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Great Lakes Science Advisory Board. Report: 1987

Great Lakes Science Advisory Board

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Report to the International Joint Commission

1987 Report

1987 Report

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INTERNATIONAL JOINT COMMISSION
GREAT LAKES SCIENCE ADVISORY BOARD
100 OUELLETTE AVENUE, 8TH FLOOR
WINDSOR, ONTARIO N9A 6T3
OR U.S. MAILING ADDRESS: P.O. BOX 32869
DETROIT, MICHIGAN 48232-2869

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International Joint Commission

Canada and the United States

Commissioners:

The Great Lakes Science Advisory Board, in partial fulfillment of its responsibilities under the Great Lakes Water Quality Agreement of 1978, is pleased to submit its 1987 Report to the Commission.

In this report the Science Advisory Board identifies two priority issues which it intends to accent over the next five years: integrative science and measures facilitating implementation of an ecosystems approach to resolving man-made problems in the Great Lakes basin, and adaptive management approaches to persistent toxic substances. The committee structure of the Board was re-organized in 1986 to reflect these priorities.

Over the past two years the Science Advisory Board has undergone a substantial change in membership, including the appointment of new Co-chairs. The Council of Great Lakes Research Managers has been expanded to include representation from a wider variety of organizations with interests in and responsibilities for biological, physical and social sciences. The Council has reviewed research needs, updating the Board's earlier reviews of 1976 and 1982.

The Science Advisory Board is now in its fifteenth year, first as the Research Advisory Board under the 1972 Great Lakes Water Quality Agreement and later as the Science Advisory Board. A review of the Board's recommendations to the Commission and Great Lakes Water Quality Board over this fifteen-year period is included in this report.

Respectfully submitted,

J. R. Vallentyne, Ph.D.
Co-Chair
Canadian Section

A. M. Beeton, Ph.D.
Co-Chair
United States Section

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Appendices to this report are published in separate volumes, which may be obtained from the International Joint Commission Great Lakes Regional Office in Windsor, Ontario, Canada.

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Executive Summary and Recommendations

The Great Lakes Science Advisory Board has restructured its activities to address two major priorities: integrative science in respect to an ecosystems approach to managing human uses and abuses of the Great Lakes Basin Ecosystem, and persistent toxic chemicals. To place the work of the Board in perspective, a review of the recommendations for the period 1973–85 has been provided. The improved coordination of efforts in education and the public understanding of ecosystem issues are needed. International workshops examined in situ contaminated sediments and the atmosphere as pathways for toxic contamination. The conclusions from other workshops provided an important perspective on biotic/abiotic interactions and underscored the need for improved coordination of the work of water quality and fisheries agencies in implementing the 1978 Great Lakes Water Quality Agreement. The findings of a Human–Machine Workshop highlighted spills and their pertinence to Annex 9 of the Agreement as a major issue. The need for integrative approaches to research on toxic chemicals has been underlined by the Council of Great Lakes Research Managers with PCBs as a case study. Finally, the need for the continuing consideration of social science to better define ecosystem problems is reflected in many areas of the report, particularly in the need for anticipatory, preventive and adaptive strategies for ecosystemic stresses.

What follows is a consolidated list of recommendations received by the Board through its infrastructure. While all of these recommendations are of interest to the Commission, many are directly pertinent to other international organizations, e.g. the Great Lakes Fishery Commission, governments, i.e. municipal, regional, provincial, state and federal agencies, internal advisory groups, i.e. the Water Quality Board, the International Air Quality Advisory Board, the Council of Great Lakes Research Managers; and Science Advisory Board subunits. Relevant sections of this report, identified in parentheses, outline the intended disposition of each recommendation.

RECOMMENDATIONS ON POLICY AND PROGRAMS

1. An ecosystems approach is required for the control of toxic chemical emissions, many of which originate outside the Great Lakes basin. Particular attention must be paid to institutional obstacles to the control of sources contributing to the deposition of toxic chemicals in the Great Lakes basin. For example, existing laws and regulations fail to address satisfactorily the long-range transport and the distant impacts of airborne contaminants **(3.2.2 and 4.0)**

2. The Commission should ensure that there is a unified international emergency prevention plan which encourages Great Lakes jurisdictions to establish a clear delineation of responsibility and provides resources and guidance to local communities, thus minimizing the risk and impacts of spills **(3.3.1)**

3. There is a need to investigate the issues of responsibility and liability in the event of a disaster resulting from a major spill in the Great Lakes Basin Ecosystem, in accordance with Annex 9 of the Water Quality Agreement **(3.3.1)**

4. There is a need to promote the development of a corporate ethic with respect to the ecosystem and associated codes of practice for persons involved in the design of technical systems, operator training, human motivation and interaction in work situations **(3.3.1)**

5. Each state and province in the Great Lakes basin should be encouraged to establish and assist in programs for use at each age level to provide basic information on the ecological and cultural history of the Great Lakes Basin Ecosystem, on how human activities interact with and affect that ecosystem, and on the importance of protecting the lakes from human abuses **(3.1.2)**

6. Risk analysis should be used for determining the relative risks associated with pollution from contaminants and other perturbations to Great Lakes biota and regional human populations **(3.2.3)**

7. Complete public participation programs for the Areas of Concern should be initiated to establish community goals and wishes. The causal, socio-economic-environmental interactions that contributed to the degraded conditions should be studied to identify the ecosystemic modifications necessary for rehabilitation **(3.2.1)**

8. Lake Superior should be maintained as a balanced and stable oligotrophic ecosystem with the lake trout as the top aquatic predator and Pontoporeia hoyi as the major benthic macroinvertebrate of the cold-water community **(3.4)**

9. Additional studies on fish-tumor incidence, pathology and etiology, and their underlying causes should be funded **(3.5)**

10. Mesocosm research facilities are required in the Great Lakes to conduct controlled, field-oriented experiments on the effects of toxic substances and other stresses on aquatic biota **(3.2.3)**

11. The concentration of total zinc in an unfiltered water sample should not exceed 10 µg/L to protect aquatic life **(3.4)**

RECOMMENDATIONS ON MONITORING AND SURVEILLANCE

1. In order to enhance monitoring efforts, the Commission should urge the Parties to adopt a uniform and comprehensive reporting system for the spills of hazardous substances and hazardous wastes, and should offer to coordinate the attainment of such a system **(3.3.1)**

2. Water quality and fisheries agencies should coordinate monitoring activities, standardize techniques, and establish and maintain long–term data sets to evaluate the effects of water quality and fisheries management activities separately as well as in terms of their potential additive effects **(3.2.4 and 4.0)**

3. A centralized storage system should be established for monitoring data to include biotic sampling, including fish health indicators and selected species of birds and mammals, and abiotic sampling, including data on the atmospheric deposition of toxic chemicals **(3.2.2. and 3.2.3)**

4. Once the known sources of contamination in the Areas of Concern have been eliminated, a protocol should be devised for remediating contaminated sediments, and it should be applied to two or more areas in the Great Lakes basin **(3.2.1)**

5. Data on organo–tins and the toxicological significance of these compounds in the Great Lakes should be reviewed and through additional monitoring, their sources, distribution and present levels should be determined **(3.5)**

6. The Water Quality Board should be asked to monitor and report in greater detail on the quantities, trends and causes of spills, including human factors **(3.3.1)**

7. There is a need for the Parties to establish specimen banks for archiving eggs, tissue, and in some cases, whole carcasses of birds, mammals, fish and other selected aquatic organisms both now and in the indefinite future **(3.2.3)**

8. Data to permit the evaluation of the health of the Lake Superior ecosystem should be collected. In addition, it is probable that similar objectives and measures of system health will be developed for Lakes Huron and Michigan. It is recommended that appropriate data for these two lakes be collected by the appropriate agencies and coordinated through the Great Lakes Fishery Commission **(3.4)**

9. Because fish–eating birds and mammals are strongly affected by contaminants, these biota should be utilized as integrative indicators of ecosystem health **(3.2.3)**

10. Edible portions of fish (suitably defined, speciated and aged) should be analyzed for both inorganic and organic species of lead **(3.5)**

11. Lead concentrations in fish in the St. Lawrence River should be monitored so that potential human exposure can be assessed more reliably and changes in potential exposure noted **(3.5)**

12. Research is needed on the effects of changes in food web dynamics on the levels of toxic substances in Great Lakes sport and commercial fishes **(3.2.3 and 3.2.4)**

13. Additional indicator organisms should be selected for more effectively measuring changes in nearshore planktonic and benthic communities **(3.2.3)**

RECOMMENDATIONS ON RESEARCH

1. There is a need for research on the effects of toxic contaminants on humans, including the measurement of body burden, multi-generational effects, metabolic impact, immunological impact, the effect on diseases, and the application of new technologies, e.g. DNA adducts **(3.2.3 and 4.0)**

2. There is a need to determine and quantify modeling coefficients required to calculate mass balances for specific toxic chemicals for each of the Great Lakes and thus estimate the relative contribution of the atmosphere as a source and sink for these chemicals **(3.2.2 and 4.0)**

3. An integrated research and monitoring network needs to be established to measure the atmospheric deposition of toxic chemicals. The research component should be established first at master stations **(3.2.2)**

4. Models of aquatic fate and of the recycling of toxic chemicals need to be better validated and should be linked to atmospheric transport and fate models for the same chemicals **(3.2.2)**

5. The results of studies in Areas of Concern such as Hamilton Harbour and the Grand Calumet River should be monitored and evaluated for the social learning processes inherent in them and analyzed with reference to the Green Bay experience. Pertinent knowledge gained from such experiences should be used to develop site-specific remedial action plans for the 42 Areas of Concern identified by the Water Quality Board **(4.1.10)**

6. Research is needed on the rates and reversibility of the sorption of contaminants on particulate materials, the rates and significance of methylation processes and rates for metals, and the biodegradation processes in contaminant breakdown in sediments **(3.2.1)**

7. Pathways, quantification of fluxes of contaminants, and microbiological/ chemical interactions of contaminants in sediments need to be more clearly identified **(3.2.1)**

8. Research is needed on the effects of changes in food web dynamics on the levels of toxic substances in Great Lakes sport and commercial fishes **(3.2.4)**

9. Research is needed on factors affecting alewife abundance and how that abundance affects lower trophic levels and water clarity **(3.2.4)**

10. Research is needed on the influence of water hardness on the toxicity of forms of zinc to aquatic organisms **(3.4)**

11. Continued research is needed on the clinical and biochemical measurements of stress and on the mechanisms of toxic action in the biota, including studies of the etiology of fish tumors **(3.2.3)**

12. More research is needed to determine why people in the Great Lakes basin are reluctant to accept facilities for the destruction of PCBs, whether fixed or mobile, using technologies that have been accepted in other countries **(4.1.8)**

1.0 Introduction

1.1 PRIORITIES OF THE GREAT LAKES SCIENCE ADVISORY BOARD

The Science Advisory Board has come to accept that it is unrealistic to assume that we can effectively manage systems as complex as the Great Lakes or the Great Lakes Basin Ecosystem; what we can do is influence human uses and abuses of the natural resources systems on which we depend. Based on this belief, the Board recommended to the International Joint Commission in July 1978, the adoption of an ecosystems approach (Caldwell 1970) to restoring and maintaining the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. In November of that year, the Governments of Canada and the United States incorporated the ecosystem concept in a revised Great Lakes Water Quality Agreement. The words "integrity" and "ecosystem" were specifically linked in the preamble to that Agreement.

Integrity implies wholeness (integer), the creation of an original whole (integrate), and systemic behaviour (integrity). Ecosystem implies an ecological system, the concepts and methods of general systems theory and a focus on organizational, particularly self–organizational, phenomena. In this report, the Board describes courses that aim to clarify the practical, operational meaning of these terms.

The 1978 Agreement represented a major shift from a primarily water quality perspective in the 1972 Agreement to an ecosystems (social, economic and environmental) perspective in the 1978 Agreement. The need for an ecosystems approach to environmental management arose in response to increasing stresses imposed by the growth of human population and technology. The succession of management approaches in response to those stresses has been characterized by Christie et al. (1986) as egosystemic, piecemeal, environmental and most recently, ecosystemic. Examples of each are given in Table 1.

At its meeting in November 1986, the Board examined obstacles to implementing an ecosystems approach under the 1978 Water Quality Agreement. The major conclusions from this discussion can be classified in the following broad areas:

- While there is a growing consensus on the need for an ecosystems approach, there is a major communication problem between the various publics and even among institutional groups with respect to a common understanding of what constitutes an ecosystems approach. The public needs some agreement on this definition before it can be expected to support broad policy decisions affecting all levels of society. There is a lack of comprehension of the ecosystem concept, a lack of an ecological perspective, and differences of opinion among professional communities regarding the implications of an ecosystems approach

TABLE 1. COMPARISON OF FOUR APPROACHES TO RESOLVING MAN-MADE ECOSYSTEM PROBLEMS. MODIFIED FROM VALLENTYNE AND HAMILTON (1987)

PROBLEM	A P P R O A C H			
	EGOSYSTEMIC	PIECEMEAL	ENVIRONMENTAL	ECOSYSTEMIC
Infectious disease	Patent medicines, quarantine	Conduits, pills	Public health programs	Prevention
Organic waste	Hold your nose	Discharge downstream	Reduce BOD	Energy recovery
Eutrophication	Stay away	Discharge downstream	Phosphorus removal	Nutrient recycling
Acid rain	Deny it	Discharge permits	Use clean fuel on bad days	Alternative energy sources
Energy shortages	Hunt a scapegoat	Increase supply	Expand grid, conservation	Renewable energy
Toxic chemicals	Hide, disperse	Treat one-by-one, pollution havens	Recover, re-use	Nontoxic alternatives
Greenhouse effect	Ignore problem	Invest in air conditioners	Breed new crops	Carbon recycling, hydrogen fuel
Pests	Broad spectrum insecticides	Selective pesticide application	Integrated past management	Ecological control
Traffic congestion	More roads through cities	More superhighways	Staggered hours	Public transport, decentralize
Demotechnic growth	Shift disbenefits	Technofix	Zoned development	Conserver society
Attitude to nature	Dominate, exploit	Cost/benefit	Environmental management	Ecosystem ethic
View of future	Egocentric	Linear, predictable	Wary of surprises	Emergent, adaptive, evolving

- There is a need for a unifying, conceptual framework so that common objectives among responsible agencies in the system can be developed. The concept of the biosphere could provide a foundation for this unifying, conceptual framework. The ecosystem concept requires that a public ethic be developed, one that emphasizes stewardship of material resources as opposed to exploitation based on materialistic or marketplace values

- Existing institutional responsibilities are so strongly compartmentalized and respond to such fragmented statutory directions, that they actively inhibit integrated approaches to ecosystem management. Because of this narrow focus, institutions can be forced into placing economic considerations above environmental ones. The tendency is to overweight economic costs in responding to environmental problems, rather than to choose more socially-oriented, health-focused, longer-range options, which would allow an ecosystems perspective to be developed for all values, including nonmonetary ones

Henceforth, the Science Advisory Board intends to take a proactive, anticipatory approach toward preventing harm to the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem. The Board will also continue providing advice to assist the Commission, the Great Lakes Water Quality Board and others in the development of ecologically sound and cost-effective measures to restore the health of degraded parts of the Great Lakes; the Board intends to carry out these activities in a manner that better reflects an ecosystems approach. The long-range focus will be on scientific knowledge and recommendations pertaining to the identification and solving of problems, using integrative techniques. Adaptive management will be stressed; prevention, restoration and rehabilitation will be its major components.

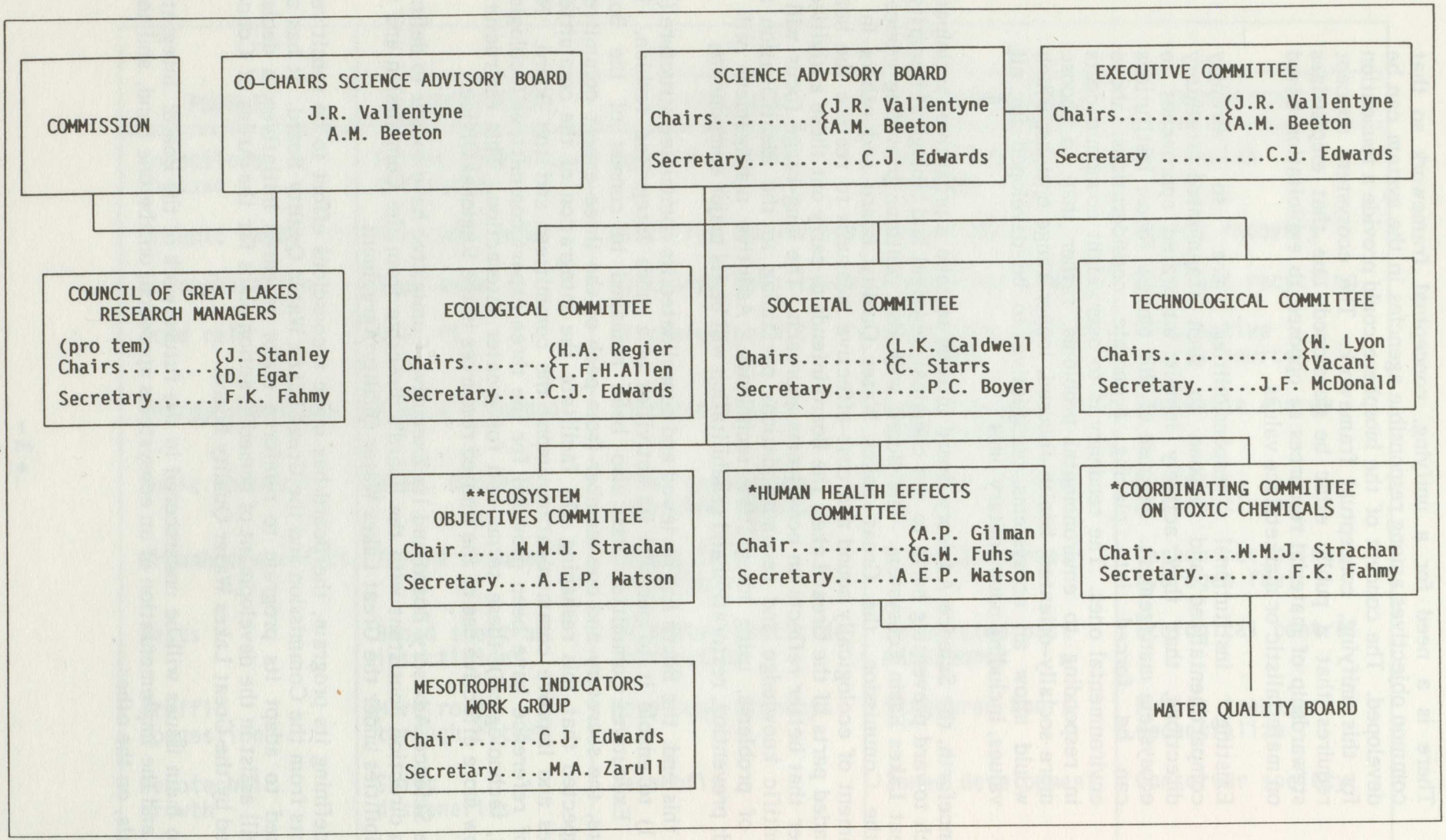
To this end, the Board has reviewed and consolidated its committee structure (see Figure 1) to enable it to perform its activities in a more integrated fashion. The Board's Executive Committee has also been reshaped to consist of the Board co-chairs, the secretary and one member from each of the three expert committees. It is expected that this reshaping will facilitate the integration of the committees' activities and improve communication among the committees and the Board. New terms of reference have been provided for the three expert committees (ecological, societal, technological): these terms call for greater interaction. This restructuring will allow more effective use of the limited resources in the Regional Office.

The Science Advisory Board and its Executive Committee have sought to define a program direction consistent with the Board's directive from the Commission and the responsibilities under the Great Lakes Water Quality Agreement.

In defining its program, the Board has made a conscious effort to be sensitive to comments from the Commission and the Great Lakes Water Quality Board. It has also attempted to adapt its program to reinforce major research initiatives, a decision which will assist in the development of remedial action plans for the Areas of Concern identified by the Great Lakes Water Quality Board.

Two main issues will be underscored in the future work of the Board: integrative science and the implementation of an ecosystems approach, on the one hand, and toxic chemicals, on the other.

Figure 1. Science Advisory Board organization chart.



* Denotes Joint WQB/SAB Committee.
** The Aquatic Ecosystem Objectives Committee was renamed Ecosystem Objectives Committee at the 67th meeting of the Science Advisory Board (June 17-19, 1987).

Integrative Science and Implementation of an Ecosystems Approach

There is a growing consensus among organizations with basinwide interests for an ecosystems approach because most problems are intractable without it. The National Research Council and the Royal Society of Canada praised the 1978 Agreement as the beginning of an evolving process of ecosystems management. In hearings conducted throughout the basin, Great Lakes United encountered major support for the ecosystems approach based on a citizens' review of the 1978 Great Lakes Water Quality Agreement. However, apart from the requirement for remedial action plans in Areas of Concern, no new operational mechanisms have been instituted to facilitate the implementation of this approach.

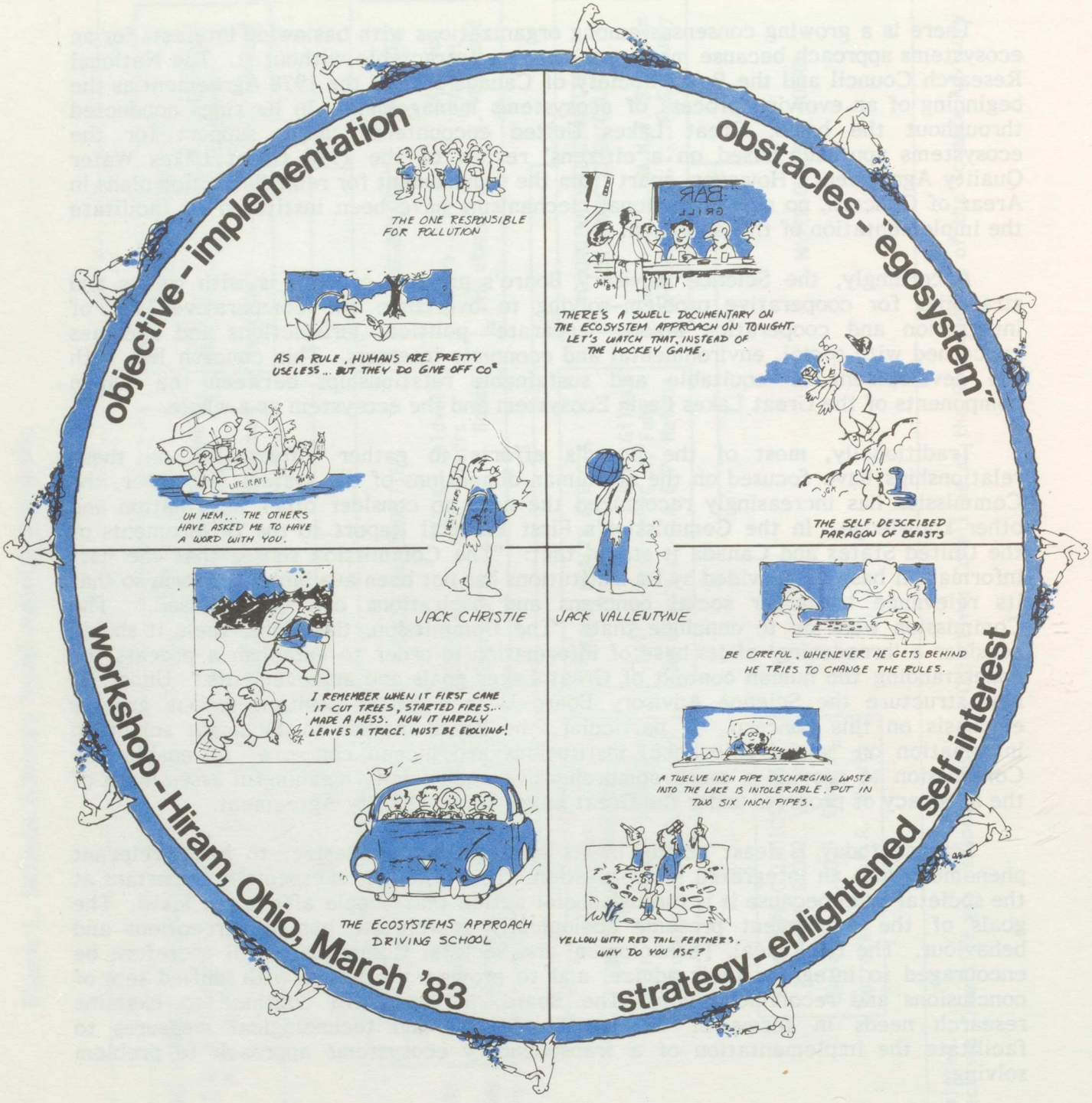
Accordingly, the Science Advisory Board's primary concern is with values and strategies for cooperative problem-solving to overcome the comparative lack of integration and cooperation among "separate" political jurisdictions and agencies concerned with social, environmental and economic interests. This concern lies with the development of equitable and sustainable relationships between the human components of the Great Lakes Basin Ecosystem and the ecosystem as a whole.

Traditionally, most of the Board's efforts to gather information on these relationships have focused on the nonhuman dimensions of the system. However, the Commission has increasingly recognized the need to consider other information and other knowledge. In the Commission's First Biennial Report to the Governments of the United States and Canada it stated that: "The Commission senses that the past information base as provided by its institutions has not been available in a form so that its relevance to larger social concerns and aspirations can be assessed." The Commission went on to conclude that: "The Commission, therefore, feels it should consider a 'broadening' of its base of information in order to establish a process for understanding the human context of Great Lakes goals and achievements." Under its new structure the Science Advisory Board is in a better position to put greater emphasis on this concern. In particular, the Board intends to document scientific information on "social relevance, institutions and human concerns" to enable the Commission to provide a more comprehensive and socially meaningful assessment of the adequacy of progress under the Great Lakes Water Quality Agreement.

Science today is least strong in its capacity to synthesize, to bring relevant phenomena into an integrated interpretation. This synthesis is especially important at the societal level because it is through social action that people affect the lakes. The goals of the Agreement presume ecologically appropriate human perceptions and behaviour. The Ecological, Technological and Societal Committees will therefore be encouraged to integrate their advice, and to provide the Board with unified sets of conclusions and recommendations. The Board, in turn, will continue to examine research needs in terms of ecological, societal and technological measures to facilitate the implementation of a transboundary ecosystems approach to problem solving.

Toxic Chemicals

The Science Advisory Board continues to view persistent toxic chemicals and their impact on the Great Lakes Basin Ecosystem as the most pressing issue under the terms of the Great Lakes Water Quality Agreement. The Water Quality Board is likewise addressing toxic chemicals as its top priority and the Council of Great Lakes Research Managers will, in alternate years, hold workshops on a priority issue in the area of toxic chemicals.



Cartoons prepared by James Kempkes, Toronto, for an Ecosystems Workshop held in Hiram, Ohio, 1983.

In accordance with its strategic plan, the Science Advisory Board will be giving specific attention to the identification and control of problems and threats arising from toxic substances.

Identification

Improved information on ecosystem stresses is required for both decisionmaking and predictive capability. To attain this information requires the identification of stresses exerted by toxic materials on the indigenous biota of the basin, including humans. The Ecological and Technological Committees will be encouraged to focus their energies on this subject and to evaluate various models for predicting the behaviour of sediment-bound contaminants. They will also be encouraged to review the adequacy of testing procedures for assessing hazards associated with contaminated sediments. The Ecosystem Objectives Committee will be encouraged to continue its development of more integrative measures of ecosystem quality, including the assessment of biotic abnormalities, especially tumors and other deformities. The linkages between the various components of contaminated freshwater ecosystems must be better understood if we are to improve our ability to assess the significance of changes in contaminant levels in components of the system.

The Board convened a workshop on Indicators of Health of Aquatic Ecosystems in 1985. The proceedings of that workshop are scheduled for publication in 1987. The workshop provided an opportunity to compare state-of-the-art measures for assessing the response of freshwater biota to stresses caused by toxic chemicals. This important area will be further developed under the guidance of the Ecosystem Objectives Committee and the Ecological Committee. Many research institutes, both within and outside the basin, are conducting excellent research in this field. The role of the Science Advisory Board under the terms of the Agreement is to integrate this research information and provide advice on areas requiring emphasis. It is anticipated that the Council of Research Managers will play a critical role in this endeavor.

Control

The 1978 Agreement stipulates that persistent toxic substances should be virtually eliminated in a manner consistent with the principle of zero discharge. Clearly this goal has not been accomplished. The Ecological Committee and Human Health Effects Committee will be encouraged to continue to examine the effects of persistent toxic substances on ecosystem (including human) health, but with a view to developing better anticipatory and preventive strategies. The Technological Committee will be encouraged to review existing technology to control the entry of toxic substances into the Great Lakes, particularly those in municipal and industrial effluents, and to review developing technologies to eliminate or reduce the impacts of waste disposal sites and contaminated sediments. The Technological Committee has recently conducted two workshops on the human-machine interface and explored how this interface influences the effectiveness of pollution control programs. The Societal Committee is developing a special report on anticipatory, preventive and adaptive strategies, and a socio-economic perspective on how the production, use and disposal of persistent toxic substances have affected beneficial uses in Areas of Concern.

1.2 REMEDIAL ACTION PLANS

In addition to the above priorities, the Board expects to contribute to other initiatives, specifically the process of developing remedial action plans in designated Areas of Concern. The requirement for these plans is a challenging departure from

most historical pollution control efforts, where separate programs for the regulation of municipal and industrial discharges, urban and agricultural runoff have been implemented without considering overlapping responsibilities. This new process will call upon the talents available in a wide array of programs, far beyond those traditionally associated with water pollution control: local communities and a wide range of government agencies at all levels. All programs, agencies and communities affecting an Area of Concern must work together on common goals and objectives, using an ecosystems approach. The process of developing remedial action plans may in fact constitute a first and necessary step in implementing an ecosystems approach.

Remedial action plans provide an opportunity for the affected public in each Area of Concern to define problems, establish goals and seek long-term solutions to water quality problems. As "owners" of the problem, each Area of Concern has a vested interest in equitable and socially acceptable approaches to remediation. Public participation, a critical element of the governing process, provides an important mechanism for bringing together economic and environmental concerns in a manner which links them with social interest.

In setting goals for the remediation, rehabilitation and delisting of Areas of Concern, it will be important to recognize the iterative nature of the planning process, the conflicting demands of multiple uses, technological options for remediation, inherent limitations and opportunities for ecosystems responses, socio-economic imperatives, educational needs and the need to identify gaps in knowledge.

The Board has directed its three expert committees and two joint committees to address these issues. The Technological Committee will be evaluating methods for predicting the behaviour of sediment-bound contaminants, the adequacy of procedures for assessing hazards associated with contaminated sediments, and the efficacy of various clean-up procedures. The Societal Committee will address institutional obstacles to remediation, to developing public constituencies in each Area of Concern, and to enhancing the development of anticipatory and preventive strategies that will help achieve the goal of zero discharge of persistent toxic substances. The Ecological Committee will examine habitat goals, anticipated ecosystemic changes in response to improving water quality, and knowledge of linkages between the various ecosystemic components needed to improve our ability to assess the significance of changes in the system.

After 15 years of documenting the nature and extent of water quality problems, it is encouraging that the collective will is now prepared to address specific requirements and to be accountable for remedial plans and the schedules for their implementation. The Science Advisory Board is prepared to apply its scientific experience and ecosystems expertise to assist the Water Quality Board in reviewing and evaluating these plans.

1.3 LAKE LEVELS

In 1986, the Commission was given a "Levels" Reference by the Governments of Canada and the United States. The Science Advisory Board offered to assist the Commission in examining the systemic effects of fluctuating lake levels. According to an ecosystems approach, the Board's concerns fall into three main areas: the need to predict trends in lake levels, ecosystemic effects of major fluctuations in lake levels, and the socio-economic consequences of these changes.

Currently, predictions are reliable only for about six months. We would like to be able to predict lake levels over a longer term, e.g. five years; without this capability there is inadequate information for planning mitigative measures to deal with future changes in present levels. For example, should planning provide for protective structures for lake levels 0.45 metres higher than at present or should temporary measures be implemented because lake levels will recede? In order to arrive at a decision, we must understand how global processes cause regional impacts, i.e. global climate trends. The final decision may be that it is more important to deal with the uncertainties of forecasts than with either high or low levels themselves, and to seek adaptive measures that enable societies to adjust to changing lake levels.

Research is also needed on the impacts of major water level fluctuations on nearshore habitats and wetlands; on the possible release of contaminants from lakeside disposal sites; on hydraulic problems associated with wastewater collection, conveyance and treatment facilities; on possible impacts of increased turbidity on biological productivity; on phosphorus release associated with shore erosion and on the effects on dissolved oxygen reserves in bottom waters in critical areas such as central Lake Erie. It appears that higher water levels do not affect concentrations of PCBs, lead, mercury or mirex, since concentrations of these chemicals have remained about the same as during the period of decreasing lake levels in the late 1970s. On the other hand, it is estimated that the total phosphorus load from shore erosion during high water levels is about five times greater than during low lake levels, but uncertainty exists about the bioavailability of this source of phosphorus. Overall we are faced with much speculation about the environmental impact of water level changes. Few facts are available to confirm or deny speculations.

The socio–economic impact of the present high lake levels on some individuals may be severe, yet there is little information on the overall costs to society. We know of hydraulic problems at wastewater treatment facilities, e.g. Milwaukee, and about destroyed homes and flooded businesses, but we have few data on the overall impacts on individuals, communities and the Great Lakes Basin Ecosystem. Such information is needed to plan the extent and magnitude of mitigative measures and to develop policies for coastal zone management.

The Science Advisory Board reiterates its offer to assist the Commission in meeting the requirements of the Parties in respect to the 1986 Levels Reference.

2.0 Review of Science Advisory Board Recommendations (1973-1985)

2.1 INTRODUCTION

Consistent with its mandate, the Science Advisory Board has periodically provided the International Joint Commission with recommendations relevant to science and research in the Great Lakes basin. A review of these recommendations provides a means of self evaluation and presents the Commission and the Parties with an opportunity to judge the utility of the recommendations and the effectiveness of the mechanisms used for their development.

The following recommendations are extracted from earlier Research Advisory Board (1973–78) and Science Advisory Board (1978–85) reports. In certain cases, recommendations have been combined, summarized or rephrased. The sequence of recommendations traces the evolution of issues, for example from nutrient pollution to toxic chemical pollution or from point sources to nonpoint sources. This historical sequence demonstrates how the Board has responded to emerging issues in its recommendations.

2.2 SOCIAL SCIENCE

One of the earliest recommendations of the Science Advisory Board recognized the importance of involving the public in the decision–making process. Consistent with this recommendation, the Board's first advisory group was its Standing Committee on Social Science, Economics and Legal Aspects of Water Quality. Following its ecosystem recommendation in 1978, the Board began to formulate more of its advice to the Commission in the context of an ecosystems approach.

The Board's recommendations concerning societal issues were:

1973 • To approve a social science study to review and evaluate the Commission's public hearings

1980 • To encourage research on methods to determine net benefits as a necessary consideration in future decision–making

1981 • To request the Parties to review their programs for making effective use of energy

• To encourage the Parties to coordinate their planning and use of energy alternatives

1982 • To encourage the Parties to increase the level of research, expertise and funding in socio–economic areas

1985 • To initiate a prototype management study involving two Areas of Concern and to evaluate the socio–economic costs and benefits of rehabilitation

The Board sponsored a workshop in 1979 to determine how the Commission might be better informed about current and emerging problems affecting the Great Lakes through anticipatory planning. In 1984, a survey was conducted among Great Lakes educators to

determine the use of teaching materials for Great Lakes topics. This survey was further updated in 1987 and resulted in the publication of a directory in support of the activities of Great Lakes educators. In 1984, an international workshop on sediments (see Section 3.2.1)concluded that public participation is crucial for implementing remedial programs in Areas of Concern. In 1985, a report was published on consensus management, using the Green Bay experience as an example. Also in 1985, critical reviews of literature pertinent to the values and benefits of environmental improvements were undertaken.

The Commission has concluded that greater public involvement in setting broad goals for the Great Lakes is desirable and is seeking means to improve its communication with the citizens of the basin, to both learn and inform. It is hoped that these efforts will contribute to the improvement of communication among all sectors of society regarding the quality and integrity of the Great Lakes Basin Ecosystem.

2.3 NUTRIENT POLLUTION

The Board came into existence at a time when eutrophication was a central issue, following the Commission's identification of phosphorus as the key to the control of eutrophication. Consequently, the Board's early recommendations emphasized nutrient control and the understanding of lake dynamics. It was apparent that the measures taken for additional sewage treatment would reduce phosphorus, Cladophora and diseases associated with raw sewage. It was also evident that increasing knowledge of lake physics would enable the development of mathematical models which could enhance informed policy-setting and decision-making processes. The Board's recommendations ranged from developing appropriate technology and knowledge of nutrient dynamics in the early years, to evaluating the effectiveness of control measures and substitutes for detergent phosphate in the intervening years, to developing programs for phosphorus management in the later years.

The Board's major recommendations were:

1974
- To increase and coordinate research on the disinfection of sewage and to accept the Board's report on sewage and virology
- To support a workshop on Cladophora
- To increase and coordinate research to clarify the relationship between coliform counts in water and human diseases contracted through the recreational uses or consumption of water

1975
- To initiate an investigation into factors governing the growth and distribution of Cladophora and to initiate coordinated research on long-term, large-scale drift and dispersal patterns to determine hydrodynamics in the Great Lakes

1977
- To encourage stringent phosphate levels in detergents, improve sewage treatment plant operations, study the efficiency of control programs, emphasize quality control in surveillance programs and encourage the replacement of phosphate in detergents with nitrilotriacetate

1978
- To reiterate the 1977 recommendations in the context of an ecosystems approach

1980 • To support research on methods to determine relationships between various forms of phosphorus and their movements in aquatic ecosystems

1982 • To urge the Commission to encourage the Parties to maintain funding levels for phosphorus management

The Board sponsored a workshop on Cladophora in 1975, and in 1982 the International Association for Great Lakes Research devoted an entire issue of its Journal to Cladophora. With declining trends in phosphorus concentrations, Cladophora no longer causes the problem it once did. The new Great Lakes International Surveillance Plan, nevertheless, contains several lake specific research projects utilizing Cladophora as an indicator of eutrophication. Cladophora may also be useful as a biomonitoring organism for metals and organic compounds. The Board sponsored two workshops to review the research required to understand both nearshore and open lake hydrodynamics.

In response to proposed substitutes for phosphates in detergents, the Board commissioned a series of reports which discussed the environmental and human health implications of nitrilotriacetate, citrate, carboxymethyloxysuccinate, carboxymethyl-tartronate, carbonates, silicates and zeolites. Five reports were published between 1977 and 1983. In addition, the Board published a report in 1980 on alternative strategies for managing phosphorus inputs; this report reviewed mathematical models, loading estimates, shoreline erosion, point and nonpoint sources, and technology to control inputs. In 1981, the Board produced a report on the biological availability of phosphorus.

The Parties and jurisdictions can take pride in the progress they have made in reducing the inputs of phosphorus into the Great Lakes. Governments should also be proud of their efforts in enhancing limnological research and surveillance and monitoring programs which have resulted in a vastly improved and internationally acclaimed understanding of the Great Lakes. Unfortunately, that knowledge base is still insufficient to meet the goals of the 1978 Water Quality Agreement with respect to nutrients. Indeed, increasing concentrations of nitrites/nitrates require careful examination to see what implications these may have on trophic status. The Great Lakes food web is another area that requires diligence and continued research. Many scientists now consider that recent changes observed in phytoplankton communities are a combined result of reductions in total phosphorus and of zooplankton abundance resulting from changes in the fish community. This subject has been the focus of two workshops, summarized later in this report (see Section 3.2.4).

2.4 THE ECOSYSTEMS APPROACH

In 1977, the Board charged an ad hoc committee to prepare a report on the need to broaden the focus of the Commission's activities from water quality to ecosystems. This report became the foundation for subsequent Board recommendations:

1978 • To urge the Commission to encourage the Parties to recognize as policy an ecosystems approach and endeavor to apply such an approach to one or more transboundary problems and use Article 10 of the Boundary Waters Treaty, if necessary, to reach these expectations

1980 • To urge the Commission to recommend research on methods to determine net benefit as a necessary consideration in future decision–making in the Great Lakes Basin Ecosystem

Significantly, the 1978 Great Lakes Water Quality Agreement recognized the ecosystem concept as a necessary feature in dealing with water quality issues. The Board continued to champion this approach through a workshop held in Hiram, Ohio in March 1983. A synopsis of the results of the Hiram workshop was published in the Journal of the International Association for Great Lakes Research in 1986, and the unabridged results are on file in the IJC Regional Office. The Board recognizes that implementing an ecosystems approach will require rethinking by agencies and the use of innovative/nontraditional tools. In support of this new approach, an ad hoc group under the Aquatic Ecosystem Objectives Committee examined detailed requirements (criteria) for an ecosystem indicator and recommended the lake trout as a surrogate in evaluating the health of Lake Superior.

In less than a decade since the Board's original proposal, a growing consensus has emerged among organizations with basinwide interests concerning the necessity for an ecosystems approach. The National Research Council and the Royal Society of Canada lauded the 1978 Agreement as the beginning in an evolving process of ecosystems management. There are thus major forces in place that support the movement toward an ecosystems approach in maintaining the quality of highly valued, politically shared national resources. However, no significant operational mechanisms, other than the requirement for remedial action plans in Areas of Concern, have been instituted to facilitate the implementation of an ecosystems approach.

"THE EARTH DOES NOT BELONG TO MAN; MAN BELONGS TO THE EARTH. ALL THINGS ARE CONNECTED LIKE THE BLOOD THAT UNITES ONE FAMILY."

– CHIEF SEATTLE

The Board considers that there are major obstacles to the implementation of an ecosystems approach which must be addressed so that we can proceed. One of these is the need for a common understanding about what constitutes an ecosystems approach in terms of discrete implementation measures (see Section 1.0).

The Great Lakes Water Quality Agreement of 1978 has been cited by the Commission as "a milestone document, one of the first international statements that technical, diplomatic, and administrative approaches to resource management need to be considered in terms of holistic ecological concepts." The Board takes great pride in having introduced the ecosystem concept to the Parties and the Commission. In effect, this action set the stage for a revolutionary change in thinking that is still in the process of development.

2.5 WATER QUALITY OBJECTIVES

The Water Quality Agreement of 1972 required the development of specific water quality objectives as limits to physical effects or levels of chemical substances in the waters of the Great Lakes. At the time, eight specific and five interim objectives were presented, most of them in qualitative terms. To examine the literature and to make recommendations on new and revised objectives for the Agreement, the Research Advisory Board and the Water Quality Board created the Scientific Basis for Water Quality Criteria Committee and the Water Quality Objectives Subcommittee, respectively. Between 1972 and 1978 these two groups jointly made recommendations on approximately forty substances. These recommendations were duly forwarded to the Commission and most of them were incorporated into the 1978 Water Quality Agreement.

In addition to the above, several workshops were held to focus scientific expertise on general phenomena pertaining to objectives. One workshop was on structure–activity correlations (1975); a second concerned toxic forms of metals (1975); a third was on environmental mapping (1976) and a fourth, on polynuclear aromatic hydrocarbons (PAHs).

In regard to the application of these objectives, presentations have been made on the need to develop a mechanism to describe mixing zones. As a consequence of these presentations, the Science Advisory Board and the Commission have recommended, as an interim measure until such a mechanism can be developed, that the objectives should apply throughout the Great Lakes system.

With the signing of the 1978 Agreement, the task of examining the literature and developing reviews and recommendations concerning specific objectives was assigned to the newly formed Aquatic Ecosystem Objectives Committee of the Science Advisory Board. A total of 17 recommendations have been made regarding specific levels of chemicals in the Great Lakes, some of which were revisions to those developed under the 1972 Agreement. These and the specific objectives developed under the 1972 Agreement are presented in Table 2.

More recently the Committee developed a new class of integrative objectives, utilizing the condition and numbers of appropriate resident biota to assess the integrity of the Great Lakes ecosystems. The purpose of these objectives is to provide additional protection in instances where multiple stresses, chemical or otherwise, disrupt the community structure of a given waterbody. The first of these integrative objectives involved lake trout in Lake Superior.

2.6 ATMOSPHERIC SOURCES OF POLLUTANTS

The atmosphere as a conveyor of pollution is certainly one area where improvements in knowledge will pay dividends in terms of pollution control and the rehabilitation of impaired ecosystems. Degradation of the ozone layer, acid rain and open lake pollution are all associated with atmospheric transport. The Board has a consistent history of recommending additional research on biota–air–water–soil interactions and transport properties as noted below.

TABLE 2. GREAT LAKES WATER QUALITY AGREEMENT SPECIFIC OBJECTIVES – BASIS, REFERENCE AND STATUS.

	SUBSTANCE	LEVEL		BASIS	REFERENCE	STATUS
PERSISTENT ORGANICS	Aldrin/dieldrin (total)	0.001	µg/L	Quantification/carcinogenic	1974 WQOS/SBWQC	1
		0.3	µg/g	Human food level	1974 WQOS/SBWQC	1
	Benzo(a) pyrene (water)	0.01	µg/L	WHO drinking water level	1983 AEOC	4
	(sediment/tissue)	1.0	µg/g	Potential tumor induction in fish	1983 AEOC	4
	Chlordane	0.006	µg/L	Fathead lethality + application factor	1974 WQOS/SBWQC	1
	DDT (total)	0.003	µg/L	Quantification/bioconcentration	1974 WQOS/SBWQC	1
		1.0	µg/g	Bird eggshell thinning	1974 WQOS/SBWQC	1
	Endrin	0.002	µg/L	Quantification/stonefly lethality	1974 WQOS/SBWQC	1
		0.3	µg/g	Human food level	1974 WQOS/SBWQC	1
	Heptachlor (total)	0.001	µg/L	Quantification/stonefly lethality	1974 WQOS/SBWQC	1
		0.3	µg/g	Human food level	1974 WQOS/SBWQC	1
	Lindane	0.01	µg/L	Stonefly lethality + application factor	1974 WQOS/SBWQC	3
		0.3	µg/g	Human food level	1974 WQOS/SBWQC	1
	Methoxychlor	0.04	µg/L	Invertebrate effects	1974 WQOS/SBWQC	1
	Mirex	0.005	µg/L	Quantification/crustacean lethality	1981 AEOC	2
	Pentachlorophenol	0.4	µg/L	Fish growth	1980 AEOC	5
	Phthalate (Dibutyl)	4.0	µg/L	Daphnid reproduction	1974 WQOS/SBWQC	1
	Phthalate (Di-2-ethylhexyl)	0.6	µg/L	Daphnid reproduction	1974 WQOS/SBWQC	1
	Phthalates (other)	0.2	µg/L	Quantification	1974 WQOS/SBWQC	1
	Polychlorinated biphenyls	0.1	µg/g	Mink reproduction	1974 WQOS/SBWQC	1
	Toxaphene	0.008	µg/L	Trout reproduction	1974 WQOS/SBWQC	3
	2,3,7,8-Tetrachloro-dibenzo-p-dioxin	0.00001	µg/L	Quantification limit	1980 AEOC	4
		0.00001	µg/g	Quantification limit	1980 AEOC	4
NON-PERSISTENT ORGANICS	Diazinon (mean)	0.003	µg/L	Invertebrate lethality	1983 AEOC	2
	(once in 30 days)	0.1	µg/L	Invertebrate lethality	1983 AEOC	2
	Guthion	0.005	µg/L	Invertebrate lethality	1975 WQOS/SBWQC	1
	Parathion	0.008	µg/L	Invertebrate lethality	1975 WQOS/SBWQC	1
METALS AND METALLOIDS	Arsenic	50.0	µg/L	Drinking water level	1974 & 1975 WQOS/SBWQC	1
	Cadmium	0.2	µg/L	Daphnid reproduction	1975 WQOS/SBWQC	1
	Chromium	50.0	µg/L	Drinking water level	1975 WQOS/SBWQC	1
	Copper	5.0	µg/L	Fish reproduction	1974 & 1975 WQOS/SBWQC	1
	Iron	300.0	µg/L	Algae toxicity		
	Lead Superior	2.0	µg/L	Lake Ontario effects and the relation between chronic effects and hardness	1980 AEOC	2
	Huron	3.0	µg/L		1980 AEOC	2
	Erie and Michigan	4.0	µg/L		1980 AEOC	2
	Ontario	5.0	µg/L	Neurotoxic effects on trout	1980 AEOC	1
	Mercury	0.2	µg/L	Fish reproduction	1975 WQOS/SBWQC	1
		0.5	µg/g	Bird behaviour	1975 WQOS/SBWQC	1
	Nickel	25.0	µg/L	Daphnid reproduction	1975 WQOS/SBWQC	1
	Selenium (water)	1.0	µg/L	Ecosystem effects on fish survival	1981 AEOC	2
	(sediment)	5.0	µg/g		1981 AEOC	2
	(fish tissue)	3.0	µg/g		1976 WQOS/SBWQC	2
	Silver (total)	0.1	µg/L	Fish development	1982 & 83 AEOC	5
	Zinc	30.0	µg/L	Fish reproduction	1975 WQOS/SBWQC	1
INORGANICS	Ammonia (undissociated)	20.0	µg/L	Fish development	1974 WQOS/SBWQC	3
	(total)	500.0	µg/L	Raw water supply level	1974 WQOS/SBWQC	3
	Chlorine	2.0	µg/L	Fish and invertebrate lethality	1974 WQOS/SBWQC	5
	Fluoride	1.2	mg/L	Drinking water level	1974 WQOS/SBWQC	1
	Hydrogen sulfide	2.0	µg/L	Fish development	1974 WQOS/SBWQC	1
	Oxygen (excluding hypolimnion)	6.0	mg/L	Unspecified	1972 Agreement	1
	Phosphorus (spring) Superior	5.0	µg/L	Maintain oligotrophic state	1978 WQOS/SBWQC	2
	Huron, Georgian Bay, North Channel	5.0	µg/L	Maintain oligotrophic state	1978 WQOS/SBWQC	2
	Saginaw Bay	15.0	µg/L	Prevent nuisance algal growths	1978 WQOS/SBWQC	2
	Michigan	7.0	µg/L	Restore oligotrophic state	1978 WQOS/SBWQC	2
	Western Erie	15.0	µg/L	Prevent nuisance algal growths	1978 WQOS/SBWQC	2
	Central Erie	10.0	µg/L	Restore all-year aerobic state	1978 WQOS/SBWQC	2
	Eastern Erie	10.0	µg/L	Prevent nuisance algal growths	1978 WQOS/SBWQC	2
	Ontario	10.0	µg/L	Prevent nuisance algal growths	1978 WQOS/SBWQC	2
OTHERS	Cyanide	5.0	µg/L	Fish behaviour	1975 WQOS/SBWQC	5
	Escherichia coli (receiving waters)	23/100	mL	Human gastrointestinal problems	1983 AEOC	4
	Enterococcus (receiving waters)	11/100	mL	Human gastrointestinal problems	1983 AEOC	4
	Pseudomonas aerug. (receiving waters)	10/100	mL	Human ear infections	1983 AEOC	4
	Temperature (general)			No stratification changes	1974 & 1975 WQOS/SBWQC	1
	(MWAT-growth)			To + (Tu - To)/3		1
	(MWAT-reproduction)			Sufficient to protect all reproductive activity		1
	(MWAT-winter)			Sufficient to maintain seasonal lethal threshold		1
	(Short-term growth)			Sufficient for incubation and hatching		1
	Unspec. toxics & complex effluents	<0.05 of 96-h LC_{50}		acute lethality	1974 WQOS/SBWQC	1
	pH	6.5 - 9.0		Fish and benthos health	1974 WQOS/SBWQC	1
	Total dissolved solids	200.0	mg/L	Non-degradation	1972 Agreement	1

1=Substance and level in 1978 Agreement as stated.
2=Change in level approved by Commission.
3=As stated in 1978 Agreement but change in level pending Commission approval.
4=Addition of substance and level approved by Commission.
5=Addition of substance proposed but not in Agreement and not approved by Commission.

WQOS – from Water Quality Objectives Subcommittee Report.
SBWQC – from Committee on the Scientific Basis for Water Quality Criteria.
AEOC – from Aquatic Ecosystem Objectives Committee Report.

The Board's major recommendations were:

1977 • To conduct research on the interactions between air, water, sediments and biota in reference to toxic materials

1978 • To reiterate the above recommendation in the context of an ecosystems approach

1979 • To encourage the Parties to formulate a reference on the causes, effects and measures for the control of the long-range transport of atmospheric pollutants with special attention to acid rain, and to request resource management agencies to coordinate their efforts with those of agencies responsible for air and water quality surveys, aiming for the improved assessment and control of atmospheric pollution

1980 • To urge the Commission to encourage the jurisdictions to institute programs for quantifying atmospheric loadings of hazardous substances

1982 • To increase the level of research, expertise and funding for conservative indicators of atmospheric pollution

1983 • To use isotopic ratios of sulphur and lead to assess sources and proportional contributions of other atmospheric pollutants

1985 • To encourage the Parties to develop a standard protocol for measuring atmospheric organics and metals along with interagency comparisons of existing methodologies

The Commission noted in its Third Biennial Report that atmospheric deposition is now widely recognized as an important pathway for pollutants in the Great Lakes. This recognition has increased greatly since 1978. Insufficient monitoring of airborne toxic substances and inadequate source inventories, however, make estimation of the extent of transport and deposition difficult and in many cases impossible. Both the Board and the Commission have sponsored major workshops which have focused on the atmosphere as an integral pathway for pollution. The findings of the Board's 1986 Atmospheric Workshop appear elsewhere in this report (see Section 3.2.2).

The Parties have made significant gains in atmospheric research and surveillance and have recently worked together on co-locating sampling stations within their respective Great Lakes monitoring networks. The United States has recently made changes in its network as a result of a major review. The Board perceives these advances as positive steps in putting the atmospheric contribution to pollutant loadings in proper perspective.

2.7 GROUNDWATER SOURCES OF POLLUTION

Groundwater pollution occurs slowly and may persist for decades or millenia. The Board has recommended that groundwater pollution, particularly that from the leakage of toxic chemical disposal sites, should receive greater attention. Groundwater contamination affecting wells and nearshore lake waters has been well documented in terms of the negative effects of aquifer misuse. Indeed, the term "irreparable damage" is often used in describing the impacts of groundwater abuse.

As noted below, the Board has alerted the Commission to a general lack of knowledge in the chemistry and physics of groundwater.

The Board's major recommendations were:

1982 • To encourage the Parties to increase the level of research, expertise and funding in respect to groundwater

1983 • To provide detailed groundwater maps so that waste disposal sites can be classified according to hydrologic setting and to provide greater research effort on sampling methods, strategies and research capabilities

1985 • To encourage the Commission to prepare a hydrogeologic inventory of the Great Lakes basin to assess the potential for groundwater contamination

Groundwater hydrology is a relatively new and imprecise science in terms of its application in the Great Lakes basin. The means of preventing as well as mitigating the contamination of groundwater are among the least understood aspects of Great Lakes science. Accordingly, the Board concluded that without further study, the potential for contamination of the Great Lakes by groundwater cannot be properly assessed nor can preventive or corrective measures be properly identified.

A proposed study, endorsed by the Board in 1985, called for the identification of areas with the greatest contamination potential to allow the Commission to focus the attention of governments on the future need for more intensive, local investigations and the adoption of both preventive and corrective measures. The Board considered that the proposed study would also advance the science of hydrology by examining methods for mapping contamination potential that might be used in other areas.

The study would assemble information on, and more importantly, map: surficial materials, depth to bedrock, bedrock geology, permeability of surficial and bedrock materials, groundwater flow characteristics, aquifer use, land use, and point and nonpoint sources of contamination. This information would then be used to prepare an interpretive hydrogeologic map of the Great Lakes basin. Hydrogeologic regimes would be characterized with respect to their hydraulic properties, degree and proximity to sources of contamination, and flow contributions to the Great Lakes.

The National Research Council of the United States and the Royal Society of Canada, in a joint report entitled The Great Lakes Water Quality Agreement, specifically recommended that the International Joint Commission proceed with the aforementioned groundwater study. These organizations strongly endorsed the 1985 Science Advisory Board's recommendation for mapping groundwater conditions around and under the Great Lakes basin and for compiling data on geology and hydrology, soils and depth to water tables.

The Commission noted in its Third Biennial Report that groundwater mapping is expensive, but necessary to develop comprehensive anticipatory programs to protect and manage Great Lakes groundwater resources. The Board is gratified to learn that the Commission has partially funded the U.S. Department of the Interior's Geological Survey to compile an inventory of all aspects of groundwater within the U.S. portion of the Great Lakes basin.

2.8 ENVIRONMENTAL MAPPING

Although not universally accepted, environmental mapping is generally considered a prerequisite to environmental awareness. As noted below, the Board recommended that environmental mapping be implemented by the Parties and jurisdictions, specifically:

1977 • To urge the Commission to recognize and adopt the broad concept of ecosystem quality and encourage the Parties to initiate environmental mapping

1979 • To urge the Commission to encourage the Parties to initiate environmental mapping of the Great Lakes basin under the Commission's coordination

The subject of environmental mapping was addressed by a workshop sponsored by the Science Advisory Board in 1976. Since then, the U.S. Fish and Wildlife Service has completed a Great Lakes atlas of fish spawning sites in U.S. waters; the National Oceanic and Atmospheric Administration (NOAA) has completed an emergency response inventory which highlights critical areas in the event of hazardous waste spills; the U.S. Fish and Wildlife Service has initiated detailed studies and reports under their estuarine profile series that review wetlands in selected portions of the Great Lakes; and the University of Waterloo has completed a list of natural heritage areas in Canadian portions of the Great Lakes. In 1987, federal agencies and universities in Canada and United States jointly produced The Great Lakes: An Environmental Atlas and Resource Book. While these and other efforts reflect some progress, they do not implement the full scope of the Board's recommendations.

2.9 TOXIC SUBSTANCES

The Science Advisory Board has, with increasing frequency and urgency, identified toxic substances as an area demanding attention. The plethora of chemicals is far too large to cope with on a chemical-by-chemical basis. Consequently, there must be a method to set priorities for evaluation and hence, regulation. The method that emerged was research on sources, transport, fate and effects as a preliminary to source control. The overall strategy was based on the development of a priority list of chemicals and research on new or improved analytical techniques. After a chemical was identified as persistent in the environment, and with a high capacity to bioconcentrate, its toxicity required assessment. Since there is no analytical instrument to measure toxicity, the Board frequently recommended research on techniques for assessing biological responses to specific chemicals. Research on rapid screening techniques to estimate bioconcentration and persistence was also frequently recommended by the Board.

The Board's recommendations were:

1975 • To use structure-activity correlations as an early warning system in the laboratory screening of new chemicals

1977 • To improve loading data
• To adopt water quality objectives for metals
• To determine the exchange between the air, water, sediment and biota of persistent toxic materials

- To provide more complete information on the toxic constituents of complex effluents
- To expand fish tissue monitoring programs
- To develop better analytical methods
- To guarantee access to precise information on production, application and characteristics of all organic chemicals currently in use

1978
- To identify existing data bases and to develop new ones on physical, chemical and toxicological information to enable the assessment of organic chemicals
- To adopt an ecosystems approach to toxic chemicals

1979
- To encourage the continued high priority for research and legislative/regulatory action regarding the dispersal of industrial chemicals
- To encourage the hazard assessment of industrial chemicals in the context of ongoing multi-agency and multi-national efforts
- To request an immediate commitment from the Parties to the Board's recommended procedure for addressing Annexes 10 and 12 of the Water Quality Agreement

1980
- To encourage governments to establish programs to develop routine information on fate and effects for hazard assessment
- To encourage the Commission to develop a centralized information system to collect, store, sort and dispense data needed by the jurisdictions for the implementation of regulations to control hazardous substances
- To encourage the jurisdictions to recover hazardous substances for reuse and to employ treatment technologies that destroy, rather than merely remove, contaminants from waste discharges
- To encourage dischargers to seek ways to reduce the use or loss of hazardous substances that may find their way into air or water effluents

1981
- To encourage research on sources, pathways monitoring and effects of hazardous substances, to facilitate the identification of the impacts of existing and future energy alternatives

1982
- To increase research on the effects of hazardous substances on the health of aquatic communities
- To maintain the present level of support for structure-activity correlations

In support of its recommendations on toxic substances, the Board approved and published in 1975 the results of a symposium on structure activity correlation and a workshop on the toxicity of metal forms to biota and, in 1980, developed a perspective on the problems of hazardous substances. The Board's Ecosystem Objectives Committee, Human Health Effects Committee and Coordinating Committee are working to complete an inventory of priority chemicals, utilizing the scheme outlined by the Board but modified to suit the respective needs of the subunits.

The problems of toxic substances will not be resolved simply by imposing additional technological and regulatory controls but will require a more comprehensive, preventive approach. A preventive approach requires reduction or even elimination of toxic chemicals prior to the production and marketing processes.

2.10 SEDIMENTS AS SOURCES OF POLLUTANTS

In 1976, following research by the Commission's Pollution from Land Use Activities Reference Group, the Board noted that the role of suspended solids in the transport of nutrients and contaminants, although not defined, could be significant. This concern was subsequently shifted to in situ sediments as they might be used in retrospective trend analyses, i.e. for sediment banks and as a source of pollution from dredging operations. The issue of contaminated, in situ sediments was referred to the Science Advisory Board by the Water Quality Board since it was considered beyond the scope of that Board's Dredging Subcommittee.

The Board's recommendations on sediments were:

1977 • To encourage governments to undertake studies to determine the exchange of persistent toxic materials between air, water, sediment and biota

1978 • To review and assess alternative policies on the disposal of dredged materials

1982 • To establish an international sediment bank along with improved methods for the preservation and characterization of samples and for the interpretation of results

1983 • To study the feasibility of maintaining a centralized repository for sediment samples

1985 • To develop management strategies for the rehabilitation of two Areas of Concern, such as Hamilton Harbour and Grand Calumet, and to monitor the biological processes and rates of recovery

The Board endorsed the recommendations from a 1975 workshop of the Pollution from Land Use Activities Reference Group which evaluated the lakewide impact of nutrients and contaminants transported through fluvial and in-lake processes. In 1985, the Board sponsored an international workshop (see Section 3.2.1) to evaluate remedial options with respect to sediment and to assess the direct and indirect effects of sediments on benthic organisms and bioaccumulation. The results of this workshop are directly applicable to 39 of the 42 Areas of Concern where contaminated sediments have been identified as a major problem. The results of the workshop are discussed later in this report (see Section 3.2.1) and in an appendix to this report.

3.0 Reports of Committee Activities

3.1 SOCIETAL COMMITTEE

The report of the Societal Committee is in two parts. The first part summarizes the results of two projects initiated by its predecessor committee, the Social and Economic Considerations Committee: valuations of benefits derived from environmental improvements, and the analysis and conclusions from a survey of educators in the Great Lakes basin. The second part sets the stage for two of the themes the Committee intends to pursue over the next few years: anticipatory, preventive and adaptive strategies, and indicators of public attitudes.

3.1.1 Valuing the Benefits of Environmental Improvements

Programs to control pollution and manage the human uses of ecosystems can produce a wide range of readily recognizable benefits, e.g. the restoration of degraded ecosystems, enhanced recreational opportunities, the reduced incidence of disease, the prevention of species extinction and other irreversible losses. In making public policy decisions, however, it can be quite difficult to assign measureable values to such benefits.

In 1985, the Science Advisory Board authorized the Societal Committee to commission three critical reviews of economic and noneconomic techniques for determining the value of benefits. The primary purpose of these reviews was to identify from the social sciences the most promising theoretical approaches which might be useful in assessing planning options and developing remedial actions.

The three papers focused on valuation techniques derived from economics, social psychology and impact assessment, and urban planning and landscape architecture. Each author was given the following terms of reference:

- Review the theoretical foundations for valuation and weighting from the relevant disciplinary perspective
- Provide an inventory of relevant valuation and weighting methods
- Give examples of the application of these methods to assess current experience
- Provide critical appraisals in theory and practice of the various techniques, with respect to data requirements, ease of application, utility of results for policy development, and consistency with relevant theory
- Give recommendations for future research

The authors were not asked to advocate any particular technique, nor were they asked to produce empirical estimates of the value of the Great Lakes or its component resources.

John Hoehn and Douglass Krieger of Michigan State University authored the economics report; Robin Gregory of Decision Research Inc. authored the social psychology and social impact assessment report; and W. David Conn of Virginia Polytechnical Institute authored the urban planning and landscape architecture report. These reports are available on request from the International Joint Commission's Great Lakes Regional Office.

The economics report provided a sophisticated review, suitable for those with knowledge of calculus, of various economic techniques for assigning values to benefits. It included a review of approaches such as the "travel cost method," where value is derived from measuring travelers' expenditures, and the "contingent valuation" method, where individuals are asked if they would accept or reject a policy change of a particular type that would cost a specified amount of money. The report draws attention to the assumption about human behaviour underling economic theory, that humans act in a fully informed, economically rational manner – a condition rarely if ever satisfied in the real world. The authors contended, nevertheless, that a number of economic valuation approaches can provide valuable contributions for decision–making.

The social psychology report noted that both psychologists and economists are fundamentally concerned with the behaviour of individuals and the choices which they make. The paper underscored some of the limitations of approaches based on conventional economic assumptions, especially under those circumstances where the choices facing citizens are novel and require that unfamiliar options be weighed or that highly uncertain consequences be evaluated. The author suggested that each of the social psychological approaches reviewed shows promise as a tool for decision makers. But it was observed that each tool is subject to a number of constraints; a major concern is analysts' and decision makers' lack of experience in using and interpreting these techniques.

The urban planning/landscape architecture report reviewed several valuation systems used by planners and architects, including Ian McHarg's wellknown approach to assessing the suitability of land for development. These approaches often are employed in environmental impact statements and other planning documents. The author cautioned, however, that they are often based on expert judgments which can be highly subjective, that procedures for assigning values can be implicit rather than explicit, and that the value of adding scores on multiple variables into one cumulative score for an option can be debated. On the other hand, the process of assigning explicit weights or values to specific impacts or objectives can serve to force individuals to think carefully about the objective or impact being weighed. If decision makers assign the weights, the weighting procedure can be an effective means of alerting them to trade–offs in a decision.

Based on its review of these reports, and on its own professsional experience, the Societal Committee concludes that:

- There is no single disciplinary approach available that fully values the benefits of environmental improvements

- Valuation approaches based on economic theory are especially limited because measurements in dollars fail to capture important dimensions of value. For example, valuing Point Pelee National Park on the basis of the money visitors spend travelling there, captures the inherent value of the park as fully as one might capture

the value of one of Shakespeare's plays by measuring the proceeds from ticket sales

- Many of the approaches described in the papers are limited by serious problems of measurement. In some instances, the posing of choices in survey questions influences values assigned by respondents. In others, the relationship between responses to hypothetical questions and actual behaviour may be uncertain. In still other cases, values may be assigned solely on the basis of unexplained "expert" judgment

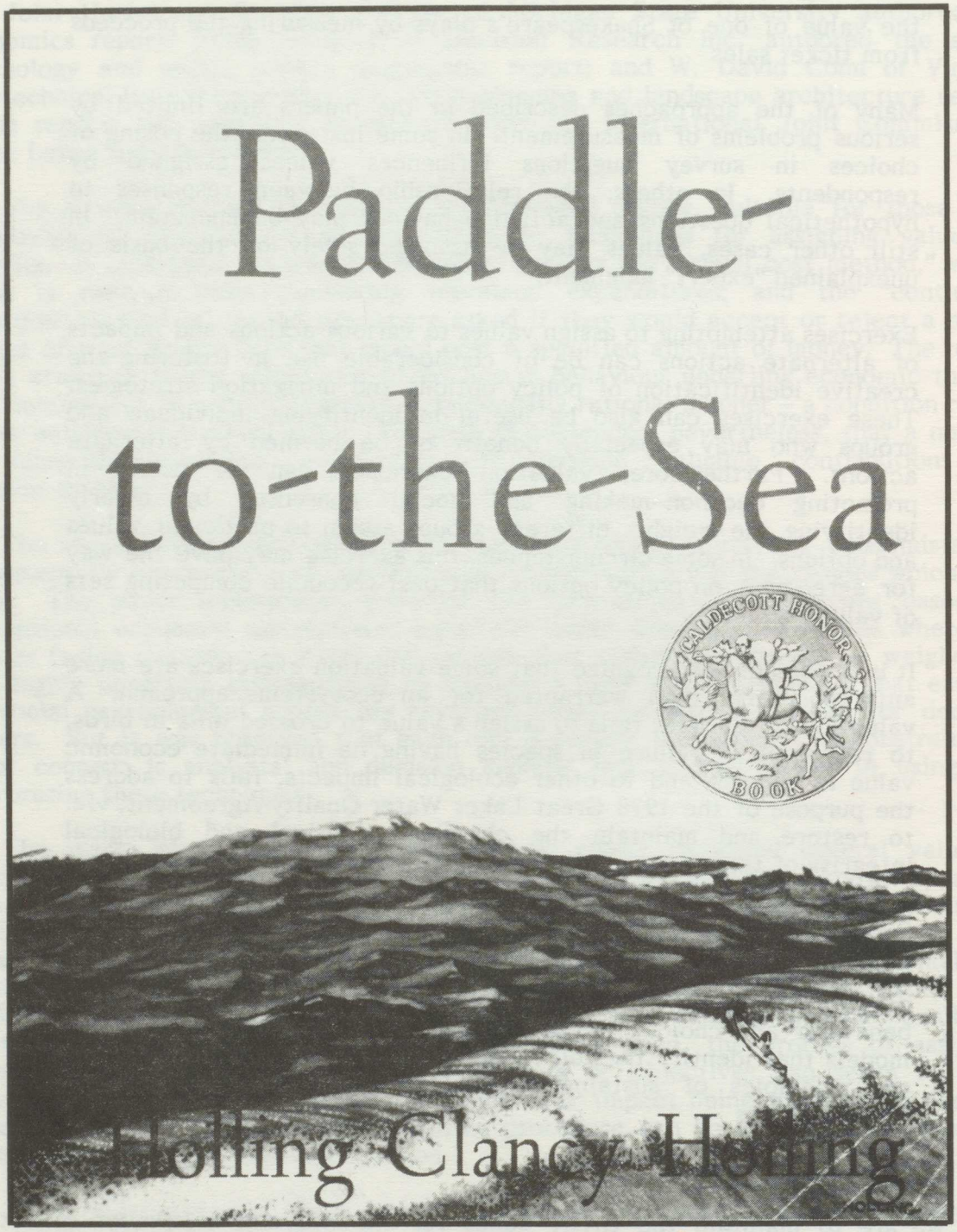
- Exercises attempting to assign values to various actions and impacts of alternate actions can be of considerable use in fostering the creative identification of policy options and mitigation strategies. These exercises can also be useful in identifying individuals and groups who may especially benefit or be harmed by alternate actions. Furthermore, valuation exercises can be useful in promoting decision-making and social consensus by clearly identifying the weights different groups assign to particular values and options. In some circumstances, this exercise may pave the way for agreement on policy options that best reconcile competing sets of values

- It is important to recognize that some valuation exercises are more anthropocentric than warranted for an ecosystems approach. A valuation system that fails to assign a value to crossed bills in birds, to reproductive failure in species having no immediate economic value to humans, and to other ecological impacts, fails to address the purpose of the 1978 Great Lakes Water Quality Agreement, viz. to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem

- In reviewing suggestions for future efforts, the Committee concludes that further work should address a related but broader and more fundamental issue: the extent to which economic factors and policies drive environmental degradation and influence social behaviour and choice. There is also a need for methodologies and models that identify the full range of benefits and costs, based on the principles of sustainable use and equity among competing resource users

3.1.2 Educators' Network

If we are to maintain the Great Lakes for the use and enjoyment of future generations, today's youth must understand the value and importance of the lakes. A survey was conducted in 1984 and updated in 1987, to ascertain whether educators teach about the Great Lakes and, if so, what materials are used and which are most relevant. Two hundred and twenty-six teachers were surveyed; 128 responses were received and computerized. Most respondents taught biology, geography, ecology or environmental education. Forty-four percent indicated that Great Lakes topics were in the school curriculum. Forty-six percent indicated that they developed their own teaching materials. Both responses are a measure of the interest and relevance of the Great Lakes. It was also noteworthy that approximately one-third of the respondents resided more than 100 miles from the lakes, an indication of the size of the Great Lakes "ecoregion."



Book cover for Holling Clancy Hollings' "Paddle–to–the–Sea," a children's story about the adventures of an Indian boy's canoe from the headwaters of Lake Superior through the Great Lakes to the Atlantic Ocean. An Activities Unit, a collection of classroom activities for teachers for "Paddle–to–the– Sea," is available from The Ohio Sea Grant, The Ohio State University, 059 Ramseyer Hall, 29 West Woodruff, Columbus, Ohio 43210 for a small fee. Reprinted by permission of Paddle–to–the–Sea by Holling C. Holling, copyright 1941©. Renewed 1969 by Holling C. Holling, reprinted by permission of Houghton Mifflin Company.

The results of the survey underlined the need to improve access to and awareness of the multitude of sources for materials (108 sources of materials were identified) that serve a pedagogical audience spanning preschool to post-graduate levels. Surprisingly, responses from the survey indicated that this informed and knowledgeable group of educators relied on word of mouth among peers to learn what was available. In 1987, the Board published a report entitled Directory of Great Lakes Education Material, based on the survey. It is the intention of the Board that this publication be made available to individual teachers, schools and publishers and that it be updated as required.

Although the Great Lakes are world renowned and provide economic, recreational and aesthetic benefits to residents of the basin, few educational systems in the United States or Canada provide a structured or required curricula on these lakes for any age level. Lesson plans devoted to the lakes appear to be introduced on the teacher's initiative rather than as a system-wide program to help young students understand the value of the lakes locally, regionally or globally. Further, they tend to be "add-ons" to specialized subject areas rather than "built-ins" common to all subject areas.

Recent studies in environmental education have shown that responsible environmental behaviour does not operate in a vacuum; it is a learned response, most likely acquired during the formative years when individuals are most influenced by familial and pedagogical role models (Sia et al. 1986). Accordingly, the development and recognition of Great Lakes instructional programs by state and provincial environmental education coordinators, in cooperation with agencies responsible for protecting the Great Lakes, would provide an opportunity to establish beliefs and values that could result in desirable adult behaviour with respect to the lakes.

The Board, therefore, recommends that:

- **Each state and province in the Great Lakes basin should be encouraged to establish and assist in programs for use at each age level to provide basic information on the ecological and cultural history of the Great Lakes Basin Ecosystem, on how human activities interact with and affect that ecosystem, and on the importance of protecting the lakes from human abuses**

3.1.3 Indicators of Public Attitudes

The GLWQA includes man and society in the ecosystem as inherent to an ecosystems approach and defines general objectives for the lakes in Article III based on judgements concerning harm, adverse effects and beneficial uses. In the final analysis, the public interprets and judges achievements in these provisions of the Agreement in terms of its values, understanding and perceptions of problems and beneficial uses. As well, public perceptions of the adequacy of the efforts being expended to accomplish progress are important monitors and provide a temporal context for action by the Parties. These attitudes are important indicators, certainly as important as measuring the physical symptoms of the aquatic environment through specific objectives for water quality, and they warrant serious consideration.

A conventional instrument used to measure public attitudes is the opinion poll. Yet it is well known that this instrument can fall prey to problems of interpretation, validity, lack of comprehensiveness, and bias. Within the basin, there is the further problem of reconciling surveys undertaken on one side of the international border with those undertaken on the other, often at different times and using different questions.

The Societal Committee considers that polls and surveys on environmental matters can further the understanding of public perceptions of problems, solutions, priorities and risks. The Committee has begun a review of data compiled on public knowledge and attitudes concerning environmental issues in general and the Great Lakes in particular. Based on its review to date of a variety of polls conducted over the last two decades, the Committee has concluded that there is a need for better techniques and more reliable measures consistent over time, in order for responses to polls to be interpreted with confidence by those creating and conducting environmental programs. The Committee intends to continue its review of survey research and to forward additional conclusions and recommendations to the Board. What follows is a preliminary summary of what polls tell us about public attitudes to environmental issues.

Although public concern about environmental pollution began to surface in the late 1950s, the environment did not appear as a topic in national public opinion surveys in the United States until 1969, and one year later in Canada. Since then, the environment has remained a subject of public opinion polling, with results showing that public concern about the environment remains consistent and strong. Environmental issues tend to be more salient in Canada, i.e. of greater importance relative to other issues, e.g. pollution appeared as the major problem in Canada in national surveys undertaken in 1970 and 1987. American polls, on the other hand, show the environment often ranking below current domestic issues such as law and order, unemployment, national security and the budget.

Over the last 20 years, responses have not varied significantly among different demographic characteristics (race, age, sex); however, the degree of environmental concern is somewhat associated with income and most closely associated with education.

The emergence of an environmental constituency has also been associated by many writers with the larger question of social change. Milbrath (1980) suggested that environmentalists constituted a "vanguard" trying to lead their fellow citizens to a new environmental paradigm against a currently dominant social paradigm which he characterized as "rear guard."

Two issues not addressed well in opinion polls are: costs (who pays, willingness to pay, and jobs) and risk (acceptance, avoidance and management). Responses to questions of costs reflect a combination of lack of knowledge, especially of the full costs of remedial measures and protection efforts, and imprecise questions. Since 1975, numerous polls and surveys in both countries have examined the question of environmental tradeoffs for economic growth through the techniques of forced choice questions, which typically characterize choice in terms of "either/or." Generally the results obtained tend to be inconclusive, owing to the large measure of responses attributed as uncommitted, i.e. "don't know," "no response," or "missing." Apart from difficulties in interpreting the replies, forced choice questions may imply conflict where none exists and infer absolutes that many respondents are unwilling to accept.

Concerns arising from toxic wastes, environmental spills, and large scale accidents have dramatized the problem of risk in modern society. The results of polls examined thus far do not differentiate between imposed and acceptable risks, or cognitive dissonance associated with the personal negation of risk.

A recent survey (Great Lakes Institute 1986) of residents of Michigan and Ontario showed that, while a majority of the public on either side of the border views pollution

problems to be as urgent as other problems, their legislators viewed pollution issues with less urgency. Almost 75% of the public surveyed perceived government and industry to be doing "too little" to address the problems of pollution. In contrast, approximately two–thirds of the legislators surveyed felt that the attention paid to pollution problems by governments and industries was "about right." More than three–quarters of those polled in both Michigan and Ontario viewed themselves as having "little" or "no influence" in relation to government. The Institute noted that perceptions of efficacy are related to people's views of government performance and responsiveness, and to an assessment of people's ability to initiate and direct social change.

As a tool to better understand human behaviour and attitudes, the last two decades of polls and surveys have been revealing both in their insights and inadequacies. Since human intervention is the primary cause of environmental impacts and degradation, ultimately, human solutions will be required to remedy problems and restore beneficial uses.

On the basis of the foregoing, the Societal Committee concludes that:

- Polls and surveys on environmental matters are relevant to further the understanding of public perceptions of problems, solutions, priorities and risks. There is a need for better techniques and more reliable measures consistent over time in order that responses can be interpreted with confidence, and measures of public attitudes take their place alongside other measures of ecosystem health

- Although the quality of the environment is a major domestic issue in both the United States and Canada, linkages to the economy and to other priorities such as public health have not been sufficiently defined or adequately characterized in questionnaires for the public to interpret meaning and make informed choices, e.g. environmental versus ecosystem contexts

- People are not confident that they can influence change, but a majority think that both government and industry should be doing more to protect the environment

3.1.4 Anticipatory, Preventive and Adaptive Strategies

Global Review

Environmental agencies and advisory bodies around the world have of necessity concentrated on existing problems: identifying the sources and pathways of air, water and soil pollution and addressing their impacts on ecosystems. The result is an array of reactive measures in the form of regulations, standards and objectives designed to limit further damage. These measures have been fairly successful in confining some blatant emissions, but have had little impact on the more pervasive causes. In the process, the base of scientific knowledge has expanded and quantitative environmental data now extend over a lengthening span of years and even decades.

Recently, there has emerged a recognition of the need to complement continuing efforts to contain problems by means of new strategies that more deliberately address human activities and decision–making. This strategic approach is being termed "anticipate and prevent." It is not completely distinguishable from the remedial

approach since the latter is put in place to deal with recurring problems and so has preventive aspects, but there are important differences. Preventive strategies are proactive rather than reactive, and are designed to identify potential threats to ecosystems in sufficient time to avoid problems. These strategies also look beyond after-the-fact regulation as the main policy option to a range of socio-economic measures that prevent or minimize the actual occurrence of damage. In other words, they move from an approach that "adds on" environmental protection after the fact, to one that "builds in" integrative policies and decisions at the outset.

Calls for this type of approach have been emanating from many quarters, such as the Organization for Economic Cooperation and Development and the joint statement issued by the leaders of the seven Economic Summit countries, including the President of the United States and the Prime Minister of Canada, following their 1985 meeting in Bonn, West Germany. These endorsements of the need for preventive strategies, however, did not elaborate on their scope nor what factors might enter into their design and implementation. What was stressed was the seriousness of the damage inflicted on the global ecosystem, and the fact that much of this damage is the direct result of economic policies and decisions made within individual nation states: by governments and corporations, by producers and consumers.

The World Commission on Environment and Development (1987) has articulated a goal towards which anticipatory and preventive strategies can be aimed, that of sustainable development. Their report defined sustainable development as "a new development path, one that sustains human progress not just in a few places for a few years, but for the entire planet into the distant future." It implies a changing state of harmony with nature in which exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are made consistent with future as well as present needs. The World Commission noted that environment and development are not separate challenges but are inexorably linked, since development cannot exist on a deteriorating resource base, nor can the environment be protected when economic growth ignores the costs of environmental destruction. The report stated:

> "The ability to anticipate and prevent environmental damage requires that the ecological dimensions of policy be considered at the same time as the economic, trade, energy, agricultural, and other dimensions. They should be considered on the same agendas and in the same national and international institutions."

The pioneering efforts of the Parties in incorporating an ecosystems approach in the 1978 Great Lakes Water Quality Agreement emphasized the need to account for the interaction among environmental components: water, land, atmosphere and biota, including humans. Anticipatory and preventive strategies go on to require the examination of economic and social policies and practices that, if continued, could threaten the integrity of ecosystems.

A Great Lakes Perspective

In many respects, the analysis offered by the World Commission on Environment and Development is mirrored in current critical assessments concerning the slow pace of progress in meeting the goals of the 1978 Great Lakes Water Quality Agreement. The focus of the International Joint Commission and its boards and of the Parties to the Agreement has concentrated thus far on broadening the knowledge base about the Great Lakes and the impacts of human activities upon them, and on standards,

objectives and controls to counteract the more serious effects on water pollution. The Remedial Action Plans now being drawn up for the 42 Areas of Concern under the leadership of the Water Quality Board are a culmination of these efforts.

The Science Advisory Board is actively supporting the Water Quality Board and the jurisdictions in this major initiative, and has offered its expertise in reviewing remedial action plans. At the same time, the Science Advisory Board has begun to explore the range of factors required for a broad, ecosystemic approach to the anticipation of threats and the prevention of harm to the integrity of the Great Lakes Basin Ecosystem.

In exploring these strategies the Science Advisory Board is following the lead of a 1979 workshop devoted to Anticipatory Planning in the Great Lakes basin. It is also responding to the challenge of the joint committee of the National Research Council of the United States and the Royal Society of Canada in their review of the Agreement, and of the Commission itself, which has called for preventive strategies directed at unmet and future problems, in addition to remedial efforts dealing with existing problems.

In exploring this new approach, the Science Advisory Board supports the contention of the World Commission on Environment and Development that attention must broaden from a focus on ecosystem effects inherent in remedial, after-the-fact measures to a focus on the human causes of ecosystem stresses. The Board has noted that it is unrealistic and even presumptuous to imagine that humans can manage systems as large and complex as the Great Lakes. The more realistic course is an approach to management that seeks to influence the behavioural patterns of society away from activities that threaten, perhaps irreversibly, the integrity of the Great Lakes Basin Ecosystem. This is a complex and all-encompassing course of action, towards which the Pollution from Land Use Activities Reference Group in the early 1970s began to point the way.

Why does it seem feasible and indeed necessary today to adopt this focus? One reason has been the failure to take the sustainability of ecosystems into account in economic decision-making. Such failure is now manifesting itself in the depletion of ecological resources and in rising economic costs. In other words, it is being recognized, within the basin and globally, that narrowly-based economic decisions that disregard the ecological resource base are in the long-term inefficient. In Canada, for example, a Senate Committee has estimated that deteriorating soil quality is costing Canadian farmers $1 billion annually in lost income.

These conclusions are part of an emerging awareness of resource-based industries in Canada and the United States, in particular those involving agriculture, forestry, fisheries and mining. The same conclusions are also emerging in the post-Bhopal consciousness of the chemical industry, spurred in part by the sharply rising costs of liability insurance. In Canada, new coalitions of government, industry and environmental groups are forming. The National Task Force on the Environment and the Economy, established by the Canadian Council of Resource and Environment Ministers, is a prominent illustration. The pollution-prevention-pays program of the 3M company (St. Paul, Minnesota) has long called attention to economic savings that can be gained from corporate efforts in pollution abatement and the recovery of waste material.

Environmental protection and economic development, once thought to be antithetical, are thus increasingly seen as complementary objectives. The examination

of economic policies for ecosystemic impacts is emerging today on the agendas of both environmental and economic agencies of national, state and provincial governments. Developing beyond present economic policies and decision rules to ones that act with less severity on the ecological resource base will be a long and difficult task. Reducing the reliance on the use of chemical fertilizers in agriculture, for example, will require changes in government policies, e.g. land use, as well as changes in the traditional mandates of established economic institutions and in the roles and responsibilities of producers and consumers. Nurturing public support for this general direction, however, would bode well for a concerted effort to redesign economic activity in ways that fully recognize the integrity of natural ecosystems and their roles in support of sustainable economies.

However major the task of reorienting economic policies, practices and decision rules may be, it is not enough. In industrial societies, including the United States and Canada, the economy has acquired the status of society's major institution. Its reorientation, therefore, demands a parallel reorientation in societal values and in the dominant world view or paradigm which those values uphold. One might ask: What are the prospects for such change?

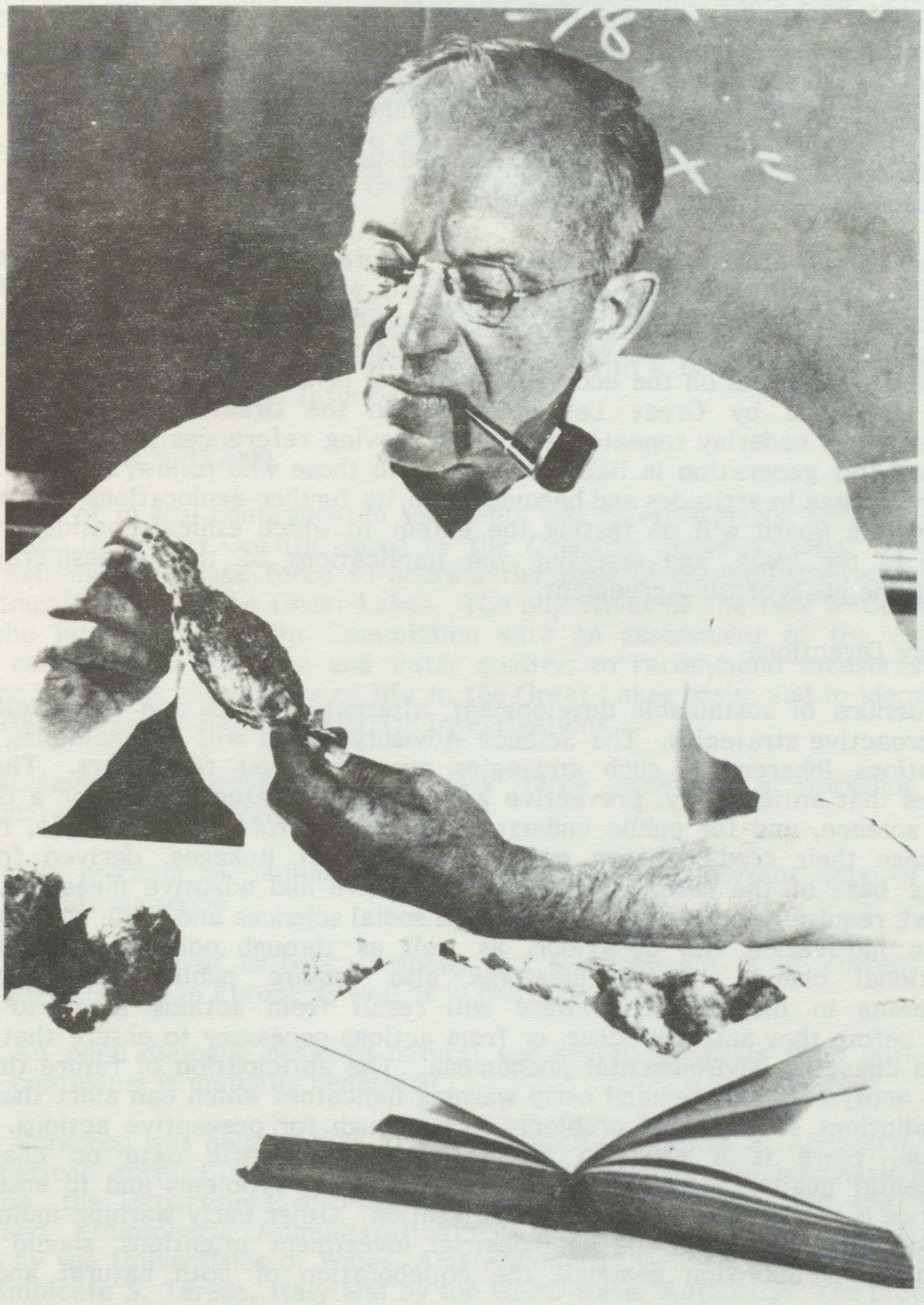
A discussion and analysis of the need to reorient values and world views has already begun. It involves Canadian and American professional futurists, some academics and citizen-based groups. Industrialization has brought remarkable progress in many areas: rising standards of living, better health, and rising levels of education, among others. It is now being argued, however, that many of the dilemmas of modern society, such as the rising ecosystemic (environmental and socio-economic) costs of material growth, can be resolved only through a new world view required by the "post-industrial" era. Just as science continually tests, assesses and changes its hypotheses, theories and paradigms, so too are societies, especially modern societies, driven by dynamic changes arising from new knowledge. Many social analysts are today suggesting that North America has entered into the early stages of a transition as fundamental as was the previous shift from an agricultural society to an industrial society.

Among those who speculate about the shape and content of a post-industrial world view, there is a consensus that one of its chief characteristics will be a focus not on the quantity of output and possessions but on the quality of relationships, especially those with the natural world. It is also clear that it is possible to invent futures that are not straight-line projections of the past, and that the process of choosing futures must begin now. Such is the message of the Global 2000 Report to the President of the United States (Barney 1980) and of Global 2000: Implications for Canada (Barney et al., 1981). It is also the message of many thoughtful citizens in Canada and the United States.

Along with discussions about the need for a new world view, one which would redefine society's relationships with nature, there is a growing discussion of environmental ethics, or more comprehensively, ecosystem ethics. This discussion builds on Aldo Leopold's "land ethic," a term he used to include all components of the ecological community, i.e. the ecosystem. That debate is bringing together philosophers, scientists, environmentalists, native people and other concerned citizens, and is surfacing in books, journals, articles and small-group conference proceedings.

Ethics refers to self-imposed limitations on human freedom of action. It speaks to what is right or wrong, just or unjust, and embodies society's most important values. The current debate on environmental ethics is raising important questions

about the obligations owed by individuals and societies to components of the natural world, and about responsibilities to future generations. This debate is slowly converging with the discussion of world views and "post-industrial" futures.



Photograph of Aldo Leopold (1887–1948) author of a "Sand County Almanac" in which a land ethic is described.

Societal ethics do change over time, albeit slowly, and each change serves to make unacceptable, behaviour formerly condoned or taken for granted. Laws respecting animal welfare and international conventions protecting whales and other endangered species are all examples of such changes in attitudes. Changes in ethical systems are most often driven by new insights and knowledge and by changing circumstances. Public knowledge of the life-threatening consequences of biospheric stress is an important impetus to a changing consciousness today. Pictures taken from outer space of the Earth appear to have galvanized a widely shared perception of the planet as a unified, living entity, owing no allegiance to national borders but rather the responsibility of all. Issues such as the integrity of the ozone layer, toxic chemicals and global climate change from carbon dioxide and other gases responsible for the "greenhouse effect" heighten this perception.

An ecosystem ethic based on respect for nature, if adopted by residents of the Great Lakes basin and by those outside the basin whose actions adversely affect the basin ecosystem, would constitute a highly desirable form of prevention. It would render unthinkable any action whose consequences might have or threaten to have serious adverse impacts on the ecosystem. Ethical principles surfaced in the Citizen Hearings convened by Great Lakes United on the Great Lakes Water Quality Agreement; they underlay repeated and often moving references about the damaged inheritance this generation is likely to pass on to those who follow, if there is not a significant change in attitudes and behaviour. In its further explorations of preventive strategies, the Board will be testing the extent to which ethical considerations are emerging in the basin, and assessing the implications of these considerations in furthering the goals of the Agreement.

Future Directions

Discussions of sustainable development, alternate futures and ecosystem ethics support proactive strategies. The Science Advisory Board will be examining various considerations inherent in such strategies over the next few years. The Board recognizes that anticipatory, preventive and adaptive strategies call for a different role for science, and for public understanding of that role. For example, remedial efforts base their credibility on proven cause-effect linkages, derived from the knowledge base of the natural sciences. Preventive and adaptive measures, on the other hand, require insights gained through the social sciences and their understandings of human motivation and behaviour, as well as through political, economic and organizational change. These measures also require public acceptance that improvements in the general welfare will result from actions taken to deflect problems before they actually occur, or from actions necessary to ensure that society adapts to changing environmental phenomena. The anticipation of future threats to the basin ecosystem will demand early warning indicators which can alert the Parties and jurisdictions to potential problems soon enough for preventive actions. In this connection, there is a need to assess existing scientific data on changes in environmental quality for their capacity to anticipate problems and to ensure that surveillance is conducted with a view to prevention. Other early warning indicators in the socio-economic area, such as industrial investment intentions, should also be examined. This approach demands the collaboration of both natural and social sciences.

The Board is aware of the difficulties ahead, including resistance due to long established thought processes, deeply ingrained decision rules, and narrowly framed institutional mandates. With these difficulties in mind, the Board will also encourage experimental probes of the kind outlined in the course of a keynote presentation at the

Wales Workshop on contaminated sediments in 1984 (Stewart 1987). In essence, what was proposed was to set aside presuppositions about the content and ranking of societal goals in order to focus fresh thinking and initiatives on one basic starting point, the biospheric context of all human activities. Such endeavors, designed to correct the intellectual errors which we make when we ignore or misinterpret the context in which we live, might well attract and inspire wisdom for a new and exciting voyage of discovery.

Anticipatory, preventive and adaptive strategies will supply the impetus for the adoption of an ecosystems approach, one that recognizes the Great Lakes Basin Ecosystem as a subsystem of the biosphere. In this manner we can hope to achieve the goals of the 1978 Great Lakes Water Quality Agreement.

3.2 ECOLOGICAL COMMITTEE

The report of the Ecological Committee includes the summaries and recommendations from four workshops: Sediments, Atmospheric, Aquatic Communities and Food Webs. The report concludes with a brief statement that sets the theme for the Committees' future endeavors.

3.2.1 Sediment Workshop

The issue of in situ contaminated sediments was referred to the Science Advisory Board through the Water Quality Board by the Dredging Subcommittee. In response the SAB established a task force to address the issue of contaminated sediments in areas of impaired use in the Great Lakes. The objectives of the task force were: to provide the International Joint Commission with an assessment of the effects of sediment contaminants on biota and water quality; to recommend measures to the Parties for improving the quality of life in the Great Lakes basin; and to identify gaps in knowledge and recommend appropriate investigations.

To achieve these objectives, the task force convened a workshop at an international level for the following reasons:

- The problem of sediment contamination is an important issue of worldwide scope
- The problem of harbour clean-up and improvement is of current significance in Europe as well as in North America
- An open dialogue between natural and social scientists from both continents is mutually beneficial

The workshop was held in 1984 at the University of Wales in Aberystwyth with North American support from the Science Advisory Board, the International Joint Commission, the Department of Fisheries and Oceans (Canada), and the National Oceanic and Atmospheric Administration (U.S.A.). In Europe, the workshop was supported by the Universities of Wales, Amsterdam and Geneva, by Centro Ricerche Energia Ambiente S. Teresa, Italy and by the Welsh Water Authority. The proceedings of the workshop appeared as Volume 39, "Developments in Hydrobiology" (1987) of Hydrobiologia.

Dramatizing the fact that contaminated sediments and other forms of ecosystem stress cannot be considered in a vacuum, the workshop began with a panel entitled

"The Social Context." The keynote presentation drew attention to the need to correct the conceptual error, frequently made in economic decisions, which results in placing the environment in the context of the economy; contaminated sediments are a manifestation of this faulty thought process. Other presentations touched on new efforts in the field of social impact assessment, societal paradigms, environmental ethics, communication between the general public and the scientific community, and links between ecosystem stress and human health.

Six geographic areas were chosen for detailed examination. These areas were divided into two major categories: localized pollution due to obvious point sources, e.g. English–Wabigoon River (mercury), Windscale (plutonium) and the Cwm Ystwyth Mine in Wales (lead, zinc and other metals); and general pollution with complex organic and inorganic pollutants from unidentifiable sources, e.g. the Port of Hamburg, Milwaukee Harbor and the Bay of Naples.

It was agreed that contaminated sediments influence various levels of organization, e.g. bacterial, planktonic and benthic communities, species of algae, invertebrates, fish and, in one case, human health. Although impacts at the social and economic levels are less scientifically demonstrable, they are nevertheless real.

While new methods have been developed to examine chemical speciation of metals in sediments, the relationship between chemical speciation and the bioavailability of sediment–associated metals needs to be further examined. The association of organic contaminants with different sediment phases and pore water needs further elaboration. Limited information exists on the uptake by and toxicity of organic contaminants to different aquatic biota. Further research and new methods are needed to determine the processes and mechanisms of pollutant transfer.

Bioassays are required to assess the long–term chronic effects of sediment–associated contaminants on different trophic levels of aquatic biota and humans. Few methods are available for measuring nonfood chain biouptake rates and food chain dynamics. Further research and better quantification are needed to understand the responses of aquatic communities to stresses induced by sediment contaminants. A number of bioassay techniques were suggested as tools for characterizing contaminated sediments. The topics most in need of additional research were: techniques to assess relationships between sedimentary chemicals, bioassays, the food chain and human exposure to contaminants.

Field–oriented research, in conjunction with laboratory studies, is needed to refine models of contaminant pathways. Methods for measuring the concentrations of contaminants in pore water need to be standardized so that a direct comparison can be made between the stability, accumulation and diffusion of different contaminants. These comparisons are necessary to predict the potential for release when sediments are disturbed by waves, currents, bioturbation and dredging. Partition coefficients of toxic chemicals between solid, aqueous and gaseous phases need to be measured under different conditions in order to understand interactive processes at the sediment/water interface.

The workshop also examined societal implications of polluted sediments. A broad discussion addressed the following major points: the inadequacies of existing institutional arrangements to deal coherently with the complexity of issues; a need to complement narrow, reductionist approaches with integrative studies based on broader perspectives; a need to examine specific issues and problem areas in local, regional and international socio–economic contexts; a need to establish individual and

community goals through dialogues between resource owners, specialists and the public; improved mechanisms for making institutions more accountable to the public and supportive of the community; and improved understanding of interrelationships and interdependencies among socio–economic systems and the environmental resource systems which sustain them.

The workshop concluded with a technical review of remedial options for contaminated sediments. Physical and chemical constraints based on existing knowledge were discussed and a proposed protocol for remediation was presented. A summary of geographical considerations and remedial options is shown in Table 3, and a possible protocol for determining the appropriate remedial option is summarized in Figure 2. This protocol is only preliminary and requires field testing before widespread application is recommended.

The six case histories showed clearly that it is difficult and expensive to correct past errors. Contaminants are always easiest and cheapest to control before they are introduced into the environment. Once in the environment, they are dispersed and transformed, magnifying problems of remediation. Thus the preferred remedial option is control at the source to prevent the release of contaminants into the environment.

The commonest cleanup measure for localized problems in small, well–defined geographic areas is to transfer contaminated sediments to areas that can be managed more effectively. Materials which have already entered the open waters of the Great Lakes or the oceans cannot be retrieved; they represent a cost transferred to future generations. If the input of contaminants into these bodies of water is curtailed, natural burial or degradation processes will eventually reduce the problems.

While much is known about physical and chemical processes involved in the transfer of pollutants in aquatic ecosystems, the transfer rates are largely conjectural. It is thus essential to undertake integrated studies to determine both the nature of the problem and the rate of change in evaluating a variety of remedial options. Such information would be invaluable in the design and implementation of remedial plans and operations.

Remediation or rehabilitation is dependent on the will of those exposed to or affected by pollution and on their ability to mobilize political resources. Corrective processes require concerted interaction among social and natural scientists working with people and their political representatives.

Recommendations

On this basis of the foregoing considerations, participants in the Sediment Workshop concluded that:

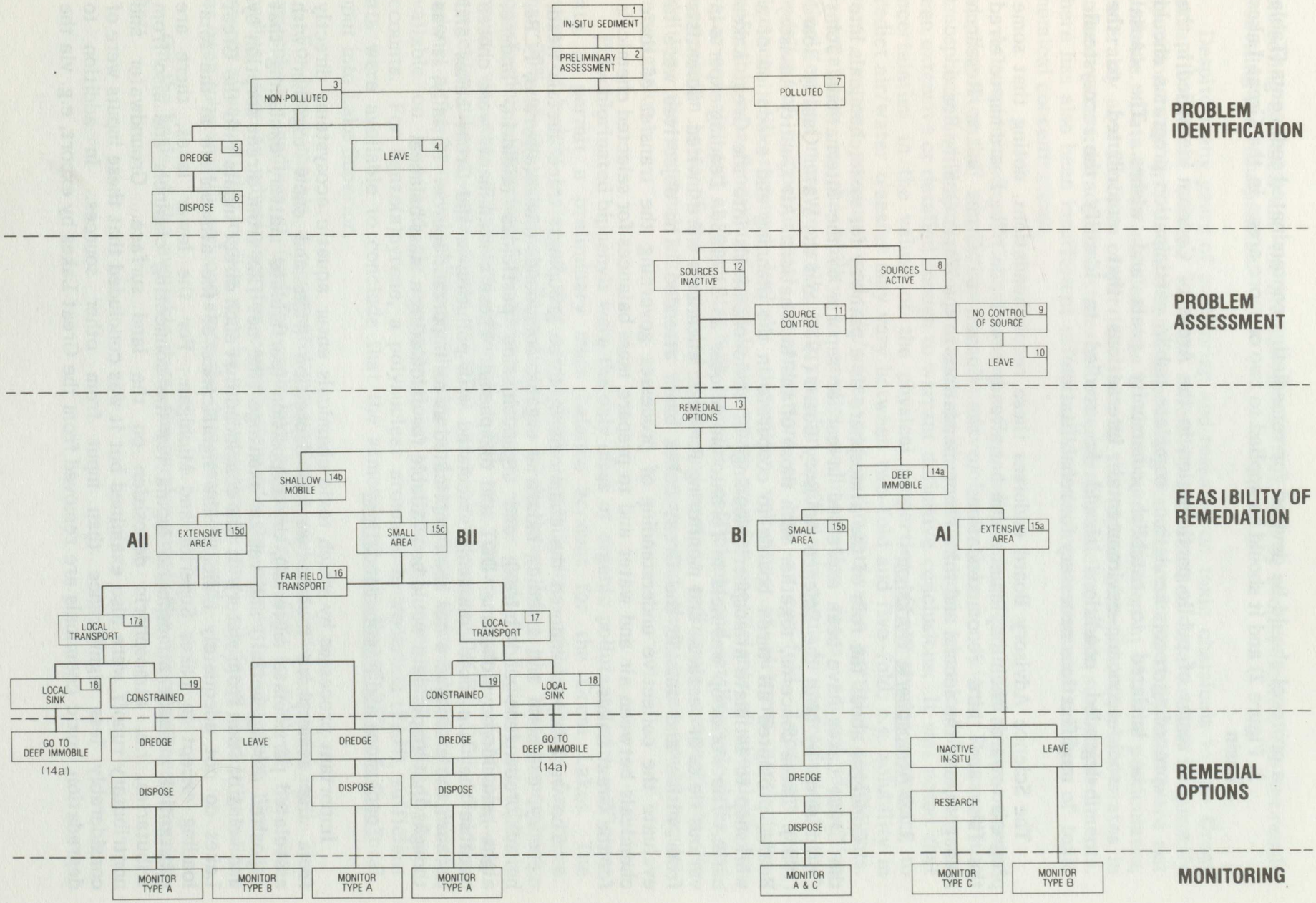
- **In terms of research needs, more detailed investigations are needed on: better identification of pathways and quantification of fluxes of contaminants, microbiological/chemical interactions of contaminants in sediments, the rates and reversibility of the sorption of contaminants on particulate materials, methylation processes and rates for metals, and the biodegradation processes in contaminant breakdown in sediments**

- **In terms of remedial options, once the known sources of contamination in the Areas of Concern have been eliminated,**

TABLE 3.
SUMMARY OF CHARACTERISTICS, REMEDIAL OPTIONS AND MONITORING FOR AREAS AFFECTED BY POLLUTED SEDIMENTS.

		I. DEEP	II. SHALLOW
A	CHARACTERISTICS	Sediment focused in depositional zones or basins with no subsequent movement.	Sediment subjected to onward movement by resuspension. Localized depositional areas will occur which must be located and defined.
LARGE	REMEDY	1. Leave. 2. Inactivate by ploughing.	Intermittent local depositional zones must be dredged to prevent large scale dispersal. If more permanent, should be ploughed. If area too large, then may be left but downstream effects must be recognized.
	MONITOR	Continued Assessment (Surveillance) Research–oriented monitoring, to measure instantaneous and subsequent recovery following ploughing.	Continued assessment if left or dredged. Monitor of dredge spoil disposal site. Research oriented monitoring if ploughing undertaken.
B	CHARACTERISTICS	Sediment focused in small depositional basins with no subsequent movement.	Comments as for large, shallow areas – given above.
SMALL	REMEDY	Artificial acceleration of sedimentation is the preferred option. Dredging or ploughing may also be considered.	Dredging of all areas of deposition to prevent downstream transmission.
	MONITOR	Research–oriented monitoring.	Continued assessment following dredging. Monitor disposal site.

Figure 2. Identification, assessment and selection of remedial options for polluted sediments.



a protocol should be devised for remediating contaminated sediments (Table 3, Figure 2) and it should be applied to two or more areas in the Great Lakes basin

- **In terms of public participation in the Areas of Concern identified in the preceding recommendation, complete public participation programs should be initiated to establish community goals and wishes. The causal socio–economic–environmental interactions that contributed to the degraded conditions should be studied to identify the ecosystemic modifications necessary for rehabilitation**

The Science Advisory Board endorses these recommendations, noting that some progress towards their implementation has already been made. The Board has referred the first and third recommendations to the Council of Great Lakes Research Managers, and the second and third recommendations to the Water Quality Board.

3.2.2 Atmospheric Workshop

Concerns about the role of the atmosphere as a pathway for toxic chemicals into the Great Lakes have been expressed in earlier reports to the International Joint Commission by both the Science Advisory Board (1979) and the Water Quality Board (1985). These concerns, together with those of the International Air Quality Advisory Board, prompted all three boards to cooperate in the planning and execution of a workshop to estimate atmospheric loadings of toxic chemicals into the Great Lakes basin. The workshop was held in Toronto on October 29–31, 1986. Leading experts in various fields of research and monitoring for toxic chemicals were invited. Scientists from within and outside the Great Lakes basin attended. The objectives were to evaluate the collective understanding of processes governing the transfer of toxic chemicals between air and water and to prepare mass balances for selected chemicals for the Great Lakes.

The workshop considered the chemicals in three groupings: trace metals (lead, mercury, cadmium and arsenic); industrial organic compounds (benzo(a)pyrene, PCBs, hexachlorobenzene and mirex); and organochlorine pesticides (dieldrin, lindane, alpha–hexachlorocyclohexane, DDT and toxaphene). These contaminants were chosen because they are most commonly associated with pollution in the Great Lakes and because the atmosphere has been implicated as an important source. Initially, it was thought that ample data would be available for calculating a mass balance.

Conclusions and Recommendations

Important processes by which toxic chemicals enter aquatic ecosystems directly from the atmosphere include wetfall deposition (rain and snow together with associated particulate material), dry deposition (particulate matter, excluding that deposited during wetfall) and vapour exchange (the net flux from direct sorption by and volatilization from water). It was concluded that such direct inputs into the Great Lakes do not adequately indicate the significance of the atmosphere in the total loading except in Lakes Superior and Michigan. For the lower lakes, there are substantial indirect atmospheric inputs via the connecting channels and also from tributaries, i.e. atmospheric deposition on the land surface. Groundwater and nontributary runoff were also examined but it was concluded that these inputs were of considerably less significance than input from other sources. In addition to degradation, toxic chemicals are removed from the Great Lakes by export, e.g. via the

connecting channels and the St. Lawrence River, and by sedimentation, the net result of settling and resuspension.

Despite many years of monitoring and research on toxic chemicals in the Great Lakes, it became evident that the extensive and detailed data needed to quantify deposition rates and to do a mass accounting for most of the compounds were not available. Data needs included: the levels of contamination in airborne particulates, preferably as a function of particle size; in the vapour phase; in dissolved states in surface waters; in adsorbed states on waterborne particles; and in surficial sediments. There has also been insufficient effort made to determine seasonal changes of toxic chemical concentrations.

Atmospheric deposition data are often collected at local and shore–oriented sampling sites that may not be representative of over–lake conditions. Research into atmospheric and limnological processes as they affect toxic chemical fates has not been extensive or detailed enough to warrant definitive conclusions. It was noted that uncertainties in the values of the physical properties of compounds necessary to predict air/water transfer may vary between two–fold and five–fold, e.g. solubility in water, vapour pressure, and air/water and sediment/water partition coefficients. Uncertainties in the ability to predict sedimentation rates, aerosol deposition velocities, and more generally, bulk transfer coefficients result in uncertainties in the modeling of compartmental concentrations as high as ten–fold. Important data elements still required include: deposition velocities of airborne particulates, preferably as a function of particle size; mass transfer coefficients of chemicals for water and air, and at least the bulk transfer coefficient; and settling velocities and resuspension rates of the suspended solids and surface sediments, respectively. In addition, the seasonal effects on these processes and their rates would require investigation.

Polychlorinated biphenyls were the only class of organic pollutants with sufficient data to permit a preliminary mass balance account for the Great Lakes. The estimated budget indicated that atmospheric contributions could account for more than 90% of the input into Lake Superior. In the lower lakes, the total atmospheric contribution approached 50% when adjustments were made for indirect atmospheric inputs via the connecting channels. For the other organic chemicals, e.g. tetrachlorodibenzo–para–dioxin (TCDDs), hexachlorobenzene (HCB), DDT, dieldrin, lindane, alpha–hexacyclochlorocyclohexane and toxaphene, there were not enough data available on lake and air concentrations to arrive at meaningful mass balance accounts. For benzo(a)pyrene, a polynuclear aromatic hydrocarbon (PAH), sufficient data were available to conclude that the atmosphere contributed 96% of the total input into Lake Superior.

For heavy metals, a meaningful mass balance could be derived only for lead. The atmospheric loadings of lead for each lake ranged from 50% to 99% of the total loading after an adjustment for contributions via the connecting channels. For the present situation, this loading may be an overestimate since alkylated lead in gasoline has been substantially reduced since the data were collected.

On the basis of the available data, the participants in the workshop recommended that:

- There is a need to determine and quantify modeling coefficients required to calculate mass balances for specific toxic chemicals for each of the Great Lakes and thus estimate the relative contribution of the atmosphere as a source and sink for these chemicals

- An integrated research and monitoring network needs to be established to measure the atmospheric deposition of toxic chemicals. The research component should be established first at master stations

- Models of aquatic fate and recycling of toxic chemicals need to be better validated and should be linked to atmospheric transport and fate models for the same chemicals

- An ecosystems approach is required for the control of toxic chemical emissions, many of which originate outside the Great Lakes basin. Particular attention must be paid to institutional obstacles to the control of sources contributing to the deposition of toxic chemicals in the Great Lakes basin. For example, existing laws and regulations fail to address satisfactorily the long–range transport and the distant impacts of airborne contaminants

The Science Advisory Board endorses these recommendations and has referred the first three recommendations to the Council of Great Lakes Research Managers, and the fourth recommendation to the Commission for referral to the Parties.

3.2.3 Health of Aquatic Communities

The 1982 Research Review conducted by the Science Advisory Board raised concerns about the paucity of information concerning the effects of persistent toxic substances on the health of aquatic communities in the Great Lakes. Accordingly, the Health of Aquatic Communities Task Force was established in 1983 to investigate the adequacy of research on the health of aquatic biota in the Great Lakes.

The Task Force first conducted a survey by means of a questionnaire sent to researchers working on Great Lakes aquatic biota. Evaluation of the questionnaire confirmed that research efforts were insufficient to address the effects of persistent toxic substances on the health of Great Lakes aquatic communities.

After completing this activity, the Task Force initiated two additional activities. The first was a literature review of the effects of persistent toxic substances on the health of Great Lakes aquatic communities. This review (Fitchko 1986) provided a background paper for the second activity, a symposium/workshop on promising methodologies to determine the effects of toxic substances on Great Lakes biota.

The Symposium/Workshop

The symposium/workshop was held June 18–21, 1985, as part of the joint annual meeting of the American Society of Limnology and Oceanography and the Ecological Society of America in Minneapolis, Minnesota. The symposium was co–sponsored by the Science Advisory Board and the American Society of Limnology and Oceanography. Invited papers, covering biotic groups from bacteria to humans, were presented during the three–day symposium and collectively appear in a special publication (Evans 1987).

Following the formal symposium, attendees participated in a one–day workshop organized by biotic group, i.e. phytoplankton, zooplankton, benthos, fish, birds and mammals, and humans. Modeling and statistics formed a seventh sub–group. Participants were asked to address three questions:

- What changes have occurred in the six biotic components of the Great Lakes aquatic community?
- What roles have toxic substances played in such changes?
- How can researchers better investigate the effects of toxic substances on these six components of the aquatic community?

Conclusions

For convenience, the conclusions are listed by biotic group; however, the need exists for a broadly based, integrative approach to investigate the effects of toxic contaminants on the health of the Great Lakes biota at all levels of the food chain.

Phytoplankton:

The health of the phytoplankton community is of vital importance since phytoplankton are the primary producers and form the basis of the food chain. Destabilization of this community thus portends the disruption of the entire ecosystem. In many cases, the effects of toxic substances on phytoplankton are chronic and sublethal and thus the stress responses are difficult to detect and quantify. It is especially difficult to discern how chemical pollution has changed the Great Lakes phytoplankton community because historical records of phytoplankton are insufficent. These problems are further complicated by the difficulty of separating the effects of toxic chemicals from the effects of other environmental stresses which have operated simultaneously.

No single approach is sufficient to predict the impact of toxic chemicals on Great Lakes phytoplankton at various levels, ranging from physiological to ecosystemic. A combination of various methods is needed. For a thorough investigation of selected chemicals, ecosystem level studies should be complemented by mesocosm studies in plastic enclosures. Laboratory studies using batch or continuous cultures should be used to examine physiological processes of selected species. The development of standardized protocols for species–specific bioassays, mixed–population bioassays and in situ methodologies are needed.

Zooplankton:

The effects of toxic substances on zooplankton communities in the Great Lakes remain largely unknown. Eutrophication, size–selective fish predation and other phenomena are major confounding factors masking the effects of toxic contaminants. The continued monitoring of zooplankton populations is recommended, with functional bioassays to elucidate the role of toxic pollutants in causing changes in Great Lakes zooplankton.

The effects on zooplankton will be most evident nearest the greatest concentrations of contaminants. Consequently, it is recommended that the 42 Areas of Concern in the Great Lakes receive more attention in biological community structure analysis.

Zooplankton has played an important role in the development of toxicological testing. Single-species bioassays, most often employing the cladoceran, Daphnia magna, have been used for decades in dose-response tests on the effects of various chemicals. Interpretations from such laboratory studies, however, are difficult to relate to mixed effluents and complex, biological communities in the natural environment. It is apparent that the effects of toxic contaminants cannot be resolved by examining zooplankton alone. Tests for toxic effects should begin with mesocosm experiments, using natural assemblages of organisms. Organisms determined as sensitive should be further tested in functional, field-oriented laboratory experiments to arrive at specific cause/effect mechanisms. Consequently, mesocosm facilities are required in the Great Lakes to investigate the effects of toxic contaminants on food web processes and to test hypotheses.

Benthos:

Differentiation between the effects of nutrient enrichment (eutrophication) and toxic substances on benthic communities is difficult. Interpretation of observed changes is further confounded because little is known about the environmental requirements, even for a few species in major taxonomic groups.

There are some data on deformities in chironomid head capsules which seem more related to toxic substances than to eutrophication. Further research is needed, particularly on laboratory validation of causes and effects.

A number of laboratory bioassays which use benthic organisms show promise in determining the toxicological effects of various chemicals. Concerns remain about the correlation between laboratory bioassays and field data. Examining the impact of toxicants at the molecular or genetic level also shows promise. Molecular alterations, however, have yet to be directly linked to actual alterations in population structure and function. Consequently, an integrated approach combining chronic and acute toxicity bioassays with studies of changes in indigenous benthic communities has the greatest promise for evaluating the effects of toxic substances on Great Lakes benthic populations.

Fish:

Changes in Great Lakes fish populations and in the fisheries which they support are perhaps most commonly noticed and discussed. This phenomenon is particularly true in the case of persistent toxic substances where elevated concentrations in fish tissue result from biomagnification of the chemicals through the food chain. These elevations are manifested in consumption advisories for certain species and areas of the Great Lakes. Discerning and measuring the effects of toxic substances on fish is problematic in the presence of so many other factors, e.g. fishery exploitation, sea lamprey predation and fish stocking. Aspects of policy, institutional arrangements and communication must be considered along with the scientific and methodological aspects of cause-effect relationships.

Birds and Mammals:

Fish-eating birds and mammals in the Great Lakes are especially vulnerable to the adverse effects of toxic chemicals. Again, however, confounding factors such as fluctuating water levels, habitat changes, human disturbance and predation can

mask the effects of toxic substances. Although field assessment data are more limited for birds and mammals than for fish, there appears to be strong evidence that persistent toxic substances have played a role in impairing the reproductive success of local populations of fish–eating birds and mammals, specifically herring gulls, mink and river otters.

In spite of strong evidence linking toxic substances with the impaired health of birds and mammals, these organisms have received comparatively little attention and are not specifically defined or covered by international environmental agreements or treaties. Fish–eating birds and mammals warrant more attention and resources in terms of the impact of toxic contaminants in the Great Lakes than previously granted.

Humans:

The human population represents a final link in the Great Lakes aquatic ecosystem food chain. In the absence of clear–cut scientific evidence concerning the significance of such exposure to human health, perceived risks drive regulatory programs towards conservative assessments and advisories to provide some margin of safety for the public. These evaluations and the state of scientific knowledge in general could greatly benefit from accelerated research on the effects of contaminants in the Great Lakes ecosystem on humans.

Modeling and Statistical Approaches:

Predicting and understanding the fate and effects of toxic contaminants in the Great Lakes require that more attention be directed to modeling and statistical approaches. The problem of toxic chemicals is much more complex than that posed by nutrients.

- The number of toxic compounds that requires consideration in modeling and in field and laboratory studies is overwhelming in comparison with the number of nutrients usually considered

- Effluents and receiving waters rarely contain just a single toxic contaminant. More likely to be encountered are contaminant mixtures that vary in composition over time and space. It is improbable that predictive toxicological cause and effect relationships will ever be developed for all possible mixtures

- Analytical and experimental techniques used in understanding toxic contaminants require considerably more time and money than nutrient studies

Combined, these problems present a formidable challenge to those who wish to predict, understand and regulate the behaviour of toxic contaminants in the Great Lakes.

Recommendations

In view of the foregoing considerations, the Task Force recommends that:

- **Integrated and coordinated monitoring programs (biotic and abiotic) at several ecosystem levels are needed to interpret changes within**

individual trophic levels; these levels should include fish health indicators and the monitoring of selected species of birds and mammals

- A centralized storage system should be established for monitoring data to allow for the interpretation of commonalities and the signficances of changes at various ecosystem levels

- Specimen banks should be established for archiving eggs, tissue, and in some cases, whole carcasses of birds, mammals, fish and other selected aquatic organisms both now and in the indefinite future

- Continued research is needed on the clinical and biochemical measurements of stress and on the mechanisms of toxic action in the biota

- Continued chemical–residue monitoring programs are needed for fish populations, but in a more streamlined and coordinated fashion than has been the case in the past

- Additional indicator organisms should be selected for more effectively measuring changes in nearshore planktonic and benthic communities

- Toxic contaminants research on humans should include measurements of body burden, multi–generational effects, metabolic impact, immunological impact, the effect of diseases, and the application of new technologies, e.g. DNA adducts

- The development of mass balance, fate and exposure, fate and effect, and complex effluent models should continue but the limitations of each approach should be clearly communicated to the intended users. It is also recommended that existing and future models be collated and compared to identify relative strengths, weaknesses and applicability of computer codes for use in Great Lakes applications. Based on these comparisons, a central repository of proven, well–documented computer codes, in particular, subroutines that describe a particular process, e.g. volatilization, should be established. Electronic access to this repository would facilitate the rapid development of state–of–the–art Great Lakes contaminant models

- Risk analysis should be used for determining the relative risks associated with pollution from contaminants and other perturbations to Great Lakes biota and regional human populations

- Mesocosm research facilities are required in the Great Lakes to conduct controlled, field–oriented experiments on the effects of toxic substances and other stresses on aquatic biota

- Because fish–eating birds and mammals are strongly affected by contaminants, these biota should be utilized as integrative indicators of ecosystem health

The Science Advisory Board endorses these recommendations. The Board has referred the first, sixth and eleventh recommendations to the Ecosystem Objectives Committee, the fourth recommendation, expanded to include studies of the etiology of fish tumours, and the tenth to the Council of Great Lakes Research Managers, and the second and third recommendations to the Water Quality Board. The Board also requests that the Commission refer the third recommendation to the Parties. The seventh, eighth and ninth recommendations overlap with other findings and recommendations presented elsewhere in the present report and will be considered further by the relevant committees of the Board; the seventh and ninth recommendations by the Human Health Effects Committee, and the eighth recommendation by the Council of Great Lakes Research Managers.

3.2.4 Food Web Workshops

In December 1985, the Ecological Committee of the Science Advisory Board hosted a Food Web I Workshop that focused on the relationship between recent changes in water quality and biological communities in Lake Michigan. It was the consensus of this workshop that abatement of nutrients (bottom–up control) reduced winter phosphorus levels in Lake Michigan, a condition which lowered the amount of spring phytoplankton and chlorophyll. In addition, predation (top–down control) initiated a cascading effect by reducing alewife abundance. This reduction resulted in an increase of a large cladoceran, Daphnia pulicaria, which increased the grazing on phytoplankton. The result of this chain of events was an increase in summer water clarity.

The Ecological Committee hosted a Food Web II Workshop in February 1987, which focused on food web dynamics in Lake Ontario. Lake Ontario was chosen because its nutrient and fish stocking trends were similar to those in Lake Michigan and it was anticipated that Lake Ontario would probably be the next Great Lake to manifest simultaneous effects of top–down/bottom–up controls.

The consensus of Food Web II was that the abatement of nutrients (bottom–up control) has significantly reduced phosphorus concentration in Lake Ontario. Some changes in phytoplankton, e.g. a decrease in blue–green algal abundance and a shift in size structure to smaller algae, have been observed. Suggestive evidence of predation effects was observed in Lake Ontario in parallel with major increases in salmonid stocking. Continued observation is warranted.

Based on the collective results of both Food Web Workshops, it was concluded that the International Joint Commission and the Great Lakes Fishery Commission could benefit from a better understanding of the effects of food web dynamics on water quality. Currently, alewifes are the "keystone" to sustaining the salmonid sport fishery in Lakes Ontario and Michigan. Alewifes also affect the size spectrum of zooplankton, which in turn can affect water quality, e.g. transparency.

Food Web II Workshop participants pointed out that a "bridge" is needed between the International Joint Commission and the Great Lakes Fishery Commission to adopt fully an "ecosystems approach" and to take advantage of the additive effects of phosphorus management and fishery management strategies. It was also pointed out on the basis of the Lake Michigan experience that the management of salmonid densities can facilitate the restoration and rehabilitation of native biological communities, e.g. fishes. Restoration and rehabilitation are common goals of the two Commissions.

The participants in the Food Web Workshops recommended that:

- **Water quality and fisheries agencies should coordinate monitoring activities, standardize techniques, and establish and maintain long-term data sets to evaluate the effects of water quality and fisheries management activities separately as well as in terms of their potential additive effects**

- **Research is needed on factors affecting alewife abundance and how that abundance affects other trophic levels and water clarity**

- **Research is needed on the effects of changes in food web dynamics on the levels of toxic substances in Great Lakes sport and commercial fishes**

The Board endorses these recommendations and has referred the first recommendation to the Water Quality Board and the second and third recommendations to the Council of Great Lakes Research Managers. The Board requests that the Commission refer all three recommendations to the Great Lakes Fishery Commission and invite its collaboration.

3.2.5 Future Directions

Much of the current research in ecology reflects a strong reliance on population-community perspectives, but it is now apparent that an increasing emphasis on process-functional approaches will be required in the future (see Figure 3). Ecology deals with a multiplicity of living systems and their interrelationships and must employ more than a single spatio-temporal scale in its various studies. In terms of a perspective, O'Neill et al. (1986) have noted that "ecologists must be careful not to extrapolate from any single type of observation to the nature of the underlying system." Hence, neither the process-functional approach nor the population-community approach is alone sufficient, as both approaches adopt limited viewpoints. To find an integrative concept, the Ecological Committee will be focusing more of its attention on the different ways in which ecosystems can be viewed and how a perspective changes the conception needed to explain the observations.

Figure 3. Two approaches currently apparent in the work of different ecologists. (From O'Neill et al. 1986).

	Dual Hierarchy of Approaches	
Levels of Organization	Population Community	Process Functional
Biosphere		Biosphere
Biome		
Ecosystem		Ecosystem
Community	Community	
Functional Component		Functional Component
Population	Population	
Organism	Organism	

3.3 TECHNOLOGICAL COMMITTEE

3.3.1 Human–Machine Workshops

Introduction

The infrastructure of the Great Lakes basin has a diversity of old and new technology in manufacturing, the generation of power, and transportation. While much has been done to control point source discharges, relatively little attention has been given to preventing inadvertent or accidental spills of pollutants. Spills of varying severity regularly occur and it is perceived that a serious spill could permanently damage the uses of one or more of the Great Lakes.

Frequently, investigations of spills reveal a breakdown in the complex communication and control links which exist between technological systems and the people charged with their operation and control. The Science Advisory Board has an interest in improving the link at the human–machine interface. To enhance its understanding of this interface and to determine how such an understanding might reduce the incidence of spills, the Board requested its Technological Committee to hold two workshops, one in April 1986, the second in March 1987.

These workshops were to assess and recommend appropriate actions to identify and overcome difficulties and deficiencies at the human–machine interface which could result in serious or catastrophic effects in the Great Lakes Basin Ecosystem.

The Workshops

The first Human–Machine Workshop attracted participants from a wide variety of occupations: the design and operation of nuclear power plants, associated nuclear control agencies, government agencies concerned with labour and the environment, air traffic safety, the petrochemical industry and the academic community. Nearly all were knowledgeable about or expert in the "human factors" field.

The first workshop forwarded a number of preliminary findings to the Board, including identification of the following needs:

- Inclusion of human design factors in the earliest stages of facility planning
- Better education and training of those charged with operating the facilities
- More comprehensive reporting and data collection from "incidents" involving failure at the human–machine interface
- The need for regulatory agencies to encourage more effective self–regulation, with appropriate safeguards and penalties

Towards the end of the workshop, the participants began to arrange these issues according to priorities; however, time was not available to complete the task. A second workshop was, therefore, recommended.

The second workshop built on the preliminary findings of the first and augmented a core of participants from the first workshop with further expertise from the nuclear

utilities sector, sewage treatment plant operations, labour and the academic community.

In preparation for the second workshop, four working papers were prepared. The first of these, entitled "SCOPE," attempted to estimate the impacts of spills in the Great Lakes basin from various sources. The second, "PROGRAM," reviewed the current and possible jurisdictional responses to those impacts. The third and fourth, "TECHNOLOGY" and "PEOPLE," tried to determine how elements of these two areas influence the occurrence of spills.

Participants in the second workshop were divided into working groups under the above four categories; each group encouraged participants to identify three principal concerns. These concerns were then combined and assigned priorities by the group, who shaped them into the findings and recommendations presented below. In responding to these recommendations, the Technological Committee adopted different categories than those originally used for the workshops.

A full report to the Board is in preparation. The conclusions and recommendations listed below are, therefore, preliminary and are presented in summary form only.

Findings

- **Spills can have a much greater impact than point source discharges**

There is a common misconception that the impact of spills, while a nuisance, does not compare over the long-term with ongoing point source discharges. The Canadian National Analysis of Trends in Emergencies System (NATES) data base reveals a unique example involving styrene spills into the St. Clair River: two spills were found to be equivalent to the pollution loadings of 1,428 and 58 years of the respective point source discharges. The comparison indicates that spills may significantly exceed the impact of regulated point source discharges.

- **Data bases on spills are inadequate**

Existing data bases on spills from basin jurisdictions are incomplete and inconsistent with respect to the data reported. Furthermore, they demonstrate a lack of liaison among jurisdictions. There is no precisely defined spill inventory for the Great Lakes basin. Furthermore, information related to human factors, if present at all, is usually not sufficiently definitive for an analysis to identify preventive actions.

Several of the U.S. data bases, particularly those maintained by the National Response Center and the Hazardous Material Information System, are inflexible and not amenable to the access and integration of data nor for the transfer of information to the public. The Canadian federal system is of a sounder design; however, a need to enter current spill data from the Province of Ontario into the federal data base was identified.

- **Programs designed to prevent spills are inadequate or nonexistent**

Any effort designed to prevent the growing volume of spills, especially of toxic substances, will require: inventories of hazardous and toxic substances and their movements; research to analyze a range of questions from total systems approaches to human factors; education and training for a wide range of responsibilities in the field as well as technological fixes; and legislation requiring prevention, reporting, program

coordination and right–to–know. There is a modicum of such program elements among the jurisdictions in the Great Lakes basin but what exists is inadequate for the task and lacks effective coordination.

The significance of spills is difficult to determine because the term has not been clearly defined. The flushing of a chemical from a truck into the nearest stream, a leaking pipe within a refinery complex whose contents alter the discharge from the facility, losses noted during the loading of ships and barges, and the introduction of oil and other toxic substances into the storm sewer system are all spills or extraordinary discharges. However, they may not be considered such by those who first detect and later report them. Once spills are detected, confusion persists; one incident may be reported to the health department, another to the police, another to the Coast Guard; others may not be reported at all. A common definition and a common approach are needed.

- **Problems arising from human errors are not adequately addressed**

Human errors frequently arise from faulty human–machine interface design: instructions can be difficult to read, machinery can be difficult to use, controls may be inappropriate, workers can become tired or bored, there may be inadequate supervision or training, automation or high technology can be inappropriately used, or the allocations of functions between humans and machines may be inadequate.

- **Social values play an important role**

As explained by a United State Congressional leader in 1985, the public perceives a serious problem if there are 150 fatalities per year for air carriers, but exhibits little concern if there are 50,000 fatalities per year on highways. This attitude reflects a difference in values. While data on spills are sketchy, there appears to be approximately 3,000 spills of hazardous substances per year in the Great Lakes provinces and states. We need to pay more attention to the ways in which a society, through its institutions and values influences attitudes and conceptualizes science, technology and human life. The values which are held by people and governments regarding spills will significantly affect the degree of success achieved in addressing the problem of spills.

Recommendations

1. Data Reporting and Analysis

All participants in the Human–Machine Workshops recommend that the International Joint Commission:

- Urge the adoption of a uniform reporting format by all jurisdictions and offer to coordinate efforts to achieve such a format. Environment Canada's National Analysis of Trends in Emergencies Systems (NATES) data base, and the U.S. Environmental Protection Agency's initiative to centralize U.S. data on spills in the Emergency Response Notification System (ERNS) data base could serve as catalysts to bring the Parties and jurisdictions together to design flexible, efficient and accessible data bases on spills in the basin

- Work with all appropriate jurisdictions to develop and use a uniform definition of a spill for reporting purposes

- Monitor and report on the quantities, trends and causes of spills in greater detail in reports on water quality, including requirements for the adequate reporting of human factors data

- Advocate the compilation of an inventory of all hazardous materials, including hazardous wastes, in the basin. The inventory should include the production, use and disposal of radioactive material and the associated transportation activities

2. Program and Legislative Initiatives

- Encourage a consideration of the question of responsibility and liability in the event of disasters involving hazardous substances

- Encourage national and international emergency prevention plans which would obligate Great Lakes jurisdictions to provide resources and guidance to local communities so that appropriate authorities can take the lead in planning and executing emergency responses and in developing plans which: a) prevent or minimize the risk of spills; b) are proactive as well as reactive; and c) collect, using established or common procedures, comparable data with respect to spills, hazard identification and response protocols, both nuclear and nonnuclear

3. Fostering of Legislation

- Define or at least outline the essential elements of acceptable right–to–know legislation and advocate that all Great Lakes states and provinces enact comparable legislation. Such legislation should include, at least, hazardous substance identification, quantities, locations, chemical forms and modes of human health impact

- Encourage the development of legislation to allow the worker or operator to refuse to execute nonroutine tasks which could result in the discharge of a deleterious substance into the environment

- Encourage the appropriate jurisdictions to impose a statutory duty to report all spills meeting an agreed basinwide definition (in some jurisdictions legislation such as is proposed above has already been enacted or is under consideration)

4. Special Attention Directed to Nuclear Facilities

- Given the prevalence of nuclear power generating facilities and related activities in the basin, consider reestablishing the Committee on Radioactivity to monitor developments in this sector

5. Training, Education and Communication)

- Ensure that various concepts of risk and methods of risk assessment be debated publicly. The Commission, by advocating a public

component to risk assessment, could ensure that all risk discussions consider societal as well as individual risks. The combined risk of human and animal exposure via air, skin, food and drinking water sources would thus be considered

- Promote the development of a uniform basinwide or North American "pollution hazard information system" for use on warnings, labels, placards, displays and material safety data sheets. For easy and effective recognition, such warnings should be nonverbal

- Advocate a "total systems" approach, including special attention to human factors engineering in the education of professionals both early in the design of new systems or equipment and in the retrofit of older systems or equipment

- Promote development of a formal communication system directed at all potential polluters to assure that guidance information on human error, prevention, human factors design criteria, and technology transfer occur on a timely basis

- Encourage the jurisdictions to engage in public education programs related to the reporting and prevention of spills. The public should be further educated as to the impact on the environment of inappropriate personal waste disposal habits. Simultaneously, viable options for the disposal of hazardous goods or household products should be presented

- Urge that there be a provision for confidentiality where appropriate, particularly in the investigation of a narrowly averted spill or "near accident." The focus should be on prevention rather than correction

6. Code of Practice for Prevention of Spills

- Promote a Code of Practice for the prevention of spills in basin facilities containing the following elements:

    * Senior management or its equivalent must set standards for the organization and must repeatedly reflect a commitment to those standards. The evolution of a "corporate ethic" is crucial to an effective pollution control program. Knowledge crucial to pollution prevention and control should be shared within the organization

    * Every attempt should be made to include the operators in the design of equipment and facilities

    * Training should encompass not only how a machine works from an operator's perspective, but also how people interact with the machine. The importance of the operator should be recognized and acknowledged through job enrichment and a diversity of challenges. Training should be enhanced to communicate broader pollution concerns, including the legal restrictions and their rationale, and the collective consequences of individual actions

7. Research Initiatives

- Encourage the use of a "total systems" approach, including human factors and socio–technical considerations, in respect to Great Lakes pollution problems

- Sponsor or advocate research on selected pollution incidents, using specialists in human factors and socio–technical systems to determine causal factors in pollution discharges

- Study human factors data gleaned from upgraded data bases and initiate research on preventive measures and the development of specific human factors design criteria as applied to pollution alarms, pollution monitoring systems annunciators and other instrumentation to ensure that releases of pollution are controlled at the source

- Sponsor or recommend studies to ensure that new technology is implemented only after a deliberate and effective allocation of functions to both humans and machines is encouraged. Appropriate information about the system and cognitive support, in a form intelligible to the user, should be included in the design

- Recommend and support research to determine the relative contribution of spills to the total pollution of the Great Lakes basin

From the foregoing, it is evident that although much has been done to control the conventional sources of water pollution to reduce point source discharges, little attention has been given to preventing spills. Investigations of spills frequently reveal a breakdown in the communication and control links between technology and people, the human–machine interface.

On the basis of the findings and conclusions formulated in connection with the Human–Machine Workshops, and considering both long–term cumulative effects and the potential disasters, the Science Advisory Board concludes that spills may, in some cases, have a greater impact on the Great Lakes than the cumulation of all point source discharges. It concludes further that data on spills and programs designed to prevent spills are inadequate or nonexistent, that the contribution of human error to spill incidents is not adequately addressed, and that the lack of social perception of the importance of the problem is reflected in the inadequacy of current preventive and remedial efforts.

The Science Advisory Board, therefore, recommends that:

- **The Commission urge the Parties to adopt a uniform and comprehensive reporting system for the spills of hazardous substances and hazardous wastes, and should offer to coordinate the attainment of such a system**

- **The Water Quality Board monitor and report in greater detail on the quantities, trends and causes of spills**

- **A methodology to evaluate the ecosystemic effects of spills be developed by the Science Advisory Board's Ecological Committee**

- The Commission investigate the issues of responsibility and liability in the event of a disaster resulting from a major spill in the Great Lakes Basin Ecosystem, in accordance with Annex 9 of the Water Quality Agreement. The Commission should ensure that there is a unified international emergency prevention plan which encourages Great Lakes jurisdictions to establish a clear delineation of responsibility and provides resources and guidance to local communities, thus minimizing the risk and impacts of spills

- The Commission encourage the adoption of right–to–know and right–of–refusal legislation in jurisdictions throughout the basin. The Commission also encourage research and the reporting and prevention of spills and research, communication and training in systems and human factors engineering, risk analysis, pollution hazard information systems and the appropriate uses of automation

- The Commission promote the development of a corporate ethic with respect to the ecosystem and associated codes of practice for persons involved in the design of technical systems, operator training, human motivation and interaction in work situations

3.4 AQUATIC ECOSYSTEM OBJECTIVES COMMITTEE

The Aquatic Ecosystem Objectives Committee (AEOC) was created by the Science Advisory Board to assist it in fulfilling its mandate to advise the International Joint Commission and the Water Quality Board on matters pertaining to water quality objectives. References to Specific Objectives are found throughout the Agreement and the Specific Objectives themselves are listed in detail in Annex 1. There are 32 identifiable chemicals, conditions and materials for which limits were specified in the 1978 Agreement; eight of these were reviewed and new recommendations have been presented since the Agreement came into effect. In addition, five new objectives have been recommended and one substance reviewed for which no recommendation could be made.

The Committee reviews existing objectives and develops new objectives by examining scientific literature on the effects of chemicals on the uses which are to be protected in the Great Lakes basin. Information is sought defining a 'safe' level which will protect all uses, including the provision of a habitat for organisms, recreational and aesthetic use, raw water supplies for drinking water and various agricultural and industrial uses.

The Committee is developing "ecosystem" objectives which provide integrative measures for evaluating the state of well–being of different parts of the Great Lakes system. These objectives are intended to provide an overall degree of protection for the lakes by ensuring that multiple stresses do not compound the effects of single stresses and reach a critical stage without being investigated. The Committee concludes that a complementary set of integrative indicators, both abiotic and biotic, are needed.

In the Committee's previous report, it was recommended that Lake Superior be maintained as a balanced and stable oligotrophic system. Four measures recommended for evaluating this state were based on the lake trout. In this year's report, the population density of the bottom–dwelling crustacean, Pontoporeia hoyi, is recommended as an additional oligotrophic indicator.

To develop a rationale for ecosystem objectives for the mesotrophic waters of the Great Lakes, e.g. Green Bay, Saginaw Bay and the western and central basins of Lake Erie where the lake trout would not be a suitable indicator, the Committee established a Mesotrophic Indicators Work Group in 1986. This group is currently investigating the use of different fish and benthic organisms, as well as other indicators, to evaluate the health of mesotrophic systems. A report is expected in 1988.

The current zinc objective needs to be revised because adverse effects on algae have been reported at levels below the existing objective. While there is evidence that differing levels of hardness affect the toxicity of zinc to some aquatic organisms, there is no information of this sort for algae. Accordingly, the Committee has recommended a single objective. A similar lack of toxicological data prevents using one or another possible forms of zinc as the basis for the objective; the Committee has taken the conservative approach and recommended a total zinc objective.

The Committee has joined with several other committees and work groups of the Water Quality and Science Advisory Boards to evaluate the potential hazard posed by the large number of chemicals in the Great Lakes system. The Water Quality Board inventory for the 1,018 chemicals (WQB 1983) has been examined and work is underway to gather all existing data on 362 compounds whose presence in the system is considered to be confirmed. These will be evaluated from a human health perspective by the Human Health Effects Committee and from an overall ecosystems perspective by the Ecosystem Objectives Committee.

Relationships between the structural properties of chlorinated and other substituted phenols and benzenes and their respective sublethal effects on aquatic biota are being reviewed. These relations will be evaluated to determine whether safe levels can be estimated for all or most members of these compounds. The validity of using application factors to estimate chronic toxicity from acute lethalities predicted from structure will also be examined.

The Committee plans to continue developing ecosystem objectives at various hierarchical levels and for systems other than Lake Superior. The possibility of developing oligotrophic ecosystem objectives for Lakes Huron and Michigan, using the lake trout as an indicator and following the rationale used for Lake Superior, is being explored. An objective for mesotrophic waters may be recommended after review by the Mesotrophic Indicators Work Group. These objectives are not designed to replace but rather to complement chemical objectives.

A review of existing data relevant to the currently recommended ecosystem objective for Lake Superior is being undertaken. Lake Superior lake trout and Pontoporeia hoyi data are being assembled with a view to presenting a state-of-the-lake assessment. This assessment will focus on a dichotomous key (Ryder and Edwards, 1985) as a diagnostic tool to evaluate the health of the system.

Data for the 362 compounds on the reduced Inventory of Chemicals in the Great Lakes ecosystem are being gathered preparatory to subjecting them to a preliminary hazard assessment. An essential data set is being synthesized using quantitative structure-activity relationships and existing literature is being abstracted for relevant information. An evaluation of the potential hazard represented by each chemical will be made and priorities will be assigned to additional data needs.

The Ecosystem Objectives Committee recommends that:

- Lake Superior be maintained as a balanced and stable oligotrophic ecosystem with the lake trout as the top aquatic predator and Pontoporeia hoyi as the major benthic macroinvertebrate of a cold-water community

  NOTE: In order to determine whether this condition exists, the following criteria should be met:

  * The lake trout productivity should be greater than 0.38 kg/ha as determined using mortality rates

  * There should be a stable number of recognizable self-producing stocks

  * The annual harvest of lake trout should not exceed 0.24 kg/ha

  * The harvest of lake trout should be free from contaminants at levels which adversely affect the trout themselves or the quality of the harvested product

  * Lakewide benthic sampling for abundance of Pontoporeia hoyi should result in a set of mean abundance values for 20-m deep contour ranges, that do not differ significantly at the 95% confidence level from the set of values detailed in the Committee's 1987 report

- The concentration of total zinc in an unfiltered water sample should not exceed 10 µg/L to protect aquatic life

- Research to better describe the influence of water hardness on the toxicity of forms of zinc to aquatic organisms be conducted

- During the course of developing specific objectives, the Ecosystem Objectives Committee has encountered data gaps which have prevented the recommendation of a numerical limit for some chemicals or have weakened the confidence in the recommended level of others. A list of these research needs was compiled and presented in the 1985 Annual Report of the Committee. The requirements were of two types: those of a general nature designed to improve the Great Lakes science community's abilities in several topic areas, and data which were needed to complete or further support objectives for specific chemicals. The Committee is unaware of progress on these recommendations and takes this opportunity to bring them again to the attention of the Science Advisory Board

- Data to permit the evaluation of the health of the Lake Superior ecosystem should be collected. Specific data on the conditions of lake trout and of Pontoporeia hoyi are recommended as the means to measure this state; details are noted in the Committee's 1987 report

- **Similar objectives and measures of system health will be developed for Lakes Huron and Michigan and it is recommended that the appropriate data for these two lakes be collected. It is suggested that this be a joint effort of the IJC and the Great Lakes Fishery Commission**

The Science Advisory Board supports the recommendations of the Aquatic Ecosystem Objectives Committee. The first and second recommendations are referred to the International Joint Commission; the third recommendation to the Council of Great Lakes Research Managers; the fourth and fifth recommendations are referred to the Water Quality Board, the Great Lakes Fishery Commission and to the Council of Great Lakes Research Managers.

3.5 JOINT COMMITTEES

3.5.1 Human Health Effects Committee

The Committee on the Assessment of the Human Health Effects of Great Lakes Water Quality was formed in 1978 to respond to technical and scientific matters relating to human health. It reports jointly to the Science Advisory Board and the Water Quality Board.

Epidemiological Evaluation of Human Health Effects of Chemical Contaminants in the Great Lakes

There is widespread public concern that contaminated fish and water in the Great Lakes basin pose risks to human health. As a result, there is increasing public pressure to carry out studies to identify these risks. Epidemiological studies have developed popular appeal, yet most studies of this type have produced equivocal results. It is essential to define the utility of epidemiological studies for the evaluation of the impacts on humans of chemical contaminants in the Great Lakes basin.

The Human Health Effects Committee is, therefore, seeking expert opinion on the feasibility of deriving well–founded conclusions using epidemiological studies relating to human health and water/fish quality. A two–stage consultative process is underway. The first stage consists of the solicitation of position papers by several recognized experts in epidemiology on a number of relevant topics. These documents will form the background for a workshop discussion on the epidemiologic research strategies best suited for the Great Lakes basin. The workshop, planned for the spring of 1988, will include the epidemiologists who prepared the background papers and a number of experts active in this field. The best use of epidemiological approaches for addressing questions concerning the human population in the vicinity of the Great Lakes will be examined.

1983 IJC Inventory of Chemicals in the Great Lakes Ecosystem: Health Hazard Evaluation

Previously published reports of the Human Health Effects Committee have evaluated potential health hazards posed by more than 100 chemical substances found in the Great Lakes basin. Over the past three years, the Committee has worked with the Coordinating Committee to reduce the 1983 inventory to the "1986 Reduced Inventory of 362 Chemicals." Toxicity profiles for over one hundred chemicals reported to be present at least once in water or fish, have already been prepared.

Potential human exposure is now being assessed, based on data provided by the IJC Regional Office and by committees of the Water Quality Board and Science Advisory Board. The Committee expects to publish its findings and the profiles in a future report.

Organometallic Contaminants in the Great Lakes

Alkylated Lead Compounds: Alkylated lead compounds are manufactured in the Great Lakes basin and are used primarily as additives to gasolines.

The Committee reviewed the toxicology data base for alkylated lead and provided recommendations in its 1985 report for maximum concentrations of total lead in edible portion of fish. Research studies on triethyl, tetraethyl and organic lead have recently been completed by the Canadian Department of National Health and Welfare in response to the Committee's request for additional data. The findings support the concern expressed by the Committee over the toxicity of the alkylated forms of lead. While the use of lead and lead compounds is decreasing, the issue of lead contamination requires continued attention in view of the mounting evidence of harmful effects on humans, especially children, at low levels of exposure.

The Committee, therefore, restates its recommendations of 1985:

- **The jurisdictions should continue to monitor lead concentrations in fish in the St. Lawrence River so that potential human exposure can be assessed more reliably and changes in potential exposure noted**

- **The jurisdictions should analyze the edible portions (suitably defined) of fish for both inorganic and organic species of lead along with the age and species of fish analyzed**

- **The primary sources of lead should be discontinued**

Organo–tin Compounds: Organo–tins are used as stabilizers in the plastics industry and serve as antifouling additives in paints for boats and ship hulls. Recent reports indicate high levels of organo–tins in some Great Lakes harbours. Several jurisdictions are evaluating the levels of organo–tins in sediment, water and fish. Their toxicity and potential for causing neurological damage in mammals is of concern to the Committee.

The Committee, therefore, recommends that:

- **The jurisdictions carefully review all data on organo–tins and the toxicological significance of these compounds in the Great Lakes and through additional monitoring, determine their sources, distribution and present levels**

Fish Tumors

In its 1985 report, the Committee stated its interest in studies of fish tumors in the Great Lakes, using the increased incidence of such tumors as an additional, possible indicator of chemical contamination. Such studies, however, must take some specific caveats into consideration. It is necessary not only to gather more data than are currently available but also to differentiate between tumors caused by viruses and

those likely caused by chemical carcinogens. In addition, it is imperative to ensure quality and consistency among investigators in the interpretation of fish-pathology data. It must also be possible to associate a fish with a particular water body within the Great Lakes to establish a correlation between the incidence of a tumor and contamination of the species' habitat, before wider-reaching conclusions on the indicator value of the incidence of certain tumors can be drawn. The Committee thinks it would be appropriate for the Commission to facilitate cooperation among researchers and the exchange of research information in this field.

The Committee, therefore, recommends that:

- **The jurisdictions fund additional studies on fish-tumor incidence, pathology and etiology, and their underlying causes**

Bases for Regulatory Standards and Guidelines Used in the Great Lakes Basin

The Committee has addressed various aspects of the generic issue of numerical standards and guidelines since its formation in 1978. Given the methodologies used by the different jurisdictions and the risk-management considerations involved, it is not surprising that slightly different values are developed for the same compound in the same substrate. Nevertheless, these differences are perceived by the public as confusing and, to some, appear to imply that experts disagree about the hazards which the chemicals present.

The Committee has been requested by the Water Quality Board to review the jurisdictional bases for the methods used to derive fish and water standards and the guidelines for the eleven chemicals in the Water Quality Board's primary track.

The Committee is planning to contract a study in 1987-88 on how standards for the eleven critical pollutants have been set, how and why they differ, why they were designed and whom they protect.

Emerging Issues Under Consideration

There have been numerous recent developments in toxicology which will probably affect the way scientists and/or regulatory agencies deal with fundamental issues in toxicology in the near future. The Committee considers that some of these developments will influence the interpretation of health effects data. The Committee is, therefore, proposing to address the following emerging issues in toxicology:

- Biochemical indicators of contaminant exposure
- Toxicological significance of mutagenicity data
- Application of the multimedia (total exposure) approach to the development of regulations

The Committee, therefore, recommends that:

- **The Commission provide funding to address these topics**

3.5.2 Coordinating Committee for the Assessment of Toxic Chemicals in the Great Lakes Ecosystem

In 1985, the Science Advisory Board and the Water Quality Board jointly established the Coordinating Committee for the Assessment of Toxic Chemicals in the Great Lakes Ecosystem. This Committee is made up of representatives from four groups responsible for dealing with toxic chemicals in the basin: the Ecosystem Objectives Committee of the Science Advisory Board, the Toxic Substances Committee and the Surveillance Work Group of the Water Quality Board, and the Committee on the Assessment of Human Health Effects of Great Lakes Water Quality, which is jointly responsible to both boards. The Coordinating Committee was charged with evaluating hazard assessments necessary to describe the significance of chemicals to environmental and human health in the basin and with providing liaison among the several committees involved with toxic chemicals.

The inventory of chemical substances identified in the Great Lakes ecosystem listed approximately 1,018 chemical substances observed in one or more of a variety of sample matrices in the Great Lakes basin. Aside from their presence in the ecosystem, little else is known about many of these compounds.

This list has been reduced to 362 positively identified substances in the 1986 Working List of Chemicals (see Annex 1 to the 1987 report of the Water Quality Board). This reduction excluded compounds which were only tentatively identified, duplicate entries, chemically ambiguous or structural improbabilities, and chemicals known to be innocuous natural products. The existing data base for each remaining chemical is being assembled and a set of essential data elements synthesized through the use of quantitative structure–activity relationships. These data will be used in a preliminary hazard assessment to determine priorities for further data development and in–depth assessments. The 1987 report of the Committee includes a scheme for the different stages in the assessment and control of chemicals. It is anticipated that this scheme will provide a rational basis for the environmental management of chemicals in the Great Lakes basin.

The Coordinating Committee has summarized background information on the fate and distribution of the chemicals on the Water Quality Board's list of Primary Track Chemicals (dieldrin, PCBs, mirex, toxaphene, benzo–a–pyrene, hexachloro–benzene, DDT and metabolites, 2,3,7,8–TCDD, 2,3,7,8–TCDF, mercury and alkylated lead). The 1987 report of the Committee includes information for each of these critical pollutants with respect to general background information, properties, uses, effects and regulations. These chemicals are widespread in the system, have well established properties which make them potentially hazardous, and many of them are the subject of various control actions. The concern for these particular compounds arises from their continuing presence in the system and the need to monitor their concentrations in various facets of the ecosystem to determine temporal trends. Many of the compounds have been observed in atmospheric samples; consequently, further controls may have to be binational or even global. The significance of atmospheric sources relative to other inputs needs clarification (see Section 3.2.2 of this report).

4.0 Council of Great Lakes Research Managers

4.1 WORKSHOP ON THE EFFECTIVENESS OF GREAT LAKES RESEARCH COORDINATION BASED ON THE STUDY OF PCBs

The Council of Great Lakes Research Managers was established in 1984 to provide guidance and advice on Great Lakes research to the International Joint Commission and the Science Advisory Board . The Council is responsible for collecting and disseminating information on research programs relevant to the Great Lakes, identifying research needs and assisting in the coordination of research efforts in the Great Lakes basin.

4.1.1 Introduction

In November 1985, the Council held a workshop on Great Lakes Research Coordination in partial fulfillment of its responsibility to the Commission and the Science Advisory Board. The principal objectives of this workshop were to review the effectiveness of Great Lakes research programs, using polychlorinated biphenyls (PCBs) as a case history, and to recommend appropriate mechanisms for improving research coordination and cooperation among Great Lakes research institutions.

Based on papers presented by invited speakers and discussions held at this workshop, the participants formulated the following conclusions:

4.1.2 Human Exposure

There are five major nonoccupational routes for human exposure to contaminants in general and PCBs in particular: air, drinking water, soil, food and consumer products. Each of these sources usually contributes to total body burden; however, the relative contributions from these various sources are still unclear.

To date, Great Lakes research on exposure has dealt with the human intake of pollutants through the consumption of contaminated fish, the levels of contaminants in human tissue and in mother's milk, the concentrations of contaminants in drinking water and the extrapolation of data from animal exposure studies. Most of the recommended maximum exposure limits or acceptable daily intake of chemicals for humans are based on drinking contaminated water or eating contaminated fish, with limited reference to other routes for human exposure.

Now, however, there is growing evidence that humans are exposed to variable but significant amounts of persistent toxic chemicals in food and in a variety of consumer products. The workshop participants, therefore, concluded that:

- More of the existing research effort should be expended on the investigation of the relative contributions of the various routes for human exposure to contaminants
- The exposure from sources other than contaminated drinking water and fish should be taken into consideration when maximum exposure limits or acceptable intake doses are established

4.1.3 Sources

Toxic chemicals enter the Great Lakes from many sources, including tributaries, industrial and municipal point sources, urban and agricultural runoff, groundwater, sediments and atmospheric deposition. Research efforts dealing with sources of pollutants focused on the development of methods for identifying, measuring and controlling the inputs of contaminants into the Great Lakes. These efforts have been successful with regard to monitoring and controlling inputs from point sources. However, very little progress has been made with regard to controlling inputs from diffuse sources. Monitoring, tracking and controlling nonpoint sources are complex and costly endeavors. The participants, therefore, concluded that:

- Research scientists seek more innovative approaches and techniques for assessing the relative importance of contaminant inputs from diffuse sources into the Great Lakes. Special attention should be given to atmospheric deposition, groundwater, tributary inputs and in situ recycling of chemicals from polluted sediments

4.1.4 Environmental Measurements

During the last two decades, the environmental measurements of toxic chemicals have centered on their concentrations in water, aquatic organisms, sediments, air and to a lesser extent, terrestrial species and humans. The main purpose of these measurements was to determine contaminant levels and distribution among the various components of the environment. Using this information, as well as the toxicological properties of the chemicals, scientists attempted to assess the potential effects of contaminants on ecosystem health.

In the past, it has been difficult to measure or even detect especially low concentrations of certain contaminants in environmental samples or to distinguish individual isomers or congeners of complex groups and mixtures such as polychlorinated biphenyls. Individual isomers may share some similarities in structure and behaviour but often differ in the intensity of their toxicological effects. Scientists recognize that reported values of total PCBs with different composition of congeners are not comparable in their effects.

Recent advances in analytical procedures and the refinement of instruments have significantly improved detection limits and allowed for better resolution and identification of individual components of complex mixtures. Because of the high cost of advanced analytical equipment, many laboratories have found it difficult to perform toxic chemical measurements at their ambient concentrations. The workshop participants, therefore, concluded that:

- Some of the existing research effort should be directed toward the design of selective but more efficient environmental sampling programs to reduce the number of monitoring stations and samples collected but still provide adequate information for environmental assessment purposes

- Environmental measurements should focus on those parameters and individual components that are of direct concern to ecosystem health

- Laboratories should be encouraged continually to update their equipment and revise their analytical procedures

4.1.5 Characterization, Transport and Modeling

Research has focused on the identification and environmental behaviour of toxic chemicals with regard to transport, partitioning, degradation, biotransformation and bioaccumulation. This information is used in conjunction with discharge data and measurements of concentrations in the environment to develop mathematical models predicting the fate of these chemicals and their effects on the ecosystem. While modeling concepts are considered to be advanced, good data sets required for their validation are still incomplete.

As indicated above, it is difficult and costly to monitor all sources and to calculate their loadings into the Great Lakes. To overcome these difficulties, research scientists are attempting to develop models based on trends of contaminant levels in sediments and biota. Their assumption is that a relationship exists between contaminant loadings and concentrations in sediment or biota. While this relationship seems simple and logical, many factors may influence it and they should be taken into consideration when models are developed.

The workshop participants, therefore, concluded that:

- Current research efforts should continue to explore the feasibility of developing mathematical models for calculating mass balances of toxic chemicals in the Great Lakes and of establishing relationships between toxic chemical loadings and their concentrations in the various components of the environment

4.1.6 Ecological Effects

Research studies conducted on PCBs have demonstrated that community structure and/or physiological changes could occur in Great Lakes biota exposed to persistent toxic chemicals. At ambient concentrations, PCBs have been shown to reduce the gross primary productivity of certain groups of phytoplankton. They have also been shown to reduce the grazing rates and ingestion in some herbivorous species of zooplankton. In the wild, PCBs and DDT have been correlated with chinook salmon mortality and a reduced rate of survival of lake trout fry. Also, because of exposure to PCBs and DDE in the Great Lakes, nine of thirteen fish–eating bird species showed decreases in egg–shell thickness, a condition which has affected their reproduction rates.

The nature and magnitude of the deleterious effects of a toxic chemical usually depend on the properties of the chemical as well as on dosage, i.e. the concentration and period of exposure. While a significant amount of research had been expended on the study of the toxicological effects of individual chemicals on a limited number of species in the laboratory, few investigations have involved chemical mixtures and their effects on groups of organisms or populations exposed to ambient concentration levels under prevailing environmental conditions.

While laboratory tests are considered essential for understanding how certain chemicals can affect specific biological systems, well–planned field studies are equally essential to an assessment of the exposure and effects of these chemicals on the health of the ecosystem. Field studies will reflect the cumulative effects of a multitude of complex, interacting factors specific to both the aquatic ecosystem and the chemicals; these effects should be duplicated in the laboratory.

Another important issue that has not yet been adequately investigated is the ability of aquatic organisms in the Great Lakes to adapt to long-term exposure to persistent toxic chemicals.

Based on the above, the workshop participants concluded that:

- Both laboratory and field investigations should be used to assess the effects of mixtures of persistent toxic chemicals on aquatic organisms and to determine the extent to which different organisms or groups of organisms can adapt to long-term exposure to ambient levels of persistent toxic chemicals

4.1.7 Human Health Effects

PCBs were found in several human tissues and organs including mother's milk, placenta, blood serum and adipose tissue. PCB levels vary widely among individuals, depending on the extent of exposure. A recent study conducted by the Department of Public Health in Lansing, Michigan, indicated that PCB levels in humans correlate with the quantity and type of Great Lakes fish consumed. The study also indicated a direct correlation between PCB concentrations in the body and the period of exposure. The longer the individuals had been consuming fish, the greater were the PCB levels in their blood serum.

The research also indicated that each individual has a baseline level of PCBs circulating in his or her body. This baseline will surge shortly after each new exposure to an additional dose of PCBs, e.g. after eating a meal of contaminated fish. These levels exceed what normally is circulating in the body and can reach critical levels.

Although PCBs are not primary carcinogens, they are considered to promote tumors. Because of this feature and because they are bioaccumulative and persistent, their potential effects on human health are of concern.

Based on these findings, the participants concluded that:

- Collaborative research is required to develop a reliable data base on the levels of contaminants in human bodies and to correlate these levels with observed physiological impairments, genetic aberrations and any other medical problems

4.1.8 Social and Economic Considerations

Research programs of government agencies responsible for environmental protection usually emphasize technology development, with passing consideration of the relative cost-effectiveness of alternate approaches. The broader question of the socio-economic consequences of the technologies is not generally considered. On the other hand, nongovernment environmental organizations take greater interest in socio-economic issues because they realize that social and economic impacts are important motivating factors.

Although the general public has been regularly polled regarding its attitudes and opinions on environmental issues and has usually expressed strong commitment to environmental quality, there have been few studies and experiments on how best to facilitate meaningful exchanges between managers and the public on Great Lakes

Basin Ecosystem issues. The public participation panels of the Pollution from Land Use Activities Reference Group were one of the best and most successful basinwide attempts to facilitate interaction.

The numerous incidents of spillage and reported cases of contamination involving PCBs have provoked wide media coverage and public concern. It is clear from the tenor of public reaction and the character of media coverage, that the people have little information about the actual health hazard and risk associated with PCBs. There is a great deal of public anxiety about PCBs and a reluctance to accept risks associated with any PCB disposal initiatives. This anxiety is attended by what some consider to be a crisis in public confidence in the efficacy of laws and regulations intended to safeguard public health and protect the environment. Only recently have the courts begun to demand incarceration of those convicted of willfully violating laws concerning the disposal of hazardous wastes such as PCBs.

After considering this information, the workshop participants concluded that:

- Better public awareness programs are needed to provide adequate information on the actual risks associated with PCBs and to describe effective technical initiatives available to dispose of PCB wastes. Citizens should be able to receive accurate information which is not just a reaction to the latest event, but which promotes increased responsibility and participation in the decision-making process dealing with PCBs and other toxic compounds

- More research is needed to determine why people in the Great Lakes basin are reluctant to accept facilities for the destruction of PCBs, whether fixed or mobile, using technologies that have been accepted in other countries

4.1.9 Control and Management

Regulatory programs have been established in Canada and the United States to limit and control the manufacture, use and disposal of PCBs. The intent of these programs is to prevent new releases of PCBs into the environment. The goal is to protect public health by reducing the risk of human exposure to these chemicals.

Nonregulatory programs have also been established to assist in the over-all management of PCBs. For example, inventory systems have been created to document the location of PCB-containing equipment and to track their movement when they are taken out of service. Also, emergency spill response actions and training programs have been initiated to deal with spill incidents in the quickest and most appropriate manner.

The main problem now facing regulatory agencies in Canada and the United States is the control of PCB-containing equipment still in service and the disposal of PCB waste currently in storage.

Accordingly, the workshop participants concluded that:

- More effort should be directed toward the development of a forced attrition policy to phase-out the use of all PCB-containing equipment

- A complete performance standard must be developed for PCB destruction technology to ensure public safety

4.1.10 Remedial Options

Effective remedial action plans and implementation strategies require close collaboration among managers, scientists and the public. The Green Bay experience is an excellent example of such collaboration and is worthy of emulation. Similar pilot studies are now underway in other Areas of Concern such as Hamilton Harbour and the Grand Calumet River. The results of these studies should be monitored and evaluated for the social-learning processes inherent in them and analyzed with reference to the Green Bay experience.

The workshop participants concluded that:

- Pertinent knowledge gained from such experiences should be used to develop site-specific remedial action plans for the 42 Areas of Concern identified by the Water Quality Board

4.1.11 Dissemination of Research Information

Workshop participants agreed that there is a need for better dissemination of information on research underway or recently completed. Such information would be useful to the Great Lakes scientific community and would facilitate the coordination of research activities.

The participants concluded that:

- The Council of Great Lakes Research Managers, with the assistance of the Great Lakes Regional Office, consider the preparation of annual inventories that:
  - Identify government and nongovernment research institutions and funding agencies in the United States and Canada involved in Great Lakes research
  - Provide summaries of all research programs relevant to the Great Lakes, including detailed information on objectives and resources allocated to each research project
  - Could be made available in written and electronic form from the Great Lakes Regional Office

4.1.12 Research Coordination

Recognizing that Great Lakes research programs suffer from a lack of coordination and focus, workshop participants concluded that:

- The Council of Great Lakes Research Managers should establish clear statements of management goals, which would serve as the basis for developing cooperative binational research programs. These statements could then be brought forward to the co-chairs of the Great Lakes Science Advisory Board and subsequently

transmitted to the Great Lakes Water Quality Board and the International Joint Commission for consideration and appropriate action

- A set of research needs integrating the requirements for human health, fisheries and wildlife management should be developed to support the goal statements above, making use of the Council to establish priorities for those needs and to develop a program of coordination to meet high priority needs

The Science Advisory Board considers that the Council has raised a number of important issues as a result of the workshop. Following completion of the full report on the workshop, the Board intends to explore the findings in detail with a view to identifying specific areas in need of research monitoring and coordination.

References

Barney G. O. *The Global 2000 Report to the President.* A report prepared by the Council on Environmental Quality and the Department of State. Vols. I–III, U.S. Government Printing Office, Gaithersburg, MD, 1980.

Barney, G. O., P. H. Freeman and C. A. Ulinski. *Global 2000: Implications for Canada.* Pergamon Press, Elmsford, N.Y., 1981.

Caldwell, L. K. "The ecosystem as a criterion for public land policy," *Natural Resources Journal* 10 (1970) pp. 203–220.

Christie, W. J., M. Becker, J. W. Cowden and J. R. Vallentyne. "Managing the Great Lakes basin as a home," *Journal of Great Lakes Research* 12:1 (1986) pp. 2–17.

Evans, M. S., ed. *Great Lakes Ecosystems: Effects of Toxic Contaminants on Their Health.* Advances in Environmental Science and Technology, Vol. 21, Wiley, New York, N.Y. (in press).

Fitchko, J. *Literature Review of the Effects of Persistent Toxic Substances on Great Lakes Biota.* Report to the Great Lakes Science Advisory Board. Windsor, ON, 1986.

Great Lakes Institute. *A Case Study of Selected Toxic Contaminants in the Essex Region. Volume II: Social Sciences.* University of Windsor, Windsor, ON, 1986.

Great Lakes Science Advisory Board. *Annual Report of the Science Advisory Board to the International Joint Commission.* Windsor, ON, 1979.

Great Lakes Water Quality Board. *An Inventory of Chemical Substances Identified in the Great Lakes Ecosystem. (Appendix E update), Vols. 1–VI,* Windsor, ON, 1983.

Great Lakes Water Quality Board. *Report on Great Lakes Water Quality.* Report to the International Joint Commission. Windsor, ON, 1985.

Milbrath, L. W. *Environmental Values and Beliefs of the General Public and Leaders in the United States, England and Germany.* Occasional Papers, Environmental Studies Center, State University of New York, Buffalo, 1980.

O'Neill, R. V., D. L. DeAngelis, J. B. Waide and T. F. H. Allen. *A Hierarchic Concept of Ecosystems.* Princeton Univ. Press, Monographs in Population Biology, No. 23, Princeton, N.J., 1986.

Ryder, R. A. and C. J. Edwards. *A Conceptual Approach for the Application of Biological Indicators of Ecosystem Quality in the Great Lakes Basin.* Report to the Great Lakes Science Advisory Board. Windsor, ON, 1985.

Sia, A. P., H. R. Hungerford and A. N. Tomera. "Selected predictors of responsible environmental behaviour: an analysis." *Journal of Environmental Education* 16:10 (1986) pp. 31–40.

Stewart, G. W. 1987. "The leading question: *in situ* structures of thought," R. L. Thomas et al., eds. *Ecological Effects of In situ Sediment Contaminants.* Developments in Hydrobiology No. 39 reprinted from Hydrobiologia 149 (1987) pp. 137–157.

U.S. Environmental Protection Agency and Environment Canada. *The Great Lakes: An Environmental Atlas and Resource Book,* 1987.

Vallentyne, J. R. and A. L. Hamilton. *Managing human uses and abuses of aquatic resources in the Canadian ecosystem.* Canadian Aquatic Resources. Canadian Bulletin of Fisheries and Aquatic Sciences 215 (1987) pp. 513–533.

World Commission on Environment and Development. *Our Common Future.* Oxford Press, New York, N. Y., 1987.

Glossary of Acronyms and Abbreviated Forms

INSTITUTIONS

AEOC	Aquatic Ecosystem Objectives Committee
The Agreement	Great Lakes Water Quality Agreement
CCACGLE	Coordinating Committee on the Assessment of Chemicals in the Great Lakes Ecosystem
ENEA	Centro Ricerche Energia Ambiente S. Teresa
GLFC	Great Lakes Fisheries Commission
GLISP	Great Lakes International Surveillance Plan
HHEC	Committee on the Assessment of the Human Health Effects of Great Lakes Water Quality
IAGLR	International Association for Great Lakes Research
IJC	International Joint Commission
PLUARG	Pollution from Land Use Activities Reference Group
RAP	Remedial Action Plans for Areas of Concern
SAB	Science Advisory Board
WCED	World Commission on Environment and Development
WQB	Water Quality Board

CHEMICALS

HCB	Hexachlorobenzene
PCBs	Polychlorinated biphenyls
TCDDs	Tetrachlorodibenzoparadioxins

OTHER

DNA	Deoxyribonucleic acid
ERNS	Emergency Response Notification System
NATES	National Analysis of Trends in Emergencies System
MESOCOSMS	Large enclosures of lake water used to simulate natural ecosystems; useful for experimental evaluation of toxic contamination effects at the ecosystem level

UNITED STATES MEMBERS (Cont'd.)

Mr. Walter A. Lyon
Engineering Consultant and
Adjunct Professor of Civil Eng.
University of Pennsylvania
20 Clifton Road
Camp Hill, Pennsylvania 17011

Secretariat Responsibilities

Dr. C. J. Edwards
Fisheries Biologist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario N9A 6T3

Correspondent
Dr. Burton Ayles
Dept. of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N2

Official Liaison
Dr. M. H. Sadar
Federal Environmental
Assessment Review Office
Fontaine Building
Hull, Québec K1A 0H3

Former Members – Changes After June 1985

Mr. Vinton W. Bacon
The University of Wisconsin

Dr. J. C. Davies III
The Conservation Foundation

Dr. David G. Frey
Indiana University

Dr. Ruth R. Levine
Boston University

Dr. Ruth A. Reck
General Motors Research Laboratories

Mr. Paul D. Foley
Ontario Ministry of the Environment

Dr. George R. Francis
University of Waterloo

Dr. Harold H. Harvey
University of Toronto

Dr. Gilles LaRoche
Triple–V, Vit–Vitaille–Viron Inc.

Dr. Robert W. Newbury
Freshwater Institute

Mrs. Grace Patterson
Environmental Assessment Board

Dr. R. L. Thomas
Department of Fisheries & Oceans

Joint Member
Dr. Marlene Evans
University of Michigan

Science Advisory Board
Record and Acknowledgements – 60th to 67th Meetings

1. 60TH, SEPTEMBER 11–13, 1985
   CANADA CENTRE FOR INLAND WATERS, BURLINGTON, ONTARIO

   - Presentation by Dr. A. Hanson on the Canadian Environmental Assessment Research Council; presentation on Hamilton Harbour, Venture Inn, Burlington.

2. 61ST, NOVEMBER 14–15, 1985
   IJC REGIONAL OFFICE, WINDSOR, ONTARIO

3. 62nd, JANUARY 29–30, 1986
   ACADEMY OF NATURAL SCIENCES, PHILADELPHIA, PENNSYLVANIA

   - Presentations on January 30, 1986, at the Academy by Dr. Lewis A. Sage, Dr. Ruth Patick, Francis Boyer, Dr. James Saunders, Dr. Sybil Seitzinge, Dr. John Sherman, Dr. I. McHarg, Dr. Arthur Johnson, Dr. John Radke, Dr. J. Hugh Ellis.

4. 63RD, MAY 29–30, 1986
   GUILD INN, SCARBOROUGH, ONTARIO

   - Held in conjunction with the International Association of Great Lakes Research Annual Meeting and the Atmospheric Deposition Workshop.

5. 64TH, SEPTEMBER 24–26, 1986
   ST. REGIS, QUEBEC

   - Meeting with Mohawk Council of Akwasasne; Grand Chief Mitchell, Chiefs Lafrance, Porter and Norton. Presentation by Francis Boots, Henry Lickers, Jim Ranson, Doug George, Dwayne White, Laura Montour. Correspondence from Chiefs M. Mitchell, B. Lafrance and T. Porter.

6. 65TH, NOVEMBER 19–21, 1986
   IJC REGIONAL OFFICE, WINDSOR, ONTARIO

   - Joint meeting with the Water Quality Board, November 20, 1986. Presentations by the St. Clair River International Citizens Network: J. White (group spokesperson), J. Gunning, J. Cathers, R. Pruner and T. Eder of Great Lakes United.

7. 66TH, MARCH 4–6, 1987
OFFICES OF THE EAST CENTRAL MICHIGAN PLANNING AND DEVELOPMENT REGION, SAGINAW, MICHIGAN

- Presentation by Mr. Don Platt, Director. Meeting in conjunction with the workshop for the "Future of Saginaw Bay," Delta College, University Center, Michigan, March 5, 1987.

8. 67TH, JUNE 17–19, 1987
IJC REGIONAL OFFICE, WINDSOR, ONTARIO

- Presentation June 17, 1987, at the Great Lakes Institute by Dr. D. Haffner, C. Alpaugh, Dr. L. Wong and Dr. J. Kolasa.