINED; AND

(ii) PROVISION FOR SEDIMENT CONTROL IN DEVELOPING AREAS, AND CONTROL OF TOXIC SUBSTANCES FROM COMMERCIAL AND INDUSTRIAL AREAS.

In the Great Lakes Basin, most concern associated with urban nonpoint pollution problems is linked with the loss of excessive sediment in developing urban areas, and the discharge of complex wastes from developed areas during periods of stormwater runoff. The concern is heightened in many developed areas where stormwater runoff is mixed with sanitary and industrial wastes in combined sewer overflows. Because storm sewers provide rapid routes to streams and lakes, special consideration and planning are needed to reduce hazards to water quality from accidental spills and discharges in urban areas.

Under the terms of the Canada/Ontario Agreement on Great Lakes Water Quality, the provincial and federal governments have taken considerable initiative with regard to stormwater runoff management. This action involved the preparation of a "Manual of Practice on Urban Drainage". This manual[91] deals with both the quantity and quality impacts of stormwater runoff, including a new methodology and criteria for its control. The manual represents a first attempt to rationalize the varying concerns of several provincial agencies regarding a specific nonpoint pollution problem.

To date, efforts to familiarize local authorities with the manual have basically been limited to their technical staffs and consultant groups hired by these authorities to carry out urban drainage projects.

Implicit in this new approach are techniques not previously used extensively in Ontario. Some of these techniques, including pollutant control at the source, use of surface retention/detention ponds, and reliance on lot grading to carry drainage in overland flow, will require a high degree of public acceptance not only to insure the commitment of municipal officials, but also to maintain the long term integrity of these measures.

In the United States, urban stormwater problems are being studied under Section 208 programs. The recently-enacted Clean Water Act of 1977 places strict statutory limits on the use of federal construction grant money for stormwater controls. These funds can, however, still be used for correcting combined sewer problems where they have been identified as having a substantial impact on water quality. Such projects would probably have a lower priority than municipal waste treatment facilities. Present U.S. Environmental

Protection Agency policy is to encourage the development of nonstructural control alternatives.

Existing urban development programs do not consider water quality problems, due to lack of information on the magnitude of the problem and its relationship to these programs. *Knowledge regarding urban nonpoint source problems and solutions has been developed by PLUARG and others, and a concerted effort is needed to transfer this information to the appropriate agencies for their use.*

Efforts need to be made at all levels of government (federal, state, provincial and local) to inform and educate appropriate public officials as to the nature and extent of urban stormwater problems in the Great Lakes Basin. The relationship between their areas of responsibility and water quality problems from urban runoff should be clearly demonstrated. Mechanisms must be developed through which public officials are brought into the stormwater management process, including the following:

(a) expansion of current information transfer programs related to problems and solutions, geared toward specific groups of public officials; and

(b) exploration of how urban stormwater management objectives can be included within the purview of other ongoing programs. Examples in the United States include the Housing and Urban Development 701 local planning assistance program, the state coastal zone management programs and others. In Canada, the local official planning process and the activities of the Conservation Authorities should include consideration of these objectives.

Education programs must be aimed at developing improved public awareness of urban stormwater problems and solutions. The Ontario Ministry of the Environment and the appropriate U.S. state and federal agencies should develop such information programs for informing Basin residents. Educational programs should stress improved urban housekeeping practices.

The adoption of a preventive stance in controlling urban drainage problems will require the development of a clearly stated urban runoff policy. The responsible federal, state or provincial authorities should complete policies on urban drainage. These policies should be emphatic on the benefits of the control of stormwater runoff at the source. Local units of governments should then be encouraged to develop stormwater management controls based on these policy guidelines. In addition, an active program to inform local elected officials concerning quality and quantity problems associated with urban runoff would accelerate adoption of this new approach.

Through other fiscal policies related to funding storm drainage projects and new urban developments, various levels of government can encourage incorporation of stormwater management controls. In Canada, under the terms of the National Housing Act, the Central Mortgage and Housing Corporation may enter into agreements with provincial and municipal governments to assist in the establishment or expansion of sewage treatment projects and the construction of storm sewer systems. Portions of these loans may also be forgiven, thus increasing their appeal with borrowing agencies. At present, these loans are not conditional upon encouraging the quantity and quality management of stormwater runoff. Priority should also be placed on developing the controls needed for reducing contaminated runoff from new developments to prevent the transfer of pollutants where urban runoff is a problem, since such action would normally be more cost-effective than altering existing systems.

Elevated lead levels in stormwater runoff have been directly linked to vehicular exhaust. Removal of lead at the source, through a program which reduces the present economic penalty for using unleaded gasoline, is one of the solutions to this problem. To this end, some of PLUARG's panels indicated that *federal, state or provincial governments should consider changing the present tax structure on gasoline to remove the price differential between leaded and unleaded gasoline.*

The control of accelerated soil erosion in developing areas is of concern to PLUARG. At present, there are no federal regulations for dealing with pollution from construction sites on nonfederal land. In addition, only two states in the Basin (Pennsylvania and Michigan) have adopted regulations for the control of erosion and sediment transport from construction sites. In Ontario, there have been few initiatives taken to reduce this problem. Action at the local level is unlikely, unless sufficient resources are provided to administer and enforce strengthened programs.

Sediment control programs for construction sites should be developed and implemented at all appropriate levels of government. Sufficient funding must be available to the implementing agencies to insure that they can adequately carry out such programs.

In Canada, the National Housing Act could be amended to require sediment control plans for new developments funded under the Act. Amendments to the Act, or the development of policies (by Central Mortgage and Housing Corporation) outlining sediment control requirements, would be useful. *Site-specific sediment control requirements must be implemented for all new developments in the Basin.*

Sediment control alternatives available in Ontario include:

(a) amending the Planning Act to require a sediment control plan before allowing subdivision approval;

(b) enacting a Sediment Control Act to establish maximum sediment losses from different kinds of land-disturbing operations;

(c) supplementing Conservation Authority regulations by statutory authorization for sediment control anywhere in a watershed; and

(d) under the Ontario Environmental Assessment Act, all public and private land developments be subject to an environmental assessment and demonstrate there will be no harmful increases in sediment levels in streams draining development sites.

Implicit in the implementation of any approach will be the need for adequate resources to review plans and to insure that required measures are implemented during the actual construction and development stage.

Along with PLUARG's general concern for sediment control at all new developments, there is a specific concern related to development in flood plains and wetlands. Because the flood plain is within the most hydrologically active area, the potential is high that land-disturbing operations during the construction phase, and subsequent land use activities, will result in water quality impacts. *If future development within existing flood plains is allowed, adequate design provisions are required to prevent increases in pollutant loads and hazards to water quality from construction activities, accidental spills or discharges.*

WETLANDS AND FARMLANDS

3.2.8 PLUARG RECOMMENDS THE PRESERVATION OF WETLANDS, AND THE RETENTION FOR AGRICULTURAL PURPOSES OF THOSE FARMLANDS WHICH HAVE THE LEAST NATURAL LIMITATIONS FOR THIS USE.

Within the Great Lakes Basin, there are many areas with unique features which should be retained to help reduce pollution. Wetland areas and Class I agricultural lands are two principal areas of concern.

Coastal wetlands act as a sink for pollutants and, as such, provide benefits in reducing Great Lakes pollution from point and nonpoint sources. These natural sinks are available at little or no cost, require little or no maintenance and provide an additional degree of protection to the lakes. Wetlands also provide wildlife habitat, have recreational value and reduce the need for local flood protection.

Conversion of wetlands to other uses may increase nonpoint pollution to the Great Lakes, through the release of pollutants from wetlands and from through-flow from upstream regions.

Natural upland wetlands, as well as man-made reservoirs, also provide protection to the Great Lakes, which should be considered in water quality plans. These regions are not considered in the coastal zone management programs, but they do serve to reduce the sediment and pollutant delivery ratios to the Great Lakes to less than 1.0, even to zero in some cases. These natural or man-made upland pollutant traps have been factored into the potential contributing area classification system used in the PLUARG study.

Normally, Class I farmland represents a soils regime which can be treated most cost-effectively, to reduce diffuse source pollutants, when used for farming purposes. Preventing the loss of such farmlands to nonfarm uses will prevent less desirable land being brought into farm use. Less desirable land may have characteristics conducive to generating greater nonpoint source pollutants and, consequently, require more complex and expensive remedial measures. Actions to reduce the loss of Class I farmlands generate additional benefits to the consumer, through the production of food at least cost.

LOCAL PROBLEM AREAS

3.2.9 PLUARG RECOMMENDS THAT THE INTERNATIONAL JOINT COMMISSION, THROUGH THE GREAT LAKES REGIONAL OFFICE, INSURE THAT LOCAL LEVELS OF GOVERNMENT ARE MADE AWARE OF THE AVAILABILITY OF PLUARG FINDINGS, ESPECIALLY AS THEY RELATE TO LOCAL AREA PROBLEMS, TO ASSIST THEM IN DEVELOPING AND IMPLEMENTING NONPOINT SOURCE MANAGEMENT PROGRAMS.

Many PLUARG (Appendix 3) and related studies resulted in considerable information and insight being gained concerning water quality problems, essentially local in nature because of the small size of the land use contributing areas, their distance from the Great Lakes and/or the level of management practiced.

A list of land use activities restricted primarily to local water quality impacts is as follows:

(a) nonsewered waste disposal;

(b) transportation;

(c) extractive;

(d) recreation;

(e) deepwell disposal;

(f) solid waste disposal;

(g) sewage sludge disposal;

(h) shoreline and riverbank erosion;

(i) shoreline landfilling; and

(j) forested areas

PLUARG land use projections indicate the intensity and magnitude of some of these activities may increase. In these situations, it will be necessary for the U.S. and Canadian governments to remain vigilant. For example, in the case of deepwell disposal, existing operations have been severely restricted. However, continued generation of toxic wastes, for which treatment technologies are currently unknown or unavailable, could result in demands for relaxation of present controls. Resultant reopening of closed deepwell disposal sites could hold important implications for the lakes. Proper treatment sites for these wastes must be developed if this situation is to be avoided.

Land disposal of sewage sludge is another example where future problems may occur. As the urban population increases, and if phosphorus loadings from municipal point sources are further restricted, the quantities of sewage sludge generated will increase. If the volume of these sludges become large enough, water quality effects due to land disposal of sludges may occur.

Although PLUARG studies indicate these various land use activities have not caused a significant effect on Great Lakes water quality, numerous instances of changes in local water quality were attributed to these activities.

The maintenance and protection of local water quality is not within the mandate of the International Joint Commission. However, the respective agencies involved in implementing PLUARG's recommendations will, in many instances, be concerned with local water quality protection.

3.3 COMPARATIVE COSTS OF PHOSPHORUS AND SEDIMENT LOAD REDUCTIONS

General Considerations

It should be stressed that the phosphorus load reductions derived through overview modelling are not intended to represent a rigid scheme or recommended sequence of controls for achieving the recommended target loads. Rather, the following analysis should be viewed as a means of quantitatively comparing various management alternatives in order to better insure the implementation of cost-effective nonpoint and point source controls. Similarly, as new information becomes available (e.g., better cost data) the process can be used to generate more detailed assessments of these controls.

Even with problem area identification on a subwatershed basis, it will still be necessary to identify sites within subbasins that contribute most of the pollution. Because of the Basin-wide scope of the PLUARG study, no attempt is made to do so in this report. However, information on the factors which combine to cause nonpoint source problems provide a guide to determining specific problem areas. Local efforts will be required to "walk the land" and identify individual sites which are actual nonpoint source problem areas. Control of these sites, which may comprise a relatively small percentage of the total land area, will likely provide the greatest return at the least cost.

In the development and implementation of remedial measures, cost-effectiveness, total costs and total amounts of materials removable are considered. Although other factors must also be considered, the PLUARG analysis does not deal with the economic implications of the recommended phosphorus target loads, and the related social, legislative, institutional and technical factors. Rather, this analysis provides information on total annual costs and unit costs associated with selected degrees of phosphorus loading reductions. The discussions below and the accompanying tables are designed to provide some indication of the most direct costs of program alternatives to achieve target phosphorus loadings. Various levels and types of programs may be undertaken for the various lakes, and the combination of measures may vary from place to place.

Other criteria are also important in the selection of remedial programs. A major technical consideration is the biological availability of phosphorus. The relative proportions of available and unavailable phosphorus vary considerably among sources. For example, phosphorus from municipal wastewater treatment plants and livestock operations is more biologically available than that associated with eroded particles arising from agricultural sources. In some cases, the unit cost of phosphorus removal is also lower for those sources with the highest proportion of available phosphorus, making control of these sources relatively cost-effective. Also, it is important to consider what other pollutants may also be removed through implementation of a specific program for the removal of phosphorus (e.g., removing metals in urban stormwater).

Cost-Effectiveness

Municipal point source removal of phosphorus, at least to a 0.5 mg/L effluent concentration, was the most cost-effective of all measures examined in this study. Cost per metric ton phosphorus reduction in lake loads, in moving from 1975 effluent levels to 0.5 mg/L, is $7,500 to $8,000. The cost-effectiveness of a reduction from 1975 effluent levels to 0.3 mg/L would be approximately $16,000-17,000 per metric ton reduced load, although the incremental or marginal cost in moving from 0.5 to 0.3 mg/L would be approximately $100,000 per metric ton.

Unit costs for rural programs vary widely. For example, they range from $5,000-6,000 per metric ton phosphorus reduced load, attributable to strip cropping programs in some areas of fine-textured soils, to in excess of $100,000 per metric ton for measures such as spring plowing for row crops (with attendant large losses in production), improved drainage practices and buffer strips (including costs for both works and lost production) in specific agricultural regions. Although livestock waste management practices should be considered for incorporation into rural programs for phosphorus reduction, their costs have not been included in the program costs presented here. These are more than 25,000 intensive livestock operations in the Great Lakes Basin, but only a few of these operations would require significant improvement (for Great Lakes Water quality benefits), and would have to be considered on a case-by-case basis.

Urban nonpoint phosphorus removal programs are extremely expensive per metric ton removed. Even the first level programs may cost $80,000-100,000 annually per metric ton removed. Second and third level programs are estimated to have unit costs of $150,000 and $250,000, respectively, per metric ton removed.

The final selection of a control program is complicated by the fact that the unit costs of some point and nonpoint control programs are similar. For example, various agricultural programs might cost $50,000 to $100,000 per metric ton of phosphorus load reduction, while the incremental cost of point source controls to reduce effluent concentrations from 0.5 mg/L to 0.3 mg/L is approximately $100,000 per metric ton.

Further details relating to analysis of remedial program effects may be found in chapter 2.6 and in the appropriate PLUARG technical report[85,87]. For more information on individual remedial measures, the reader is referred to the report[92], "Evaluation of Remedial Measures to Control Nonpoint Sources of Water Pollution in the Great Lakes Basin". A summary of the remedial measures examined in this latter report is presented in matrix form in Appendix 4.

Program Costs and Results

Based upon the phosphorus loading information provided in chapter 1 and the recommended phosphorus loads in Table 21, it is reiterated that a whole lake phosphorus loading reduction program is not required for Lakes Superior and Michigan. Special attention, however, is required for segments of both lakes to protect nearshore water quality. In Lake Superior, this includes reduction of point source loads to restricted embayments (e.g., Thunder Bay, Duluth-Superior Harbor) and not further disturbing the highly erodible red clay area along the southwestern part of the lake. The southern portion of Lake Michigan should be treated as a sub-system similar to Saginaw Bay by agencies developing management plans for phosphorus load reductions.

Phosphorus load reductions, for the whole of Lake Huron, required to meet the target load, are negligible, amounting to only 100 metric tons/yr. However, Saginaw Bay, which also impacts on the waters of southern Lake Huron (as discussed in chapter 1) represents a special case for which additional load reductions are required to achieve local water quality objectives. Phosphorus reduction to the Task Group III's recommended loading of 440 metric tons/yr would require removal of 760 metric tons/yr from the base year load[a]. The reduction to the target load of 440 metric tons/yr is designed to reduce the trophic status of Saginaw Bay from eutrophic to mesotrophic, and to reduce taste and odor problems in drinking water. This would require a very intensive program and would probably cost close to $31.5 million (U.S. total in Table 23), and even so may not fully achieve the target load. A reduction as suggested by Task Group III to a loading of 620 metric tons/yr to achieve *minimal* compliance with present taste and odor standards would still require a reduction of municipal point source effluents to 0.5 mg/L (for treatment plants discharging 1 million gallons/day or greater), and rural level 2 and urban level 1 measures, at a total annual cost of $12.5 million. This latter strategy would appear to be the best compromise which even though it will not attain optimum water quality in Saginaw Bay, will be of benefit to the water quality of southern Lake Huron. Canada should implement a program of comparable effort in southern Lake Huron.

The trophic status of Lake Erie is a transition from eutrophic to mesotrophic from the western to the deeper eastern basin. The recommended annual phosphorus target load is 11,000 metric tons. This target requires an average annual load reduction of about 6500 metric tons from the 1976 baseload of 17,474 metric tons, or 2400 metric tons following the agreed upon[1] municipal sewage treatment plant effluent concentration of 1.0 mg/L. This can be achieved, for example (Table 24), by a reduction in municipal treatment plant effluent concentrations to 0.5 mg/L, at an incremental cost of $10.5 million/yr, to reduce the load by 1300 metric tons, and an additional diffuse source reduction of 1100 metric tons, 13 percent of the diffuse source load. This diffuse source reduction can be achieved by combined level 2 rural and level 1 urban control programs, at an annual cost of $59.0 million. This results in a total estimated annual cost for point and diffuse source control of $69.5 million. Extrapolation of point source phosphorus loading (assuming 0.5 mg/L effluent concentrations) on the basis of population projections to the year 2020, results in a required additional annual load reduction of 550 metric tons. This would require, for example, application of a level 3 rural and some additional urban control programs, at additional costs shown in Table 24, or some combination of a further point source control program (to 0.3 mg/L) and diffuse source control programs.

The loading reductions brought about by point source and rural and urban nonpoint controls in the Lake Erie basin will occur primarily in the western basin, due to the large phosphorus inputs to this portion of the lake.

[a] the 1976 base loads as defined by Task Group III are considerably less than the PLUARG 1976 estimated loads because of annual variations in nonpoint source loads, resulting from hydrologic variations. The reduction of 760 metric tons/yr refers to the 1976 load of 1200 metric tons determined by Task Group III (see chapter 1.2 for details concerning Task Group III recommended target loads).

An estimated 40 percent of the phosphorus load to Lake Ontario is derived from the Niagara River, predominantly from Lake Erie. A reduction of the phosphorus load to Lake Erie in accordance with the recommended target load will produce an estimated annual reduction of the Niagara River load by 1200 metric tons (Table 25). A further annual load reduction of 1200 metric tons will be required to meet the recommended target load of 7000 metric tons/yr with municipal point sources at 1.0 mg/L[1]. This is based upon a 1976 base year load of 11,755 metric tons. According to the schedule in Table 25, the annual reduction of 1200 metric tons can be readily achieved by reduction in municipal point source effluents to 0.5 mg/L, at an annual cost of $7.5 million, plus a rural program of sound management practices (level 1) at minimal cost, together with a level 1 urban nonpoint program at an estimated further cost of $14.0 million, for reducing sediment and phosphorus loss. With municipal point sources operating at a 0.5 mg/L phosphorus effluent concentration, loads will have increased progressively to 800 metric tons/yr above the target load by the year 2020. This will require the phased-in control program of a reduction of municipal phosphorus effluent concentrations to 0.3 mg/L, and a level 2 urban program, at costs indicated in Table 25. Little additional phosphorus may be removed in a level 2 rural program, probably no more than 25 metric tons, in the Lake Ontario basin.

Probable rural costs in the southern Lake Huron, Lake Erie and Lake Ontario basins are estimated to be between $26.5 and $57.0 million annually, depending upon the levels of treatment selected. Average annual cost per hectare of agricultural land is estimated to be $3.50 (about $1.40/acre), ranging from minimal additional cost for level 1 to about $60 for some hectares ($24/acre) given level 3 treatment. About 112,000 km^2 (about 27,400,000 acres) of agricultural land should receive at least level 1 treatment. Close to 40 percent of this land will require additional treatment beyond level 1 in order to meet target loads.

Much data are available to permit calculations of reductions of certain other pollutants through phosphorus control programs. For example, in the Canadian basin of Lake Erie, suspended solids from rural sources would be reduced, from about 450,000 metric tons/yr, by about 40,000 metric tons at the sound management level for rural nonpoint sources, and by about 170,000 metric tons at level 2 and 200,000 metric tons at level 3. Metals and suspended solids removal with phosphorus in urban nonpoint programs should be examined in similar ways.

Developing land, in most regions and under most circumstances, should have sediment control programs. In fact, agencies promoting erosion control for rural lands should require a practicable level of effort on developing urban lands, notwithstanding that these lands contribute a low percentage of *total* sediment load. Rough estimates of costs and effects have been made for Lakes Erie and Ontario. Over the period of 1975-2000, approximately 8000 hectares (20,000 acres) are expected to be developed annually in the Lake Erie basin, and 4500 hectares (11,250 acres) in the Lake Ontario basin. Costs may amount to $2000 per hectare ($800/acre) for seeding, mulching, and other measures of value in retarding erosion. The annual cost in Lakes Erie and Ontario with the above assumptions, would be $25 million per year. The total appears large, but it translates to no more than $200 per single family residential lot, on the average. This program could reduce suspended solids losses by 10,000 to 15,000 metric tons/yr.

TABLE 23

PHOSPHORUS REDUCTION ALTERNATIVES APPLICABLE TO LAKE HURON[a]

Remedial Measure Options		Estimated Incremental Phosphorus Reduction (metric tons)	Estimated Cumulative Phosphorus Reduction (metric tons)	Estimated Incremental Annual Cost ($ million)	Estimated Cumulative Annual Cost ($ million)	Estimated Annual Incremental Unit Costs ($ thousand/ metric ton reduction)
URBAN POINT SOURCES:						
Reduction of municipal sewage treatment plant effluent concentrations[b]:						
a) present concentration to 1.0 mg/L	U.S.	260	260	0.5	1.5	
	Canada	25	25	0.5	0.5	
	TOTAL	285	285	1.0	2.0	3.5
b) 1.0 mg/L to 0.5 mg/L	U.S.	90	350	1.0	2.5	
	Canada	35	60	0.5	1.0	
	TOTAL	125	410	1.5	3.5	12.0
RURAL NONPOINT SOURCES:	land area U.S. 9,500 km^2 Canada 20,000 km^2					
Level 1 Sound management on all agricultural lands (10 percent phosphorus reduction; southern Lake Huron and Saginaw Bay)	U.S.	50	50	Minimal	Minimal	Minimal
	Canada	40	40	Minimal	Minimal	Minimal
	TOTAL	90	90			
Level 2 Level 1 measures, plus buffer strips, strip cropping, improved municipal drainage practices, etc., depending on region (25 percent reduction in phosphorus losses on soils requiring treatment; southern Lake Huron and Saginaw Bay)	U.S.	40	90	2.5	2.5	
	Canada	35	75	1.5	1.5	
	TOTAL	75	165	4.0	4.0	53.3
URBAN NONPOINT SOURCES:	land area U.S. 1,500 km^2 Canada 125 km^2					
Level 1 Program of pollutant reduction at source	U.S.	100	100	7.5	7.5	
	Canada	5	5	0.5	0.5	
	TOTAL	105	105	8.0	8.0	76.2
Level 2 Level 1 measures, plus detention/sedimentation	U.S.	120	220	19.0	26.5	
	Canada	5	10	1.5	2.0	
	TOTAL	125	230	20.5	28.5	164.0

[a] based on 1976 datum, a reduction of 100 metric tons/yr to southern Lake Huron and 580 metric tons/yr to Saginaw Bay have been recommended. Most of the total urban point and nonpoint programs listed above would occur in the Saginaw Bay basin. Costs are current dollars to nearest $0.5 million and reductions to nearest 5 metric tons.

[b] Includes chemical phosphorus removal at some U.S. and Canadian plants. Approximately $1.0 million has already been spent, $0.3 million in Canada and $0.7 million in the United States.

TABLE 24

PHOSPHORUS REDUCTION ALTERNATIVES APPLICABLE TO LAKE ERIE[a]

Remedial Measure Options		Estimated Incremental Phosphorus Reduction[b] (metric tons)	Estimated Cumulative Phosphorus Reduction[b] (metric tons)	Estimated Incremental Annual Cost ($ million)	Estimated Cumulative Annual Cost ($ million)	Estimated Annual Incremental Unit Costs ($ thousand/ metric ton reduction)
URBAN POINT SOURCES:						
Reduction of municipal sewage treatment plant effluent concentrations:						
a) 1.0 mg/L to 0.5 mg/L	U.S.	1180	(est.) 6330	9.0	31.0	
	CANADA	125	(est.) 355	1.5	3.5	
	TOTAL	1305	6685	10.5	34.5	8.0
b) 0.5 mg/L to 0.3 mg/L	U.S.	580	6910	54.5	85.5	
	CANADA	65	420	6.5	10.0	
	TOTAL	645	7330	61.0	95.5	95.5
RURAL NONPOINT SOURCES:	**land area** U.S. 34,000 km^2 CANADA 22,000 km^2					
Level 1 Sound management on all agricultural lands (10 percent phosphorus reduction)	U.S.	350	350	Minimal	Minimal	Minimal
	CANADA	100	100	Minimal	Minimal	Minimal
	TOTAL	450	450			
Level 2 Level 1 measures, plus buffer strips, strip cropping, improved municipal drainage practices, etc., depending on region (25 percent reduction in phosphorus losses on soils requiring treatment)	U.S.	200	550	12.5	12.5	
	CANADA	150	250	10.0	10.0	
	TOTAL	350	800	22.5	22.5	64.3
Level 3 Level 2 measures at greater intensity of effort (to achieve 40 percent reduction in phosphorus losses on soils needing treatment)	U.S.	180	730	32.5	45.0	
	CANADA	125	375	20.5	30.5	
	TOTAL	305	1105	53.0	75.5	174.0
URBAN NONPOINT SOURCES:	**land area** U.S. 6,000 km^2 CANADA 670 km^2					
Level 1 Program of pollutant reduction at source	U.S.	425	425	34.0	34.0	
	CANADA	20	20	2.5	2.5	
	TOTAL	445	445	36.5	36.5	82.0
Level 2 Level 1 measures, plus detention/sedimentation	U.S.	575	1000	89.5	123.5	
	CANADA	40	60	7.0	9.5	
	TOTAL	615	1060	96.5	133.0	156.9

[a] based on 1976 datum, a reduction of 2400 metric tons/yr has been recommended. Costs are current dollars to nearest $0.5 million and reductions to nearest five metric tons.
[b] reduction in 1980 from the 1976 existing load; phosphorus reduction and cost estimates are cumulative only within each specific urban and rural source category.

TABLE 25

PHOSPHORUS REDUCTION ALTERNATIVES APPLICABLE TO LAKE ONTARIO[a]

Remedial Measure Options		Estimated Incremental Phosphorus Reduction (metric tons)	Estimated Cumulative Phosphorus Reduction[b] (metric tons)	Estimated Incremental Annual Cost ($ million)	Estimated Cumulative Annual Cost ($ million)	Estimated Annual Incremental Unit Costs ($ thousand/ metric ton reduction)
URBAN POINT SOURCES:						
Reduction of municipal sewage treatment plant effluent concentrations:						
a) 1.0 mg/L to 0.5 mg/L	U.S.	300	1650	2.5	8.5	
	Canada	700	1740	5.0	15.0	
	TOTAL	1000	3390	7.5	23.5	7.5
b) 0.5 mg/L to 0.3 mg/L	U.S.	160	1810	15.5	24.0	
	Canada	125	1865	20.0	35.0	
	TOTAL	285	3675	35.5	59.0	124.6
RURAL NONPOINT SOURCES:	**land area** U.S. 9,600 km² Canada 18,000 km²					
Level 1 Sound management on all agricultural lands (10 percent phosphorus reduction)	U.S.	25	25	Minimal	Minimal	Minimal
	Canada	55	55	Minimal	Minimal	Minimal
	TOTAL	80	80			
URBAN NONPOINT SOURCES:	**land area** U.S. 1,400 km² Canada 1,500 km²					
Level 1 Program of pollutant reduction at source	U.S.	90	90	7.5	7.5	
	Canada	50	50	6.5	6.5	
	TOTAL	140	140	14.0	14.0	100.0
Level 2 level 1 measures, plus detention/sedimentation	U.S.	110	200	19.5	27.0	
	Canada	150	200	18.5	25.0	
	TOTAL	260	400	38.0	52.0	146.0
REDUCTION FROM LAKE ERIE (AT 11,000 METRIC TON RECOMMENDED TARGET LOAD)			1200	(see Lake Erie program on Table 24)		

[a] based on 1976 datum, a reduction of 2400 metric tons/yr has been recommended. Costs are current dollars to nearest $0.5 million and reductions to nearest 5 metric tons.
[b] reduction in 1980 from the 1976 existing load; phosphorus reduction and cost estimates are cumulative only within each specific urban and rural source category.

This is not a large proportion of suspended solids inputs to the lakes from all sources, but it is significant, especially in terms of local effects near urban areas. A considerable improvement in data on sediment losses and program costs, collected under Great Lakes region conditions, will be necessary before more useful cost estimates can be produced. Also, actual *sediment* sampling by approved procedures would be necessary, rather than the *suspended solids* data which are commonly available.

3.4 REVIEW AND EVALUATION OF MANAGEMENT PLAN IMPLEMENTATION

After the governments have submitted management plans for implementing a program of nonpoint source pollution control, the following actions should be undertaken:

Review of Implementation

3.4.1 PLUARG RECOMMENDS:

(i) THE INTERNATIONAL JOINT COMMISSION INSURE REGULAR REVIEW OF PROGRAMS UNDERTAKEN FOR THE IMPLEMENTATION OF RECOMMENDATIONS ARISING FROM THIS REFERENCE; AND

(ii) THAT NONPOINT SOURCE INTERESTS BE REPRESENTED DURING THESE REVIEWS.

In 1974, PLUARG, at the request of the Commission, submitted an Early Action Report[93] based on preliminary findings from its study. There was, in the opinion of the Reference Group, a decided lack of action by governments in responding to the Report at that time. The serious nature of water quality problems in the Great Lakes, and the increase in the number of existing agencies involved in management plan implementation, will require a regular and coordinated review to insure that required implementation of programs and reductions of pollutants is being achieved.

Those groups and individuals who will ultimately be affected by the implementation of these programs should also be provided with a formal opportunity to become involved in this review process.

Surveillance

3.4.2 PLUARG RECOMMENDS THAT TRIBUTARY MONITORING PROGRAMS BE EXPANDED TO IMPROVE THE ACCURACY OF LOADING ESTIMATES OF SEDIMENT, PHOSPHORUS, LEAD AND PCBs. SAMPLING PROGRAMS:

(i) SHOULD BE BASED ON STREAM RESPONSE CHARACTERISTICS, WITH INTENSIVE SAMPLING OF RUNOFF EVENTS, WHERE NECESSARY; AND

(ii) SHOULD BE EXPANDED TO INCLUDE TOXIC ORGANIC COMPOUNDS, TOXIC METALS AND OTHER PARAMETERS AS MAY BE DEFINED IN THE FUTURE.

FURTHER, THE ROLE OF ATMOSPHERIC INPUTS SHOULD BE CONSIDERED IN THE EVALUATION OF GREAT LAKES POLLUTION, WITH SPECIAL CONSIDERATION GIVEN TO DETERMINATION OF THE SOURCES OF MAJOR ATMOSPHERIC POLLUTANTS.

EFFORTS SHOULD BE MADE TO IMPROVE THE COORDINATION BETWEEN DATA COLLECTION AND DATA USER GROUPS, AND AGREEMENTS ESTABLISHED REGARDING DATA COLLECTION STANDARDS AND ACCESSIBILITY.

PLUARG FURTHER RECOMMENDS THAT THE ADEQUACY OF U.S. GREAT LAKES NEARSHORE AND OFFSHORE WATER SURVEILLANCE EFFORTS BE EXAMINED.

PLUARG used historic river monitoring data for estimating nutrient and sediment loads. Evaluation of these data established that tributaries could be correctly ranked on the basis of the magnitude of their loads. However, the loadings for event-related parameters (i.e., sediment-associated) are biased toward low estimates. This clearly indicates the need for an event-related sampling program to: (1) enhance tributary load estimates; (2) improve understanding of local and lakewide processes; and (3) assess loading reductions resulting from remedial measures. A long term commitment to such an enlarged tributary monitoring program will be required, because of loading fluctuations in response to climatic variations.

Historic tributary monitoring data for toxic substances were either nonexistent or too sparse to permit accurate loading estimates. Consequently, PLUARG initiated monitoring programs in the Canadian portion of the Basin for estimating loadings of these substances. These programs indicated that more comprehensive analyses for toxic substances are required to improve loading estimates and to identify sources. In addition, less frequent, but methodical, sampling for more exotic contaminants should also be incorporated to periodically ascertain their presence or absence and, if present, to provide a reference for more detailed assessment. The strategy of this supplementary sampling should be based upon the chemical characteristics of the designated compounds, as these characteristics determine the need for analyses on water, suspended sediments and biota.

PLUARG gained some insight into the magnitude of atmospheric loads of nutrients and toxic substances, both directly to the Great Lakes and to their watersheds. Improved estimates of atmospheric loads are considered essential, and can be accomplished only by the maintenance of an adequate sampling network. Information from such a network will be required in any future program directed towards the determination of pollutant sources to the atmosphere and their effects on lake ecosystems. From the evaluation of past monitoring data, PLUARG determined that a need exists for an improved data base, through greater emphasis on toxic substances, improved coordination of sampling and analytical accuracy, and improved communication between collection and user agencies, thereby facilitating accessibility to an improved primary data base.

3.5 ROLE OF THE PUBLIC

3.5.1 PLUARG RECOMMENDS THAT THE INTERNATIONAL JOINT COMMISSION ESTABLISH A COMPREHENSIVE PUBLIC PARTICIPATION PROGRAM AT THE OUTSET OF FUTURE REFERENCES.

PLUARG initiated citizen input in this study by establishing a public information and consultation program midway through the study. As a part of this program, nine U.S. and eight Ontario public consultation panels, the largest citizen participation program ever undertaken under the International Joint Commission, met formally four times in open meetings to evaluate and make recommendations on the social, economic and environmental aspects of the PLUARG study. The panelists represented a wide range of interests, including industry, small business, labor, education, agriculture, environmental organizations, women's groups, sportsmen's associations, wildlife federations and elected or appointed governmental officials.

Each panel submitted a report to PLUARG summarizing their views and recommendations of panel-identified problems and panel-proposed solutions. In some instances, panels identified their preferences and expectations for future use and water quality of the Great Lakes. These views were considered in the preparation of this report. The experiences gained from these panels, by PLUARG, has been invaluable in deciding the feasibility and practicality of the final recommendations.

PLUARG believes that this process should be incorporated in the early stage of any future References as an integral part of the study process.

This early involvement of the public will allow for a more substantive input to study priorities and design.

4. NEEDS FOR THE FUTURE

INTRODUCTION

The PLUARG study has produced new knowledge concerning the relationships between nonpoint source pollution and land use activities in the many watersheds draining to the Great Lakes, the impact of these land use activities upon the quality of the receiving waters, the pollutants that are transported by the tributaries to the lakes and the impacts of these pollutants from land drainage upon the Great Lakes themselves. PLUARG's focus on nonpoint sources of pollutants produced an extension in the breadth of knowledge of the Great Lakes ecosystem by interrelating the impacts of land drainage, atmospheric pollutants, industrial and municipal wastewater residuals and shoreline erosion contributions of pollutants to the Great Lakes.

During the course of the PLUARG study, knowledge and technology have also improved in the field of nonpoint pollution control. Other studies conducted in the Great Lakes Basin have added to this knowledge, including, for example, the Upper Lakes Reference Group Study[37] conducted by the International Joint Commission, as well as the Areawide Wastewater Management studies and the Lake Erie Wastewater Management Study[94] conducted in the United States.

We must build on the PLUARG study results and those of other studies in the Great Lakes Basin. In addition, it is noted that not all previous recommendations concerning Great Lakes pollution, such as those found in the 1970 International Joint Commission Report to governments[95], have been carried out. Consequently, a brief summation of unknowns and future recommended activities related to Great Lakes water quality is presented.

SUGGESTED FUTURE ACTIVITIES

In addition to the conclusions and recommendations concerning the Reference questions (Appendix 1), PLUARG concluded the following with respect to future research and data collection needs:

Increased efforts must be made to assess and analyse existing monitoring and research data in the Great Lakes Basin. PLUARG finds that a wealth of data currently exists in various institutions throughout the Basin, but that because of this wide dispersal, its availability and potential usefulness is restricted. Current data storage and retrieval mechanisms have been found to be inadequate, and substantial improvement is required to insure efficient access to this data and adequate technology transfer.

Future studies would be of greater value if they were of a more holistic nature and their relationship to the Great Lakes System considered as an integral part of the study. Research efforts on the Great Lakes have, in the past, often been piecemeal and without unifying objectives.

Greater emphasis must be placed on study of the nearshore areas of the Great Lakes. The Reference Group found that few comprehensive studies have been carried out in these areas; yet they are the areas most affected by man's activities.

Lake Michigan, especially the southern end, should be further studied to determine its possibly unique response to pollutant inputs. Unlike the other Great Lakes, Lake Michigan is not legally part of the Boundary Waters and has different flow-through characteristics. In addition, it has the largest population number and density in the Great Lakes Basin, as well as some of the world's largest industrial centers. For these reasons, the southern end of Lake Michigan should be given priority in terms of pollutant response research.

Further study of the biological availability of pollutants is required. PLUARG has not been able to satisfactorily resolve questions on the biological availability of pollutants (except for some progress concerning phosphorus) from different land use activities or pollutant transmission to the lakes from various land uses and land characteristics existing in the Basin.

In-lake sediment contamination requires further study. No demonstrated, practical solution to the problem of in-lake sediment contamination (e.g., mercury in Lake St. Clair sediments) has been determined during the PLUARG study. Research on this problem and demonstration of alternative technologies is warranted.

Quantification of pollutant loads coming from agricultural and urban lands requires further attention in many areas. Unit area loads must be refined further to indicate the effects of combined sewer overflow, etc., in order that remedial measures to be applied to Great Lakes watersheds may be the most effective and efficient.

Future study of atmospheric loads, including their magnitude, sources and effects on water quality in the Great Lakes, is required. PLUARG concludes that atmospheric loads are a significant source of many pollutants to the Great Lakes and constitute a potentially controllable source.

The safe disposal of radioactive and other toxic wastes in the Great Lakes Basin warrants much greater attention and study. Safe, permanent disposal systems for such wastes have not yet been established.The increasing quantities of these wastes being produced will likely result in serious water quality problems in the future unless appropriate measures are taken.

A better definition of pollution in the Great Lakes is required. PLUARG found that, in trying to ascertain whether the Great Lakes were being polluted by land use activities, traditional yardsticks of pollution such as water quality objectives or standards were insufficient to adequately evaluate the effects of diffuse sources of pollutants on Great Lakes water quality. While individual nonpoint source parameters may not in themselves result in violations of water quality objectives, in combination with other sources or with other parameters, they do result in "pollution" of the Great Lakes. Comprehensive toxicological studies of the effects, both of single compound (e.g., metals and organics), and combinations of compounds, on the aquatic biota of the Great Lakes are a research priority.

Field and laboratory studies should be maintained at a high intensity as an "early warning system" for identifying and evaluating the effects of such materials on Great Lakes water quality. Past and present investigations, both within and outside the PLUARG studies, have identified only a limited number of pollutants from land use activities. This limited identification is due in part to insufficient knowledge concerning the sources and significance of both identified and unknown material loads to the lakes.

The short and long term effectiveness of various remedial measures or alternatives for controlling erosion and sedimentation of fine-textured soils requires further attention. Similarly, more effective technological means are needed for controlling urban storm water wastes, septic and on-site disposal systems, etc.

The cost-effectiveness and socio-economic tradeoffs of the various remedial alternatives available for nonpoint source pollution control require further study. Nonstructural means of reducing pollution, including resource recovery, recycling, conserver ethics, etc., may be the most effective and efficient means of preventing Great Lakes degradation from nonpoint sources in the long run.

Hydrologically active areas in the Basin must be identified more clearly. Future impacts of such areas must be anticipated through proper land use monitoring, and remedial measures applicable to such areas must be developed and refined.

APPENDICES

APPENDIX 1

TERMS OF REFERENCE

Text of Reference to the International Joint Commission to Study Pollution in the Great Lakes System from Agriculture, Forestry and other Land use Activities

I have the honour to inform you that the Governments of the United States of America and Canada, pursuant to Article IX of the Boundary Waters Treaty of 1909, have agreed to request the International Joint Commission to conduct a study of pollution of the boundary waters of the Great Lakes System from agricultural, forestry and other land use activities, in the light of provision of Article IV of the Treaty which provides that the boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health and property on the other side, and in the light also of the Great Lakes Water Quality Agreement signed on this date.

The Commission is requested to enquire into and report to the two Governments upon the following questions:

(1) Are the boundary waters of the Great Lakes System being polluted by land drainage (including ground and surface runoff and sediments) from agriculture, forestry, urban and industrial land development, recreational and park land development, utility and transportation systems and natural sources?

(2) If the answer to the foregoing question is in the affirmative, to what extent, by what causes, and in what localities is the pollution taking place?

(3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measure would, in its judgement, be most practicable and what would be the probable cost thereof?

The Commission is requested to consider the adequacy of existing programs and control measures, and the need for improvements thereto, relating to:

(a) inputs of nutrients, pest control products, sediments, and other pollutants from the sources referred to above;

(b) land use;

(c) land fills, land dumping, and deep well disposal practices;

(d) confined livestock feeding operations and other animal husbandry operations; and

(e) pollution from other agricultural, forestry and land use sources.

In carrying out its study, the Commission should identify deficiencies in technology and recommend actions for their correction.

The Commission should submit its report and recommendations to the two Governments as soon as possible and should submit reports from time to time on the progress of its investigation.

In the conduct of its investigation and otherwise in the performance of its duties under this reference, the Commission may utilize the services of qualified persons and other resources made available by the concerned agencies in Canada and the United States and should as far as possible make use of information and technical data heretofore acquired or which may become available during the course of the investigation, including information and data acquired by the Commission in the course of its investigations and surveillance activities conducted on the lower Great Lakes and in the connecting channels.

In conducting its investigation, the Commission should utilize the services of the international board structure provided for in Article VII of the Great Lakes Water Quality Agreement.

APPENDIX 2

LITERATURE CITED

[1]Great Lakes Water Quality Agreement with Annexes and Texts and Terms of References, Between the United States of America and Canada, Signed at Ottawa, Canada, April 15, 1972, International Joint Commission, Washington, D.C. and Ottawa, Ontario.

[2]International Reference Group on Great Lakes Pollution from Land Use Activities, "Land Use and land use practices in the Great Lakes Basin; joint summary report – Task B, United States and Canada". Windsor, Ontario, September 1977. 49 pp.

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APPENDIX 3

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APPENDIX 4

REMEDIAL MEASURES APPLICATION MATRIX[a]

	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Wast Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
1	Chemical Soil Stabilizers	S n	S n				S n				S	
2	Roof Top Ponding	s n										
3	Dutch Drain (Gravel filled ditches with option drainage pipe in base)	s n										
4	Porous Asphalt Paving	s c		S n			s c					
5	Precast Concrete Lattice Blocks and Bricks	s n c					s n c					S n
6	Seepage Basin or Recharge Basin (Single Use)	s n c										
7	Recharge – Detention Storage Basins (Multi-Use)	s n c	s n									
8	Seepage Pits or Dry Wells	s n c										
9	Pits, Gravity Shafts, Trenches and Tile Fields	s n c										
10	Recharge of Excess Runoff by a Pressure Injection Well	s n c										
11	Conservation Construction Practices	S			S	S	S				S	
12	Temporary Mulching and Seeding of Stripped Areas	S			S	S	S					
13	Conservation Cultivation Practices on Steep Slopes	S	S		S		S					
14	Temporary Diversions on Steeply Sloping Sites & Temporary Chutes	S	S		S	S	S				S	
15	Temporary Check Dams on Small Swales and Watercourses	S	S			S	S				S	
16	Seeded Areas Protected with Organic Mulch	S	S		S	S	S				S	
17	Seeding Areas protected by Netting or Matting	S			S	S	S				S	
18	Single Family Aerobic Treatment Systems	N c	N c	N c								

[a] Information taken from reference 9 (appendix 2)

Significantly Effective in Reducing Magnitude of Pollutant

C – chemicals
N – nutrients
P – pesticides
S – sediments

Moderately Effective in Reducing Magnitude of Pollutant

c – chemicals
n – nutrients
p – pesticides
s – sediments

#	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Wast Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
19	Contour Listing		S									
20	Disposal of Treated Sewage Effluent by Spray Irrigation	s N c	s N c	s N c				s N c	s N c			
21	Surface Water Diversion	S	S		S	S	S					
22	Terraces (Diversion Terraces)	S	S		S	S	S					
23	No-Tillage Cultivation (Shot Planting, Zero Tillage)		S									
24	Pesticide Application Methods	P	P	P	P		P					
25	Alternatives to Chemical Pesticides	P	P	P	P		P					
26	Slow Release Fertilizers		N c		N c							
27	Placement of Fertilizer		N c		N c							
28	Timing of Fertilizer Application		N c		N c							
29	Roughening of the Land Surface		S									
30	Promotion of Soil Clods or Aggregates		S									
31	Stripcropping		S		S	S						
32	Miscellaneous Tillage Alternatives		S									
33	Conservation Tillage		S									
34	Sod-Based Crop Rotation		S									
35	Winter Cover Crops		S									
36	Improved Soil Fertility		S									
37	Timing of Field Operations		S									
38	Contouring or Contour Cultivation		S									
39	Grassed Outlets	S	S				S				S	
40	Direct Dosing of Alum to a Septic Tank	N	N	N								
41	Swirl Concentrator for Runoff Treatment	S n	S n									
42	Retention Basins for the Treatment of Wet-Weather Sewage Flows	S n										
43	Stationary Screens	S n										
44	Horizontal Shaft Rotary Screen	S n										
45	Vertical Shaft Rotary Fine Screen	S n										
46	Treatment Lagoons *	s N	s N	s N								
47	Rotating Biological Contactors *	N	N	N								
48	Trickling Filters *	N	N	N								
49	Contact Stabilization	N		N								

Remedial Techniques	Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Wast Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
50	Air Flotation	S n										
51	Physical-Chemical Systems	s N										
52	Reverse Osmosis of Mine Tailings Effluent					C						
53	Chemical Adsorption onto Clays in Experimental Environment		P		P							
54	Surface Water Diversion		S n c		S n c	S n c				S n c		
55	Reducing Ground or Mine Water Influx					n C				n C		
56	Underdrains for Mineral Stockpiles or Tailings					nC						
57	Evaporation Ponds					n c						
58	Street Cleaning	Snc					Snc					
59	Interception of Aquifers		n c	n c		n c				n c		
60	Neutralization of Mine Acid Waste					c						
61	Stream Neutralization					n c						
62	Improved Methods of Sludge Disposal on Land	n c	n c					ṅ c				
63	Annual Storage and Land Application of Livestock Wastes		N									
64	Sewer Flushing	S n c										
65	Combined Sewer Overflow Regulators	S N c										
66	Overburden Segregation	S n				S n	S n					
67	Mineral Barriers or Low Wall Barriers					S n c						
68	Longwall Strip Mining					S n c						
69	Modified Block Cut or Pit Storage					S n c						
70	Head-of-Hollow-Fill					S n c						
71	Box Cut Mining					S n c						
72	Area Mining					S n c						
73	Auger Mining					s.n c						
74	Reducing Surface Water Infiltration					n c				n c		

	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Wast Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
75	Road Planning & Design				S		S					
76	Blocking					C						
77	Check Dams	S	S				S				S	
78	Retaining Walls for Road Construction for Steeper Slopes				S		S					
79	Revegetation –Reforestation Cut Areas and Bare Slopes	S			S	S	S				S	
80	Vegetative Buffer Strips	S	S			S	S	S n				
81	Sediment Basin	S	S		S	S	S			S		
82	Rip Rap Bank Protection	S	S				S				S	S
83	Protection of Culvert Outlet, Chute Outlets, etc.	S	S				S				S	
84	Dolos (Offset asymetric tetrapods)											S
85	Engineering Design & Management For Shoreline Landfilling											S n c
86	Revegetation of Mines Tailings: Stabilization					S						
87	Slope Lowering of Spoil and Tailings Stockpiles					S						
88	Package Sewage Treatment Plants (Multi-Family Use)	s N c	s N c	s N c								
89	Waste Exchange for Resource Recovery									C		
90	Head Gradient Control									s n C		
91	Biological Treatment									S N C		
92	Streambank Protection with Vegetation	S	S								S	
93	Grass Channels or Waterways	S n	S n				S n				S	
94	Permanent Diversions	S n	S n		S n		S n				S n	
95	Bank Protection by Jetties, Deflectors	S	S				S				S	S
96	Reduction and Elimination of Highway Deicing Salts	C					C					
97	Septic Tank/Tile Bed Sewage Disposal	N	N	N								
98	Miscellaneous Methods to Reduce Storm Runoff	S n					S n					
99	Exclusion of Livestock From Watercourses		S n									

	Remedial Techniques / Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Wast Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
100	Land Smoothing		S									
101	Gabion Baskets	S	S								S	S
102	Miscellaneous Erosion Control Fabrics and Materials	S	S								S	S
103	Miscellaneous Individual Wastewater Treatment Systems	N	N	N								
104	Clivus Multrum	N	N	N								
105	Controlling Feedlot Runoff		N									
106	Landfill Liners									C		
107	Hydroseeding	S			S	S	S				S	
108	Catch Basin Cleaning	Snc					Snc					
109	Plant Materials For Bank and Slope Stabilization	S	S	S	S	S	S				S	S

GLOSSARY

In order to give the public a better understanding of its study results, PLUARG prepared this glossary of terms, as used in this report.

ALGAE – Aquatic plants having a simple cell structure and containing chlorophyll. Most live submerged in either fresh or salt water.

ANION – An atom or group of atoms containing a negative electric charge.

ANTHROPOGENIC – Induced or altered by the presence and activities of man.

APATITE – Any of a group of calcium phosphate minerals containing chloride, hydroxyl or fluoride ions. This form of phosphorus was considered by PLUARG to be largely unavailable for aquatic plant growth in the lakes. It constitutes a large portion of the tributary particulate loads and shoreline bluff to the lakes.

BACKGROUND LEVEL – The amounts of materials present in the water due to natural sources.

BASEFLOW – The part of stream flow contributed by groundwater seeping into surface streams.

BEDLOAD – Soil, rock particles or other debris rolled along the bottom of a stream by moving water.

BIOACCUMULATION – A build up of a specific organic or inorganic compound within specific tissues of given organisms; usually applied to certain heavy metals, pesticides or metabolites.

BIOLOGICAL AVAILABILITY – That portion of a chemical compound or element that can be readily taken up by living organisms.

BOUNDARY WATERS – Those waters of the Great Lakes System, as defined by the Boundary Waters Treaty of 1909, between the United States and Great Britain (for Canada).

BUFFERING CAPACITY – The ability of water to resist changes in pH due to the input or formation of acids or bases in the water.

CAPITAL COSTS – The costs associated with the initial building or construction of a facility or plant.

CHLOROPHYLL – The green pigments of plants.

CHLOROPHYLL *a* – One of the types of chlorophyll present in aquatic plants.

CLEARCUTTING – The forest harvesting technique involving the complete removal of all trees from a designated area.

COMBINED SEWER OVERFLOW – In sewerage systems which carry both sanitary sewage and storm water runoff, the portion of the flow which goes untreated to receiving streams because of sewage treatment plant overloading during storms.

COMPUTER ALGORITHM – In computer terminology, a detailed logical procedure which represents the solution of a particular problem.

CONSERVATION PLANS – Any plan to manage human ecology whereby man achieves an optimum relationship with the resources in his natural environment; it embraces both preservation and wise use of natural resources.

CONTAMINANT – An element or chemical compound which, by its introduction, results in one or more components of the ecosystem being deleteriously affected.

DEEPWELL DISPOSAL – Transfer of liquid wastewater to underground strata; usually limited to biological or chemically stable wastes.

DENITRIFICATION – The process of the reduction of nitrates and nitrites, usually by denitrifying bacteria, to elemental nitrogen or ammonia.

DIRECT LOADINGS – The input of a material directly into a lake, as contrasted to an input into a tributary which drains into the lake.

DISPERSION (IN LAKES) – The scattering or mixing, through natural lake processes, of substances in tributary waters or point source effluents discharged to a lake.

DRAINAGE DENSITY – The ratio of stream miles to drainage area in a watershed.

DRAINAGE LIQUOR – The liquid which seeps out of agricultural storage silos as a result of fermentation and compression.

ECOSYSTEM – The interacting system of a biological community and its nonliving environment.

EFFLUENT LIMITATIONS – The limits set for the concentration of a given material in waters discharged from municipal or industrial plants.

ESCHERICHIA coli – A genus of bacteria normally present in the human intestine; indicative of fecal contamination when found in streams and lakes.

EVENT SAMPLING – The collection of water samples in rivers and streams for biological, physical and chemical analyses, in response to the occurrence of snowmelt or storm events.

FECAL COLIFORMS – Certain types of bacteria common to the intestinal tracts of man and animals.

FECAL *STREPTOCOCCUS* – A pathogenic bacterium of the genus *Streptococcus* which may be found in the intestinal tracts of man.

FILTERABLE ORTHORPHOSPHATE (BIOLOGICALLY AVAILABLE PHOSPHORUS; SOLUBLE ORTHOPHOSPHATE) – The dissolved fraction of phosphorus in water which is available for immediate uptake and assimilation by algae (see biological availability).

FLOOD PLAIN – That portion of a watershed adjacent to a stream that is subject to periodic flooding.

FLOW SENSITIVE PARAMETER – A water quality variable (e.g., phosphorus concentration) whose quantity or value is a function of stream or river flow.

GREAT LAKES SYSTEM – As defined in the 1909 U.S. – Great Britain Boundary Waters Treaty, all the streams, rivers, lakes and other bodies of water that are within the drainage basin of the St. Lawrence River at or upstream of the point of which the river becomes the international U.S. – Canadian boundary.

GROSS EROSION – A measure of the potential for soil to be dislodged and moved from its place of origin; it is not necessarily the amount of soil which actually reaches a stream or lake.

HEAVY METALS – Metallic elements with high atomic weights, generally occurring in trace amounts in waters, including iron, mercury, manganese, copper, chromium, cadmium, lead and vanadium. These elements are generally toxic to plant and animal life in low concentrations and may exhibit biological accumulation (see bioaccumulation).

HOLISTIC – Emphasizing the relationship between the parts of a system and the whole system.

IMPERVIOUS – Not allowing the entrance or passage of water through a surface (e.g., paved street or driveway).

INDICATOR BACTERIA – Non-pathogenic bacteria whose presence in water indicate the possibility of pathogenic species in the water.

INFILTRATION CAPACITY – A measure of the flow of a fluid into a substance through pores or small openings; used in hydrology mainly to denote the flow of water into soil material.

INTER-CONNECTING CHANNELS – The rivers or straits connecting the Great Lakes.

LAKE ERIE WASTEWATER MANAGEMENT STUDY – A study being conducted by the U.S. Army Corps of Engineers to develop a recommended program of activities designed to improve the environment of Lake Erie.

LIMITING NUTRIENT – That aquatic plant nutrient present in a water body in the least quantity relative to the biological needs of the plant community; hence it controls or 'limits' the growth of the aquatic plant population in the water body.

LIMNOLOGY – The study of the physical, chemical and biological aspects of fresh water lakes.

LOAD – The quantity (i.e., mass) of a material which enters a water body over a given time interval.

LOADING SCHEDULE – A timetable indicating an agreed-upon load of a material to a water body for a given time interval.

MATERIALS USAGE – The quantity and types of materials applied to the land surface for a given land use activity (e.g., fertilizer, pesticides).

METHYLATION – The introduction of methyl groups (CH_3) into a chemical compound, either chemically or biologically (e.g., methylation of lead).

MINERALIZED ORGANIC PHOSPHORUS – Phosphorus which has been changed from organic form (e.g., as in algal cells) to a dissolved inorganic form (e.g., soluble orthophosphate) through chemical or bacterial processes.

MINE TAILINGS – Waste materials produced when raw mineral ores are screened or processed.

MOBILE – As used in hydrology, the easy transport of materials (e.g., nitrogen as nitrate) over or through the soil.

MONOCULTURE – The cultivation or growth of a single genus of organism. An example is the extensive growing of corn in large areas of the Great Lakes Basin.

NONAPATITE INORGANIC PHOSPHORUS – The inorganic phosphorus fraction, excluding the apatite phosphorus; usually indicates the fraction of phosphorus considered biologically available.

NON-DEGRADATION – As used in the Great Lakes Water Quality Agreement, the maintenance of present good water quality in Lakes Superior and Huron (open waters).

OBJECTIVES (WATER QUALITY) – The concentration of a substance in water or a description of a condition that is considered to be safe for the most sensitive use of that water.

OPERATING COSTS – The costs associated with the daily operation of an established facility or plant (as opposed to capital costs).

ORDER OF MAGNITUDE – Increasing a number, quantity or value by a factor of ten (i.e., multiply the number by ten).

ORGANICS – Referring to chemical compounds containing carbon atoms bonded together with other elements.

ORGANOCHLORINE PESTICIDES – A class of organic pesticides containing chlorine atoms.

PARAMETERS (WATER QUALITY) – A distinct measureable variable or quantity indicating the general quality of the water (e.g., phosphorus concentration, chlorophyll concentration).

PATHOGENS – Organisms, usually bacteria, capable of causing diseases.

PERSISTENT ORGANIC COMPOUNDS – Organic compounds which do not readily degrade in the environment.

PESTICIDES – An agent, usually chemical, used to destroy plant or animal pests.

pH – A measure of the intensity of the acidity or alkalinity of a solution; specifically the negative logarithm of the hydronium ion (H_3O+) concentration.

PHYSIOGRAPHY – A description of the features (relief) of the earth's surface.

PHYTOPLANKTON – Free-swimming or floating microscopic algae.

POLLUTANT – Any material introduced into the environment that makes a resource unfit for a specific purpose.

POTENTIALLY BIOLOGICALLY AVAILABLE PHOSPHORUS – The phosphorus fraction which may become biologically available over time because of chemical or biological processes in water bodies.

PRIME FARMLAND – Land particularly well suited for the production of crops.

POTENTIAL CONTRIBUTING AREAS – Geographic areas whose morphology, hydrology and other characteristics result in a potential for contributing pollutants to the Great Lakes.

PSEUDOMONAS aeruginosa – A pathogenic bacterium of the genus *Pseudomonas*.

PUBLIC CONSULTATION PANEL – A group of individuals delegated by PLUARG to provide citizen participation, relative to the PLUARG Terms of Reference.

QUASIEQUILIBRIUM – Non-permanent equilibrium or steady state condition. Equilibrium may be disestablished and reestablished, depending on conditions.

REACTIVE CONTROL – The initiation of a control program in response to an identified problem.

REMEDIAL MEASURE – A measure or process to control or reduce the input of pollutants to the Great Lakes.

RESUSPENSION – The movement of a material in a stream or lake from the sediments back into the overlying waters.

REVISED WATER QUALITY AGREEMENT – The Agreement between the United States and Canada resulting from the re-negotiation of the Canada/United States 1972 Great Lakes Water Quality Agreement.

RILL EROSION – The erosion of soils by the movement of water and materials through minute gullies in the soil surface.

SALMONELLA – Pathogenic bacteria of the genus *Salmonella*.

SANITARY LANDFILL – A site for collection, compaction and disposal of solid wastes.

SCARIFICATION – The process of breaking up or loosening the surface soil.

SEDIMENT – The solid material that settles to the bottom of a river or lake.

SEDIMENT DELIVERY RATIO – A measure of the sediment actually reaching a stream or lake; equal to the quantity of material reaching the Great Lakes or a tributary, divided by the quantity of material eroded.

SEPARATE STORM SEWERS – A sewerage system that carries storm and surface waters, but excludes municipal waste waters (see combined sewer overflow).

SECCHI DEPTH – A measure of water clarity; specifically the depth in water at which a black and white circular disk is no longer visible in the water.

SOIL SURVEYS – The physical and chemical characteristics of soil as denoted geographically on maps.

SOIL TEXTURE – The physical delineation of particle sizes in soils.

SOLUBLE PHOSPHORUS – (see filterable orthophosphate).

STORMWATER RUNOFF – The water and associated materials draining into streams, lakes or sewers as a result of a storm.

STRUCTURAL CONTROLS – A construction designed to prevent pollution.

SURFICIAL GEOLOGY – The geology of the upper portions of the earth's surface.

SURVEILLANCE – Close and continued observation of waters of the Great Lakes Basin for the presence, absence or change in a given environmental quality parameter.

SUSPENDED SEDIMENT – Particles suspended in water, either prior to settling to the bottom or as a result of resuspension of bottom sediment particles.

SUSPENDED SOLIDS – All solid particles suspended in water.

TARGET LOADS – Recommended phosphorus loads for the Great Lakes as determined by the Task Group III of the Revised Water Quality Agreement.

TASK GROUP III – A technical working group charged with developing total phosphorus loading objectives to each of the Great Lakes as part of the re-negotiation of the 1972 Water Quality Agreement.

TERRESTRIAL – Of or on the land surface, as opposed to being of or in water bodies.

TOXICITY – The quality or degree of being poisonous or harmful to plant or animal life.

TRANSFORMATIONS – Changes in chemical or biological parameters from one form to a different form.

TRANSMISSION – The movement of water or associated pollutants from one location to another.

TRANSPORT MECHANISM – The method or mode by which a pollutant is transported from one location to another.

TRANSPORTATION CORRIDORS – Narrow strips of land containing roads, highways and tracks and used to transport motor vehicles and trains.

TURNOVER RATE – The rate at which a given volume of water in a water body is replaced by an equal volume of water (= 1/turnover time)

UNIT AREA LOAD – The quantity of a material delivered to the Great Lakes or a tributary from a given unit area of land surface over a given time interval.

UNIVERSAL SOIL LOSS EQUATION – An equation developed for predicting potential sheet erosion (i.e., the detachment of material from the land surface by raindrop impact and its subsequent removal by pre-channel or overland flow).

UPPER LAKES REFERENCE GROUP – A reference group established by the International Joint Commission as a result of the Water Quality Agreement of 1972 to study the international Upper Great Lakes (i.e., Lakes Superior and Huron).

URBAN HOUSEKEEPING PRACTICES – Any measures or practices performed in urban areas to lessen the runoff of pollutants into the Great Lakes (e.g., street sweeping, minimizing lawn fertilizer applications).

VAPORIZATION – The change of a substance from the solid or liquid phase to the gaseous phase.

WATER QUALITY OBJECTIVE – The concentration of a substance, or a description of a condition in water, that is considered to be safe for the most sensitive use of the water.

WATER QUALITY STANDARD – Criteria or objectives which have been included as part of the enforceable environmental control laws of a unit of government.

WATERSHED – The entire land area drained by a given stream to a single point.

WETLANDS – Land containing much soil moisture (e.g., marshes, bogs, swamps); usually characterized by high organic productivity.

LIST OF CONVERSION FACTORS

TO CONVERT	TO	MULTIPLY BY
metric tons (tonne)	pounds (lb)	2205
kilograms (kg)	pounds (lb)	2.205
grams (g)	kilograms (kg)	0.001
milligrams (mg)	grams (g)	0.001
micrograms (μg)	milligrams (mg)	0.001
parts per million (ppm)	milligrams/kilogram (mg/kg)	1.0
parts per million (ppm)	milligrams per liter (mg/L)	1.0
parts per billion (ppb)	micrograms/kilogram (μg/kg)	1.0
kilograms/hectare/year (kg/ha/yr)	pounds/acre/year (lbs/acre/yr)	1.12
hectares (ha)	acres	2.471
square kilometers (km^2)	square miles (mi^2)	0.3861
cubic meters (m^3)	cubic yards (yd^3)	1.308

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