
Great Lakes Science Advisory Board

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Great Lakes Science Advisory Board

1991 Report to the International Joint Commission

International Joint Commission
United States and Canada
ERRATA

On page 19, Figure 3.1, "Bill Defects in Double-Breasted Cormorant Chicks per 10,000, 1979-1987; the percentage sign should be eliminated from the values given on the figure. Thus, the number of defects in chicks in the vicinity of Green Bay is 52.1 per 10,000, not 52.1%.
International Joint Commission
United States and Canada

September 29, 1991

Commissioners:

The Great Lakes Science Advisory Board herewith submits its 1991 Report to the Commission and the Water Quality Board (WQB), as provided for under the Terms of Reference for the joint institutions under the Great Lakes Water Quality Agreement. Over the past biennial cycle, the Board has directed its efforts to address the priorities of the Commission, expressed in your memorandum of June 7, 1990, as well as to respond to the WQB request for direction and advice concerning research with respect to wetlands (recommendation #33, 1989 WQB report).

In order to provide science advice on matters related to the virtual elimination of persistent toxic substances and the state of the Great Lakes basin ecosystem (formerly referred to as state of the lakes), the Board participated cooperatively with the WQB and the Council of Great Lakes Research Managers in the initiatives of two joint task forces. The resulting task force reports, and relevant Board comments, are dealt with under separate cover. This report then, represents Board conclusions and recommendations pertinent to Commission priorities associated with Remedial Action Plans, emerging issues and unforeseen events, as well as other matters requiring the Board's attention. The most important of these, dealing with human health, builds on the findings of the 1989 Report and calls for the declaration of persistent toxic substances, particularly organochlorines, to be a hazard to human health in the Great Lakes basin.

While the Board welcomes the inclusion of Chapter 12 to the report by the Council of Great Lakes Research Managers, it is acknowledged that future reporting from the Council will likely occur directly to the Commission in accordance with the revised Terms of Reference for the Council. Notwithstanding this new provision for direct reporting, the Board recognizes the continued importance of coordinating activities closely with the Council and in this regard will be conducting annual joint meetings, the second of which is scheduled to coincide with the upcoming Biennial Meeting.

The Board is looking forward to the opportunity to interact with basin citizens and others in the IJC family, along with the presentation of its report to the Commission in Traverse City on September 29 to October 2, 1991.

Respectfully submitted,

J.R. Vallentyne, Ph.D.
CoChair, Canadian Section

A.M. Beeton, Ph.D.
CoChair, United States Section
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The Cover: The illustration, originally used for the 1989 Report, by Mr. Brad "Totanake" Bonaparte, a member of the Akwesasne Nation, Snipe Clan. Photo credit, Mrs. Becky Burrell and daughter, Erin Kathleen, by photographer, Mr. Rodney Denis.

At an IPM Monitoring Location in Essex County, a Program Coordinator is Checking a Pheromone Trap to Determine Insect Pest Levels (photo). 73

Cartoon Drawing by W. Miller; © 1991 The New Yorker Magazine, Inc. 77
SUMMARY OF RECOMMENDATIONS

CHAPTER 2: STATE OF THE GREAT LAKES BASIN ECOSYSTEM FRAMEWORK

It is recommended that:

- The International Joint Commission continue to develop the reporting strategy for the state of the Great Lakes in the context of a basin ecosystem framework as envisaged by the Agreement (2.2.2)

- A code of ethics to guide human activities and involving young people, be developed for the Great Lakes Basin Ecosystem, under the auspices of the IJC (2.2.3)

CHAPTER 3: HUMAN AND ECOSYSTEM HEALTH

It is recommended that:

- The Science Advisory Board's 1989 recommendation to the Parties be implemented to develop ecosystem objectives that specify the number of pairs of bald eagles (Haliaeetus leucocephalus), their productivity, and egg and brain residues, associated with the virtual elimination of persistent toxic substances from the Great Lakes and connecting channels (3.1.1)

- The Parties develop an ecosystem objective for the double-crested cormorant (Phalacrocorax auritus), with particular reference to embryo mortality, incidence of deformities and eggshell thickness and associated levels of persistent toxic substances (3.1.2)

- The Parties develop an ecosystem objective for lake trout that specifically relates the incidence of embryo mortality, fry survival and developmental anomalies in samples of eggs of fish exposed to persistent toxic substances (3.1.3)

- The Parties investigate the feasibility of developing ecosystem objectives relating the status of mink and otter populations to exposures to persistent toxic substances (3.1.4)

- The International Joint Commission declare persistent toxic substances, particularly organochlorines, to be a hazard to human health in the Great Lakes basin (3.2.6)

- Levels of persistent toxic substances in mothers' milk; be used as a surrogate for the transfer of persistent toxic substances from mother to fetus; that scientific criteria and objectives be developed for acceptable levels of persistent toxic substances in mothers' milk and that the goal of the Parties be to achieve virtual elimination of persistent toxic substances, especially organochlorines, from mothers' milk (3.2.6)

- The Parties establish a coordinated, multidisciplinary, binational program to more clearly understand and to prevent injurious health effects of chemicals designated as priority chemicals by the International Joint Commission (3.2.6)
CHAPTER 4: REMEDIAL ACTION PLANS

It is recommended that:

- Remedial Action Plan problems and solutions be divided in accordance with their degree of complexity to achieve a strategic planning approach similar to that used in the control of point sources of phosphorus (4.1.2)

- Conventional pollution problems be put on a fast-track that is separate from the present Remedial Action Plans (4.1.2)

- Specific time tables be developed for load reductions of pollutants and linked to budgets and regulatory actions (4.1.2)

- Early consideration be given to implementation of Stage 2 recommendations with attention to (4.1.2):
  - economic sanctions, e.g. elimination of government contracts and purchasing agreements with polluters
  - legal innovations, e.g. use of injunction
  - effective enforcement techniques, particularly for those areas where violations of laws and permits have existed for many years and where traditional enforcement methods have not achieved regulatory compliance

- Socio-economic considerations relevant to Remedial Action Plans receive increased attention by the Parties, particularly those plans at Stage 2 in the planning process, and, that increased efforts be directed at developing a comprehensive understanding of the social, economic and ecological implications and effects of remedial actions (4.2)

CHAPTER 5: LAKEWIDE MANAGEMENT PLANS

It is recommended that:

- The Canada-United States Framework for Lakewide Management Plans for Critical Pollutants be further developed to include (5.1):
  - specific reference to joint institutional roles and responsibilities for the development and implementation of Lakewide Management Plans
  - criteria and procedures for evaluation
  - an ecological perspective that assesses the role of processes such as the internal cycling of lake contaminants and fish predation on the prospects for achieving ecosystem objectives through reductions in toxic loading
  - recognition that Lakewide Management Plans are a comprehensive systematic planning framework, which is not solely limited to the control of critical pollutants, if an ecosystem approach is to be achieved

- A critical assessment of the effect of the current regulatory approach in terms of the adequacy of reporting and compliance be addressed in a Stage 1 Lakewide Management Plan (5.1)

- A manual, such as The Manual on Public Involvement in Environmental Assessment: Planning and Implementing Public Involvement Programs, be adopted as a basis for public participation programs in Lakewide Management Plans with the goal of achieving “joint planning” as defined in the manual (5.3)
• Essential information on loadings, pathways and fate of the critical persistent toxic chemicals be obtained as a priority so that practical mass balance models of critical classes of pollutants can be developed and priority can be assigned to source control in Lakewide Management Plans for each lake (5.4)

• Each Lakewide Management Plan incorporate objectives for reductions in toxic substances that will eliminate deformities and reproductive problems in fish, fish-eating birds, reptiles and mammals (5.5)

• The International Joint Commission and the Great Lakes Fishery Commission ensure that the peer review process is part of Lakewide Management Plans and Fishery Management Plans (5.5)

CHAPTER 6: SPILLS

It is recommended that:

• The Commission urge governments to give spill prevention a higher priority than contingency planning (6.1)

• A basinwide spill data system be established to monitor the number and causes of spills on the Great Lakes (6.1)

• A goal be established for reducing the number of marine transport spills by one-half every three years (6.1)

• Great Lakes transportation policy be reviewed and evaluated in terms of three questions (6.1):
  - What is the safest mode of transport for oil and toxic substances?
  - Would a single, binational Great Lakes Coast Guard be feasible and more effective than the two systems currently in use?
  - How can marine transport be made safer?

CHAPTER 7: POLLUTED GROUNDWATER

It is recommended that:

• the Parties and jurisdictions adopt and implement the recommendations of the SAB Technological Committee Workshop on Assessing the Potential for Great Lakes Contamination via Groundwater (October 1989, University of Waterloo), restated as follows (7.4):
  - using Geographic Information System computer technology, collate all hydrogeological data
  - develop a directory of hydrogeological expertise as a resource for conducting the required studies
  - produce a single, comprehensive, "state-of-the-knowledge" report, incorporating case histories of significant pollution of the Great Lakes by contaminated groundwater and examples of the transboundary movement of contaminants, should be prepared by the International Joint Commission to illustrate the significance of the problem
  - coordinate a United States/Canadian groundwater initiative so that resultant databases are fully integrated and compatible

• The Government of Canada and the Province of Ontario give priority to implementing the recommendations of the 1990 "Groundwater in Canada" report, published by the Science Council of Canada, including efforts to address (7.4):
- the lack of comprehensive regulations for groundwater protection and management
- minimal groundwater research activity
- the lack of activity in continuing educational retraining in groundwater science
- the manpower shortage and "brain drain"

- The Government of the United States give priority to addressing management and training questions related to Superfund and Resource Conservation and Recovery Act, and to taking steps to apply Superfund resources to appropriate Areas of Concern (7.4)
- The Commission issue a Special Report to the Parties urging action in remediating groundwater contamination and in establishing effective groundwater protection programs in partnership with provincial/state governments (7.4)
- The United States and Canada promote the use of alternative agricultural practices in the Great Lakes basin, such as low input farming, sustainable agricultural systems and integrated pest management, as national demonstrations for protecting groundwater and controlling nonpoint source pollution (7.4)

CHAPTER 8: GREAT LAKES EDUCATION

It is recommended that:

- The Great Lakes states and provinces develop environmental programs and courses in education facilities of universities and colleges that focus on issues relevant to the Great Lakes Basin Ecosystem (8.0).
- The Parties, in coordination with state and provincial governments, provide adequate financial and human resources to create and maintain a Great Lakes Education Clearinghouse, that will serve the functions already outlined above and assist in ensuring that the Great Lakes become an important component of curricula in a variety of subject areas (8.0)

CHAPTER 9: WETLANDS AND HERITAGE PROTECTION

It is recommended that:

- Research into the internal functioning of Great Lakes wetlands be encouraged to determine their contribution to the basin ecosystem (9.1.5)
- The inventory of the current status of wetlands be determined utilizing advanced technologies and standardized techniques (9.1.5)
- Both natural and human-induced stresses on wetland integrity be investigated and the individual and synergistic implications of these stresses on wetland community dynamics be identified (9.1.5)
- Further research be conducted into wetland creation and restoration techniques and incorporated into comprehensive management strategies to protect wetland integrity (9.1.5)
- Effective educational means be developed to identify, quantify and more effectively communicate the functional and aesthetic values of wetlands to humans (9.1.5)
- The Parties address the potential of the cluster Biosphere reserve concept, together with Canada/Man and the Biosphere, and United States/Man and the Biosphere in terms of Lake Superior as a priority for further extending Man and the Biosphere into the Great Lakes (9.2)
CHAPTER 10: INTEGRATED PEST MANAGEMENT

It is recommended that:

- Basinwide guidelines, outlining development goals for Integrated Pest Management programs, be established by the Parties under the Agreement and evaluated periodically by the Commission in its role of providing advice and recommendations to governments (10.0)

- Governments at all levels increase their resource commitment to all aspects of the development of Integrated Pest Management programs (10.0)

- All basin jurisdictions adopt Integrated Pest Management as their official state or provincial pest management policy, and government agencies with the responsibility for pest management implement Integrated Pest Management policies and practices and apply them to their own operations (10.0)

- Research on Integrated Pest Management concentrate on interdisciplinary efforts that develop options to chemical controls and reconcile the development of the agro-ecosystem with related concepts such as sustainable and organic agriculture, multiple cropping, conservation tillage and low input farming (10.0)

CHAPTER 11: EMERGING ISSUES

The following emerging issues receive further study:

- A Great Lakes Strategy
- Long-Range Transport of Toxic Substances
- Radionuclides
- Global Climate Change

CHAPTER 12: COUNCIL OF GREAT LAKES RESEARCH MANAGERS

It is recommended that:

  The Council of Great Lakes Governors and the Premiers of Ontario and Quebec, with support from the International Joint Commission, the Great Lakes Fishery Commission, and federal agencies on both sides of the border, begin to build a broadly based public consensus for a decade “Great Lakes 2000.” This statement of purpose will define a social, economic, environmental and political vision for the region in the 21st century (12.2.1)

- A Vision of and for the Research Community
  The research community in the Great Lakes basin interact more with the community at large if it is to deal effectively with the anticipated environmental, economic, social, technical and political challenges in the 1990s and beyond (12.2.1)

- Accepting Global Leadership
  A Great Lakes - St. Lawrence Ecosystem Studies International Center/Network be established as a clearly identified research entity (12.2.2)
• Developing Ecosystem Integrity Indicators
   A set of indicators of ecosystem integrity for the Great Lakes - St. Lawrence River basin be developed, that are scientifically-sound and socially-relevant that would provide a general sense of the state of the changes over time (12.2.2)

• Establishing Environment-Economy Linkages
   Research to quantify the relationship among economic development, ecosystem stress and environmental costs be undertaken as a priority so that decision-making in the Great Lakes basin in the 1990s can better incorporate environmental values in economic development (12.2.2)

• The 3 Rs: Recruitment, Replacement and Retention
   Within the next two years, the managers of research institutes in the Great Lakes, in conjunction with their colleagues in surrounding universities, develop a comprehensive, basinwide plan to double the number of trained scientists by the year 2000 (12.2.3)

• Transdisciplinary and Interjurisdictional Research
   Science programs developed by universities and laboratories include exploratory and anticipatory research initiatives (12.2.3)

• Using an Ecosystem Vision and Charter
   The decade, “Great Lakes 2000,” be a major component of a basinwide education and communication strategy. The initial focus should be on the development of a Great Lakes Ecosystem Charter through the involvement of schools, citizen interest groups, private corporations, universities and governments at all levels (12.2.4)

• Extension Services
   Research programs in the Great Lakes basin place greater emphasis on extension services that communicate and interpret research results for the public (12.2.4)

• Answering to the Public
   The research community in the Great Lakes improve communication links both to and from the public that it serves (12.2.4)

• Marketing Research and the Research Community
   The Great Lakes research community, and the Council of Great Lakes Research Managers, in particular, develop a proactive stance to public communication. An easily-accessible electronic “bulletin board” and other frequently-updated descriptions of research projects for the Great Lakes basin be developed and made available to all those who work with social and natural science issues in the region (12.2.4)

• Greater Community Involvement
   As part of the strategic plan for Great Lakes research for the 1990s, a citizen-oriented effort be encouraged to enhance environmental reporting, to marshal public involvement and to increase opportunities for exchanging information with the research community in the basin (12.2.4)

• Support to Policy and Management
   The Great Lakes - St. Lawrence Ecosystem Framework (GLSLEF) be designed so decision-makers can easily analyze and assess the implications of policy and management decisions (12.3.5)

• Interdisciplinary and Intersector Research
   Interdisciplinary research be strengthened by developing new working relationships among all the relevant disciplines and sectors (12.3.5)
Application of GLSLEF
As soon as possible a systems framework approach be applied to as many of the major issues in the basin as possible. Next, the GLSLEF should be developed to integrate the sets of relatively simple, issue-based models, which incorporate dominant ecological processes (12.3.5)

Cooperation and Sharing
Researchers and scholars must work together to make innovative and efficient use of existing data and models. The process must explicitly include social and economic information (12.3.5)

An Indicator of Each Type for Each Lake be Developed
- compliance indicators, those measurements that can be used to judge whether a stated ecosystem objective has been achieved
- diagnostic indicators, those measurements that can be used to determine the cause of impacts that prevent the achievement of the stated objectives
- early warning indicators, measurements that are especially sensitive to ecosystem stress and, thus, are capable of detecting the onset of deleterious conditions before significant impact has occurred (12.4.7)

Development of a Suite of Indicator Species
Several species be identified to integrate adequately the effects of all important stressors (12.4.7)

Further Identification of Integrator Species
Integrator species, such as the lake trout and the walleye, are suitable for use as monitoring tools in the Great Lakes. Other species include the herring gull as an indicator species for monitoring the effects of persistent organic toxicants and an alga, such as *Cladophora*, for monitoring changes in phosphorus availability (12.4.7)

Research on Ecosystem Indicators
Basic research be conducted in translating concepts related to ecosystem integrity into concrete measures that can be used as indicators of integrity (12.4.7)

Indicators of Human Health
- Biomarkers that measure both human beings and sentinel species (e.g. herring gulls) should be developed and validated for future use as early warning systems
- Registries should be established to gather statistical data on mortality and morbidity in the basin in such a manner that data from different jurisdictions can be compared and pooled, that data are amenable to cross-linkage with other statistical data banks, and so that trends in population health can be tracked in future years. As a minimum, tumors, respiratory and heart disease and congenital abnormalities should be included
- Studies of the offspring of women who consume large amounts of Great Lakes fish need to continue in order to investigate further the relationships between maternal fish consumption and effects such as cognitive and motor deficits, birth weight and gestational age (12.4.7)

Reasonable Human Use
Environmental goods and services be translated into monetary terms for compatibility with most economic policy-making instruments requires further research (12.4.7)

Perceptions of Environmental Quality and Quality of Life
A standardized instrument be developed to monitor trends in perceived environmental quality and quality of life for shareholders in the Great Lakes basin (12.4.7)

Develop a Framework of Indicators of Ecosystem Health
Research be conducted to determine the linkages between ecosystem and economic indicators related to human activities. The determination of these linkage relationships could monitor sustainable development concepts (12.4.7)
• A standardized framework be established to serve as a mechanism to facilitate the identification of water quality research needs and the coordination of research activities in the Great Lakes basin. Annual or biennial research inventories should become an integral part of this process, providing baseline information for the evaluation of the adequacy of the existing research programs of the Parties (12.5.1)

• Increased cooperation among research institutions and the inclusion of experts from disciplines other than the physical sciences (e.g. social sciences, economics, law, citizen groups) be encouraged to arrive at well-balanced, interdisciplinary approaches to the design of water quality research programs, consistent with the ecosystem approach adopted by the Parties (12.5.1)

• Continued significant research in the natural sciences is required to elucidate ecological processes in the Great Lakes, as well as to maintain a focus on water quality problems caused by toxic chemicals and other significant environmental perturbations (12.5.1)
1. INTRODUCTION

The characteristic purpose of an annual report is twofold. First, it is an assessment of the accomplishments during the preceding year. Second, it is an affirmation of objectives for the coming year. This introduction, however, takes a broad view of the challenges that are likely to confront the Board and the International Joint Commission (IJC) during the 1990s.

The duties and responsibilities of the Board have been set forth in the Great Lakes Water Quality Agreements (GLWQA) of 1972, 1978 and the Protocol of 1987. These provisions, subject to interpretation by the International Joint Commission (IJC) and the Science Advisory Board (SAB), are reflected in the priorities adopted by the Board to guide its work and to allocate its resources. The work plans and budget proposals of the Board express its strategies for fulfilling its obligations within the parameters established by the Agreements, as interpreted by the Commission and the two federal governments. The project proposals of the Board are, as they should be, detailed and specific. The immediate work plans of the Board cannot, however, cover all aspects of the comprehensive tasks necessary to attain the objectives of the Water Quality Agreements.

Assessment by the Board of accomplishments for any reporting period resemble snapshots taken of a complex and dynamic process: the restoration and protection of the Great Lakes - St. Lawrence Basin Ecosystems. Thus, the significance of the work of the Board, or indeed of the Commission, should not be judged by an assessment limited to a relatively brief period of time. The periodic reports by the Board (and also by the Commission) are inherently and unavoidably incomplete relative to the immense task to which the federal parties have committed themselves. To remedy the accumulated environmental degradation or contamination of the past and to achieve an ecologically sustainable and sanative future is a task requiring decades. To assess progress realistically toward the goals of the Water Quality Agreements one needs to review at least a decade of proposals or recommendations to see how and why tactical priorities have been implemented, disregarded or changed. The Science Advisory Board has from time to time undertaken this task, especially in regard to ascertaining the extent to which its findings and recommendations have been considered, adopted or ignored by the Commission and the governments. This report, however, in so far as it records accomplishments, provides an unavoidably-limited view of the work of the Board in relation to challenges in the future.

This Introduction looks ahead to the challenges that the Board may anticipate during the '90s. In substance, these are also challenges which will confront the International Joint Commission. We can anticipate future problems with some confidence because they are a continuation of the unsolved problems of the past. Many have been present since the first Water Quality Agreement was adopted in 1972; and yet with the passing of time and the growth of popular concern and impatience, most of them are becoming more acute. The sequence of events during the past two decades supports an inference that the decade of the '90s will be different in the following respects. First, our techno-scientific capabilities in terms of analysis, information and remediation seem certain to improve. Second, organized, popular concern over the state of the lakes will likely continue its growth and momentum; and third, programs to which the Parties are already committed (e.g. Remedial Action Plans) will have reached the implementation stage.

Over the past decade there has been a consistent rise in popular expectations regarding the restoration and protection of environmental quality in the lakes and their tributaries. An unprecedented show of popular concern characterized the public meeting on the Fifth Biennial Report on Great Lakes Water Quality (International Joint Commission 1990d), held by the
Commissioners at Hamilton, Ontario in October 1989. The growth in numbers, membership and activities of nongovernmental organizations on both sides of (and transcending) the international boundary indicates an awakening and informed concern for the future of the Great Lakes among the peoples of the region. This concern is being visibly and audibly translated into expectations regarding the role and responsibilities of the IJC. More may be expected of the Commission than it is able to deliver under existing political, legal and administrative circumstances. Yet enlarged expectations are being brought to bear on both the Commission and the Governments. If, as seems probable, these pressures are maintained during the ensuing decade, significant advances toward a more coherent and directive course of policymaking may be required in response to focused and informed public demand.

When considering what these developments might be, three basic aspects of policy will be addressed in which circumstances are changing and trends may be foreseen. These aspects are (1) Anticipation of Issues, (2) Assessment of Priorities and (3) Adaptations for Implementation.

1.1 Anticipation of Issues

In its June 7, 1990 statement of priorities for the current biennial cycle, the Commission declared that each of its advisory boards “should build into its work plans time and resources to consider emerging issues and unforeseen events so that the Commission can provide timely advice to governments.” This concern for the future has been a continuing priority for the Science Advisory Board, expressed in its strategy of “anticipate and prevent.” This Board priority is closely related to the Commission priority on assessment of the State of the Lakes and basinwide monitoring and reporting of environmental change. It also involves less critical priorities identified in the June 7 statement of the Commission. These “other matters” included exotic species and heritage (nondegradation) areas, both of which necessitate anticipatory or proactive strategies.

Elimination of toxic substances in the lakes has been at the top of Commission and Board priorities. Attention has been shifting from establishing levels of tolerance and estimating mass balances to the virtual elimination of persistent toxic substances. Prevention of further contamination is an obvious first step, but it requires changes in manufacturing, agriculture and waste management practices that demand time and money to accomplish and the will to make the effort. The atmospheric deposition of toxics causes the International Joint Commission concern regarding sources of pollution beyond the basin and even beyond national frontiers. Pollution of the air and water has become an international, even a global issue. The global warming question is only the most dramatic of a growing number of issues that will enlarge the scope of the Commission’s concerns in the years ahead.

Assessment of the state of the lakes is another high priority, but may need to be expanded beyond water quality to include all major ecological relationships throughout the basin. The reporting of human activity and behavior affecting the lakes needs to be incorporated in the assessment process. The Commission’s June 7, 1990 message to the Science Advisory Board (SAB) endorsed a broadening of focus beyond assessments limited to water quality to a more comprehensive review of effects. Certainly, the processes occurring cumulatively in the interface areas, between human activities and natural systems, will determine the future state of the lakes. The state of the lakes will inevitably affect human activities and options, not only in the basin but, more broadly, balanced in the biosphere.

These matters have been on the Board’s agenda and are continuing subjects of concern. They are most effectively addressed through timely action which will forestall further loss of quality and reduce the need for remedial measures in the future. Experience has demonstrated
the high cost of coping with undesirable exotics (e.g., sea lampreys, alewives and zebra mussels). Prevention measures, such as prohibiting the discharge of ballast water into the Great Lakes from ships in international commerce, allocate the cost of prevention at the source of the problem, whereas remedial measures are borne by communities and industries throughout the region. The Technological Committee of the Science Advisory Board has recommended measures to reduce the probability of the inadvertent introduction of exotic species. Intentional introductions from public or private sources need to be assessed in the context of the ecosystem approach to Great Lakes resource management.

Heritage areas have also received Board attention. Here, preventive measures are needed if the loss of currently nondegraded areas is to be avoided. The heritage issue is characterized by both hope and despair. A positive side is its relationship to a worldwide movement to safeguard and preserve the fast-dwindling natural areas now suffering the loss of variety and diversity of species and ecosystems, and impairment of natural beauty. The heritage issue also includes the preservation of sites of historic and cultural significance, including those of concern to Native American peoples. The Parties to the Water Quality Agreements are likewise signatories to the International Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO 1975); both are participants in the Man and the Biosphere programs sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO; this participation is still in effect despite the United States formal withdrawal from membership in UNESCO). Thus, the heritage issue is consistent with international commitments by both Parties. On the negative side is the failure of political will. Factors militating against preservation are legal interpretations of private property rights; economic imperatives associated with the promotion of economic growth, in particular with respect to land use, and budget restraints (largely short-term, but real) associated with allocating resources for protection.

Remedial Action Plans (RAPs) now being developed are, or should be, the beginning of major efforts toward environmental reconstruction and ecological restoration. According to conventional yardsticks, a great amount of money will be needed to move from plans to action. The public, the federal governments and the subnational jurisdictions should recognize this eventuality so that shortfalls between intentions and realizations do not breed cynicism regarding the whole Remedial Action Plan process and the sincerity of the Commission and the federal Parties. The ultimate test of the Remedial Action Plans will be in their implementation. The plans themselves resemble blueprints for action, but they are not self-executing. Their realization will require the adoption of environmental reconstruction and restorative ecology in terms of funded and administered public programs, organized to provide for public participation and intergovernmental cooperation.

Board activities are governed by the priorities set by the Commission. The priorities are characteristically stated as general policies and goals. A function of the Board is to review these priorities from a scientific perspective to further their refinement and propose other means for implementing them. The Board’s function is not to set priorities for the Commission, but it does have a responsibility to advise the Commission of any problems which its policies might encounter in implementation. The Board may also serve the Commission by bringing to its attention latent issues or alerting them of emerging issues, matters which may have failed to reach the attention of the Commissioners, but which they might wish to consider.

Two factors complicate the adoption and evaluation of priorities. The first is, obviously, the scope and complexity of the task of restoring and protecting the various aspects of environmental quality in the Great Lakes Basin Ecosystem, consistent with other priorities and
In neither of the Parties is there a single coordinating authority for policies pertaining to the Great Lakes.

values (e.g. economic). It is not easy to determine or to obtain universal agreement on the ordering of priorities. How priorities are ranked depends significantly upon the criteria applied to their assessment.

Here a second complicating factor arises, the political one. In neither of the Parties is there a single coordinating authority for policies pertaining to the Great Lakes. In theory, this policy-making could be performed by the offices of the President and Prime Minister. In fact, policies in each country are developed through a process of interagency negotiation within general parameters of fiscal and foreign policy laid down by the governments of the day. To the extent that Great Lakes issues are not first-order concerns of the political parties or chief executives, policy questions devolve among the bureaucratic agencies, each with its own limiting mandates and interests in the lakes. These interests may conflict and sometimes affect agency personnel, programs and budgets. The process is not necessarily conducive to setting a coherent policy for the lakes nor to extending the role of the International Joint Commission in the formulation and execution of policy. In the United States, an analogy may be found in the opposition of line agencies during the 1930s to the creation of a Tennessee Valley Authority to which, within the area of its jurisdiction, the individual agencies, in effect, were to be subordinate.

The priorities of the Science Advisory Board reflect its assessment of the tasks that are mandated under the Water Quality Agreements. But from the viewpoint of political realism, it is reasonable to wonder to what extent the preferences of the Parties expressed through budget allocations, reflect a coherent and considered judgment regarding the best ways to fulfill the commitments made in the Water Quality Agreements. The Parties are not monolithic entities, and lead positions on policy, as the U.S. Comptroller General (U.S. General Accounting Office 1982) has observed, may be taken by different agencies of the Parties on different issues. General policies of the Parties are more likely to reflect interagency compromise than they are coherent policy syntheses. It is, nonetheless, politically necessary and realistic for the Commission and the Board to work within the policy decisions of the federal Parties. While it is not the function of the International Joint Commission or its Boards to inquire into the motives and methods of the respective governments, it is their responsibility to provide advice regarding the possible consequences of the Parties’ decisions. This responsibility may become more critical as a growing public awareness of the Great Lakes and their problems finds expression through direct political action.

Opinion analysts indicate a time-lag between the public’s perception of a problem and the preparedness of its political representatives to acknowledge it. Conventional political wisdom calls for visibly addressing the problems of the day, not the problems that may (or may not) become politically significant tomorrow. There is little political payoff today for long-range anticipatory planning that will yield benefits only at some indefinite time in the future (e.g. the issue of global climate change). Risk aversion is characteristic of most governments: popular apprehension elicits a rhetorical response; scientific uncertainties argue for research and “justify” the postponement of politically-inconvenient action.

Priorities for policy may be assessed differently, depending upon the position and value judgment of the assessor. Elective officials hesitate (sometimes wisely) to avoid borrowing trouble from the future. Scientific evidence may suggest high priority for an issue that does not warrant the same level of concern politically. Public policy-makers, fully engaged with present troubles, are not likely to accord high priority to issues of uncertain significance for the future. But organized and articulate public demand for action can raise an issue in the scale of political priorities. For example, a large oil or chemical spill in the Great Lakes could arouse a popular reaction, disproportionate perhaps to chronic hazards, but capable of inducing a dramatic reassessment of priorities in relation to the Great Lakes.
Of course, the Commission and the Parties are public institutions. Their priorities may or may not be consistent with those of the governments of the day, although, as has been implied, there may be gaps and inconsistencies in public policy. During the coming decade, the public is likely to become more insistent that the Board and Commission underscore for the Parties the urgency for positive action to anticipate possible disasters and to take firm measures to prevent catastrophic accidents and recurring violations of ecosystem integrity, such as the introduction of non-indigenous species (e.g. sea lampreys, alewives and zebra mussels) from the discharge of ballast water from ships entering the Great Lakes from abroad. Thus, the Commission may find itself obliged to act in the absence of guidance from the Parties. In such circumstances, the Commission may benefit from the recommendations of the Science Advisory Board. If the function of the Board is “to speak truth to power,” it is important that the Board have the capability and independence to effectively and fairly address the issues of concern, especially those larger issues which cut across agency and disciplinary boundaries.

Comprehensive formulations of issues are likely to become better articulated during the 1990s. Advancements in the environmental sciences and improved understanding of complex systems will, in all likelihood, increase this probability. Efforts to resolve specific environmental problems (e.g. atmospheric deposition of pollutants, lake levels or zebra mussels) encounter linkages with other problems. Thus, it happens that the specific frequently cannot be resolved without dealing with the general. For this reason the Science Advisory Board has deemphasized its disciplinary committee structure in favor of issue-defined, multi-disciplinary task forces.

The multi-disciplinary team approach to issues may lead to a redefinition of priorities and even to their reordering as more is learned regarding causes, effects, and predictable impacts. The respective sciences, unaided, cannot easily reveal these interrelationships or assess their policy significance. "Pure" science is seldom directly translatable into decisionable propositions. A multi-disciplinary Science Advisory Board, composed solely of scientists eminent in their own disciplines, but without the interest or inclination to merge their capabilities into more inclusive, interdisciplinary problem analysis, could not safely be relied upon to serve the needs of the Commission.

The Science Advisory Board, formerly the Research Advisory Board, is constituted to bring coherent and evaluated findings of science into the policy process. It is not a Scientist's Advisory Board. In its role of translating scientific findings into policy alternatives, the Board, in addition to its strength in the natural sciences, needs the involvement of social scientists, economists, legalists, engineers, and opinion analysts. Unless the Board comprehends the policy process that it is expected to inform, its services to the Commission are likely to be imbalanced or, at worst, misleading. If the challenges of the 1990s to Great Lakes policy are as compelling as they appear, neither the Commission nor the Parties can afford to settle for anything less than the best science-based policy advice obtainable. This advice is best provided by a Board conversant with the art of giving advice and appreciative of the significance that its advice may have on the decision-makers who receive it. Thus, scientific expertise alone will be insufficient to enable the Board to help the Commission effectively.

Issues of implementation present the Commission and, hence, the Board with dilemmas to which each must adapt, but which neither can unilaterally resolve. These grow out of an incongruity among the Boundary Waters Treaty of 1909 and the Water Quality Agreements of 1972, 1978 and the Protocol of 1987 (International Joint Commission 1909; 1972; 1985; 1987b). The Treaty of 1909 and the recent intentions of the Parties to play a more active role in the implementation of the Agreements assume the separate responsibility of each respective Party...
Can coherent, systemic policies be generated by the collective action of disparate, autonomous governmental agencies, without an overall coordinative authority?

Regardless of anyone's intent, the International Joint Commission has become the symbol of binational responsibility for the custody and care of the Great Lakes. The expectations and objectives of organized nongovernmental groups in Canada and the United States are focused primarily on the Commission, rather than on the Parties. Decision-makers in Ottawa and Washington are rarely visible and usually nameless to the public-at-large. Citizens seldom know who makes the decisions within the offices of the agencies. But the Commissioners in public representations, as at Hamilton in October 1989, are very visible and personally identifiable. The interested public knows who appointed them, although not necessarily why. The public may question the Commissioners and engage in dialogue on matters of policy, opportunities seldom enjoyed with respect to officials in Ottawa or Washington. Should the Parties be perceived to be unresponsive to concerns in the region, the Commissioners, not the agencies, are out in front to "take the heat" of popular discontent. Should the Commissioners also be perceived as unresponsive, the more activist elements in the population are more likely to seek intercession from their political representatives than to seek to penetrate the opaque barriers shielding decision-makers in the bureaucracies.

Here is an incipient issue that may come to the fore in the 1990s. If public expectations are disappointed by the perceived inadequacy of official responses, the IJC may be first to suffer the loss of public credibility. Should this situation occur and the agencies still fail to respond effectively to popular dissatisfaction, the United States Congress and the Canadian Parliament could be importuned to establish new institutional arrangements for managing the environmental problems in the basin. This restructuring might be achieved by amplifying the role of the IJC by endowing it with executive powers and placing an administrative authority under its direction, or vice versa. The SAB, because of its concern for the social and economic implications of the Water Quality Agreements, should be in position to offer constructive advice should either action occur.

To discount this scenario as improbable and unrealistic would be, in effect, to disregard the history of the Boundary Waters Treaty and the IJC, and to discount the significance of the international regional seas programs adopted by a large number of nations during recent years. The pace of history is quickening and institutional adaptations not currently in demand may become necessary before the end of the decade. In any event, this possibility might suggest a closer look at how well the Parties, the Commission and its Boards are doing in moving toward the goals established by the Agreements. If there are ambiguities regarding initiatives and responsibilities, efforts should be made to resolve them.

In fact, the Commission has already undertaken this closer look through its Roles and Priorities Task Force. The Board needs to assist the Commission in alerting the Parties to the continuing growth of popular concern that exists in the Basin. And as the first line recipient of messages from the public concerning popular hopes and expectations, the IJC is in a position to advise the Parties concerning the direction and timing of official action toward realizing Water Quality Agreement objectives and operating beyond those issues. In performing this critical role, the IJC needs the most reliable advice possible from the Science Advisory Board. The Board ought not lose sight of this larger purpose in its preoccupation with detailed studies (which, of course, should not be neglected). There are few certainties in the future of the lakes for the administration of policies jointly agreed upon. Yet the extant Water Quality Agreements, in contrast to the Boundary Waters Treaty, adopt a holistic systemic approach to policy and administration for the Great Lakes basin. Implementation of this approach implies coherent, systemic policies. Can coherent, systemic policies be generated by the collective action of disparate, autonomous governmental agencies, without an overall coordinative authority? The roles assumed by the agencies representing the Parties under the 1987 Protocol show that they are unwilling to allow the IJC or some comparable body to assume this authority.
the lakes but there are discernible probabilities and possibilities. These prospects should be considered in shaping the agendas of the Commission and its Board during the coming decade.

Today, more than ever, the Commission needs an independent, forward-looking Board. To achieve the basinwide, comprehensive, integrative objectives of the Water Quality Agreements there must be a focal point for the coordination of policy and action. At present, the Commission is not fully empowered to occupy this position. But, it is the one institution best able to facilitate a holistic, basin-wide approach to the remediation of accumulated damage to the lakes and to the restoration of their ecological integrity. However good their intentions, the multiple agencies of the Parties, in fulfilling their designated missions, will never be able to provide the unifying, coordinative pressure that the achievement of the binational commitment to a sustainable Great Lakes Basin Ecosystem requires.
2. STATE OF THE GREAT LAKES BASIN ECOSYSTEM FRAMEWORK

... it is better to deal incompletely with the whole than wholly with the incomplete.

Herman Daly

The Great Lakes Water Quality Agreement (GLWQA)(Annex 2) refers to a systematic and comprehensive ecosystem approach to the restoration of the impaired uses of the resources in the Great Lakes. The Science Advisory Board has been concerned for some time about difficulties in applying an ecosystem approach to Remedial Action Plans. This difficulty is partly due to the language of ecology, which is generally unfamiliar to administrators concerned with Great Lakes cleanup and management. In part, the problems lie with the institutional/jurisdictional mandates, which impose restraints on decision-makers. Consequently, holistic prescriptions implied in the ecosystem approach can be ignored because they lie beyond their domain of responsibility. These factors are further exacerbated by the narrowness of the vocabulary defining performance objectives, limited, by and large, to physico-chemical properties of impaired uses. While performance indicators based on ecosystem criteria, such as health and integrity, are increasingly advocated in professional literature, they are often dismissed as too complex for day-to-day management. One should not be surprised, therefore, at the tendency to fall back on the traditional engineering fixes for ameliorating water quality.

An assessment of the “state” ultimately relies on a judgement of the rightness and wrongness of human actions as they affect nature. The theory underlying moral choice is the domain of ethics, the field of moral science. While central concerns in this field have been anthropocentric, involving person-to-person and person-to-society relationships, there is a growing awareness of the need to develop an ecosystem ethic, based on man in nature. The development of such a code would provide a powerful complement to the GLWQA, the implementation of an ecosystem approach and to any framework developed to assess the State of the Great Lakes Basin Ecosystem.

The Introduction points to socio-political impediments to implementing a comprehensive ecosystem approach to restoring the Great Lakes. Another point is unfolding as the first phase of the Remedial Action Plans (RAPs) are nearing completion. This is the weakness in the analysis of socio-economic causes of the degradation of the lakes and the social benefits obtained from restoring impaired uses (e.g. the rise in the economic and aesthetic values of shorelines). Conclusions of workshops, views expressed in public hearings, and other forms of feedback from communities in the basin indicate a general awareness that the whole is greater than the parts. The public has strongly urged the Science Advisory Board (SAB) to take a leadership role in developing holistic assessments of the benefits of the ecosystem approach. This urging may translate into practical “how to” manuals for grass roots application at one level and the expression of ecological values in public policies at another.

The Science Advisory Board through the Societal Committee has identified the need to develop a comprehensive framework for integrating ecological values in socio-economic decisions. Such a framework would act as a template for including physical and social indicators and would provide a common vocabulary to transcend the social and physical objectives of the Great Lakes management and cleanup programs.
While the underlying thesis is holistic (i.e. maintaining the integrity of the basin's aquatic and terrestrial ecosystem), the operative language is still based on the traditional, reductionist approach to science. The framework does not usurp the need to develop dynamic models for understanding system behaviour. Rather, it helps identify key indicators in environment-economy interactions. Furthermore, the framework should provide incentives to reorient the current system of socio-economic data in terms of the needs for environmental analysis. Thus, new spatial frames, such as ecoregions and watersheds, and activity sectors, such as waste residual generation, environmental restructuring and harvesting, need to be introduced into the data collection system. These questions were the subject of the SAB Scoping Workshop on Human Activities and State of the Ecosystem Reporting (February 18-19, 1991), University of Ottawa (International Joint Commission 1991a).

There is a wealth of socio-economic data describing the social and economic state of the Great Lakes basin. Nonetheless, the workshop participants found that these data are of limited use in analyzing the levels and trends of human stresses on the basin’s ecosystems. Some of the major factors are the poor quality of data on loading from municipal and industrial sources, the lack of information on harvesting practices in agriculture, forestry and fishing, and the failure to establish a systematic, land-use-change database. Work in the latter tended to be ad hoc and many of these data are a decade or so old. Other issues raised in the workshop were the lack of coordination in data collection between the United States and Canada, the fragmentation of data sources, and the paradox of too many details obscuring broad-based trends.

Key conclusions of the workshop were: (a) government cost cutting results in easy-to-collect data as opposed to the more complex, but relevant, indicators of ecosystem health; (b) the framework of socio-economic statistics, particularly as reflected in national accounting concepts (i.e. Gross National Product), is largely inappropriate for environment-economy analysis; (c) information value is greatly enhanced when linked to system behavioural models; (d) scientists have not been as forthcoming as they should have been with respect to communicating the nature of environmental risk to decision-makers and the public; (e) environmental analytical frameworks are generally unfamiliar to the “uninitiated.” Greater efforts need to be made in communicating new methods and techniques in environmental analysis. A better understanding of the ecosystem approach would encourage political commitment to resource reallocation; (f) environmental research needs to be directed more towards the macro perspective of environment-economy linkages, governments need to adapt to holistic management, and the public requires better information on the implications of continuing on the current high energy-material path and (g) environmental stress and ecosystem response knows no frontiers. The need for natural boundaries for the analytical frame was strongly urged, such as river basins and ecological areas. A corollary is for greater integration of United States - Canada environmental database.

### 2.2.1 What is Meant by a Systematic, Comprehensive Ecosystem Approach

It is becoming increasingly clear that systematic means that everything is connected with everything else. The linkages of concern here are those that connect human well-being with the quality of the environment. Human health is perhaps the most important of these. The new science of systems analysis describes physical processes in terms of work, which must conform to the law of the conservation of matter and energy. From an environmental perspective, economic production can be described as a transformation process: resources are extracted and harvested and turned into useful commodities for human consumption. In a systems approach, where the law of conservation must apply, a “useful product” must also include the generation of waste residuals and the depletion of natural resources in order to account for a mass material-energy balance. Consumption must similarly be viewed as a physical process where all products are eventually “used up.” Pollution loadings are treated
as unwanted residuals of production and consumption processes. An effective Remedial Action Plan must account for the mass balance, described by production processes and consumption processes within their Area of Concern.

Comprehensive extends the systems concept to include temporal and spatial linkages of physical production and consumption processes to the ecosystem. The pathways are complex. First, waste residuals are manifest in the three fundamental states of matter: solids, liquids and gases. Second, the spatial interactions of physical stocks and flows must be accounted for, such as air pollutants transported in the high atmosphere and deposited far from their original source. Third, production processes are important factors in restructuring the environment. Here we need only think of man-made construction activities reflected in urbanization processes, transport infrastructure, dams and so forth. Fourth, demographic aspects need to be considered, not only in terms of population growth and migration, but also in terms of implications of aging populations and changing lifestyles and values. All these factors have various physical impacts on the state of the environment. Fifth, comprehensive includes the dynamic interaction of among natural and human activities (i.e. climate, hydrology and geophysical factors).

In this way the ecosystem approach is viewed in the context of a natural productivity system, which is impaired by human activities. These impairments can be characterized as stressors of the following types: (1) pollution and contaminant loadings, (2) harvesting of biological resources and (3) permanent environmental restructuring. The third impairment reflects the modification of ecosystems to human cultural stresses, that is human settlements, industrialization and large-scale development projects.

2.2.2 State of the Great Lakes Basin Ecosystem Reporting

Reporting on the state of the basin, rather than the state of the lakes, is essential for understanding the interactive relationship of humankind and the environment. This approach falls in line with comprehensive State-of-Environment (SOE) assessments, referred to as SOE reports. National State of Environment reports were initiated in the 1970s as a country-wide audit of environmental conditions. Recently, SOE reporting has become a method of coherent, spatial audit for regions and even municipalities. The Science Advisory Board is encouraged by the development of comprehensive, regional audits and the implied accountability of the political process to environmental states.

The traditional State of the Lakes Report, produced by the Water Quality Board for the International Joint Commission (IJC), is currently being reconsidered in light of the government's SOE reporting programs. The question is whether the IJC should produce its own independent report or whether it should review SOE reports produced by government agencies (i.e. Parties) concerned with managing, protecting and cleaning up the Great Lakes system.

The SAB members have expressed reservations in relegating the IJC's role to being merely a "reviewer" as opposed to a "producer" of Great Lakes SOE reports. There are three main concerns. First, one of the strengths of the IJC is its arms-length advisory role in assessing programs and activities undertaken to carry out in terms of the Great Lakes Water Quality Agreement. Government SOE reports never escape the public perception that these reporting agencies are both "player" and "referee." Second, the IJC mandate transcends the jurisdictional boundaries; it is, therefore, the only agency that can survey the Great Lake's basin as a whole. Third, the IJC has proven experience in state-of-the lakes reporting and is more likely to utilize innovative methods and approaches than are those that produce official government reports.
2.3 Creating a Code of Ethics for the Great Lakes Basin Ecosystem

Considerable interest in creating a code of ethics to guide human functioning in the Great Lakes Basin Ecosystem has surfaced over the past ten years (Schaefer 1989). Scholars, Native American tribes, religious and secular organizations, governments at various levels, industries and foundations in the region have endeavored during this time to conceptualize their valuing of the natural environment and to identify the kind of behavior needed to assure its conservation for multiple, beneficent uses. These diverse efforts were identified in a report published in 1989 on behalf of the Science Advisory Board of the International Joint Commission, and a rationale was proffered for the Commission to take the initiative in developing an ethics code specifically for the ecosystem (Schaefer 1989). The responses to this report indicate that a project of this type is needed to facilitate the “ecosystem approach,” adopted by the United States and Canada in the Water Quality Agreement of 1978 and affirmed in subsequent amendments for dealing with the myriad problems in the basin. Young persons should play a leading role in the development of a code of ecosystem ethics.

Subsequent endeavors by various organizations and governments make it clear that the creation of an ethics code is an emerging issue of importance to the Commission. Prominent among recent efforts is the seminal work by the Rawson Academy of Aquatic Science in formulating “The Ecosystem Charter” for the Great Lakes - St. Lawrence basin (Rawson 1989), the Province of Ontario’s commitment to codify an environmental Bill of Rights, the “Earth Covenant: A Citizens’ Treaty for Common Ecological Security,” brought about by diverse multinational grassroots organizations (Global Education Associates 1989) and the “Ecumenical Theological Affirmation on Justice, Peace and the Integrity of Creation,” (World Council of Churches 1989/90).

These recent efforts add to the impressive array of initiatives already taken by the United Nations in its “World Charter for Nature,” the AuSable Institute’s “Christian Land Ethic,” the Akwesasne “World Constitution,” and many others which are at various stages of formalization (Schaefer 1989). Whether identified as charters, Bills of Rights, covenants or ethics codes, all of these efforts are aimed at articulating an understanding of the way human beings ought to function within the natural environment of which they are integral parts. The use of the term “ethics” has the advantage of identifying both individual and group actions from the perspective of what is right and, therefore, places these actions within the context of morality, where human thinking and behavior can be significantly affected.

At the present time, there is widespread interest within governments and various sectors of society to frame ethical standards which would guide collective and individual conduct. This interest and the aforementioned endeavors to develop charters, Bills of Rights and covenants pertaining to the environment has the potential to contribute to the creation of an ethics code for the ecosystem. Through a code of ethics, the kind of thinking and acting which is essential to restore and maintain the integrity of the ecosystem will be brought to the fore as envisioned in the Agreement and its amendments (Schaefer 1989).
2.3.1 A Method for Developing an Ethics Code for the Ecosystem

The most important aspects of creating a code of ethics include public involvement from the inception of the developmental process and the formal involvement of representatives of all sectors of society. Only when the values of people as individuals and groups are fully incorporated can the goal of an ethics code be achieved.

Because several eminent philosophers from academic institutions in Canada and the United States have contributed to the dialogue on environmental ethics from an ecosystemic perspective, they would be invaluable in the task of initially writing and creating a draft code for discussion (Schaefer 1989). A small number (five) of them could prepare brief papers, which would explain how each would conceptualize an ethics code, based on the "ecosystem approach" language of the Agreement.

Approximately one month after the papers are prepared, at least three of the philosophers would be invited to a roundtable with the Commissioners and members of the Board to discuss their papers and to answer questions posed by invited representatives of the various societal sectors as well as from the interested public in attendance. Directions for drafting an ethics code would be determined by the roundtable participants and a further draft would be prepared at that time on the basis of the discussion.

The next step in the process would be the wide dissemination of the draft code submitted by the philosophers and a critical discussion of the draft at a series of workshops held in different parts of the basin. Again, representatives from all sectors of society should be invited to attend the workshops, which should also be open to the public, and suggestions for altering the draft would be solicited.

While the workshops are ongoing, an in-depth public survey would be conducted throughout the region. The purpose of this survey would be to test the compatibility of the draft ethic with the values of the people basin-wide and the moral principles which they believe ought to flow from these values.

The results of the workshops and the survey would be reviewed to determine any consensus for specifically altering the draft ethic. The proposed code of ethics would then be submitted to the Commission for consideration at the next biennial meeting.

At subsequent biennial meetings, the ethics code should be assessed in terms of how it has been applied at various levels of endeavor within the states and provinces. This kind of review and evaluation would assure that the code remains a dynamic concept and not one that is adopted and then forgotten.

2.3.2 The Form of the Ethics Code

There are diverse ways in which a code of ethics for the ecosystem can be configured, and the interactive among between the Commission, philosophers, roundtable participants and the public will, in large part, determine its actual framework and much of its substance. The draft code developed by the philosophers will be embellished through the input provided by invited representatives of various sectors of society in the basin and the interested public at the workshops described above.

Some basic features of a code of ethics can be anticipated. For example, an ethics code for the ecosystem would probably begin with a preamble succinctly describing the fundamental purpose of the Commission and the "ecosystem approach" which it adopted in 1978 to tackle
the myriad problems in the region. Awareness statements could follow, acknowledging that the ecosystem is composed of interacting elements of water, air, land and biological life, including human beings; that human beings are dependent upon the well-being of the ecosystem for their wide variety of endeavors; that the condition of the ecosystem affects the larger biosphere; that human beings as the rational biological life of the ecosystem are morally responsible to each other and future generations for its well-being and that human beings ought to determine the kind of behavior which is conducive to restoring and maintaining the integrity of the ecosystem.

Broad threats to the ecosystem due to inappropriate human behavior could subsequently be enumerated briefly. A statement of conviction would most likely follow, indicating that human beings as individuals and groups at the various levels of political, economic and societal life can rise above their self-interests and identify behavior which is conducive to the common good, that is to the ecosystem as a whole, now and in the future.

General principles to guide the conduct of individuals and groups in the ecosystem could then be listed. Specific principles to guide groups such as governments, corporations, small businesses, families and individuals in their various roles in life could follow. All principles would aim at appealing to the inherent moral sense of the people basin-wide in an effort to show confidence in their innate ability to think about and to do what is right.

The code of ethics would undoubtedly conclude with anticipation that the code would be considered for implementation in creative ways at the various political, economic and social levels of endeavor throughout the ecosystem. These directions would be couched in language which appeals to the perception of what is right and just and good for all in the ecosystem as a whole.

2.3.3 Conclusion

The Commission has a unique role to further binational goals pursuant to the Agreement by initiating the creation of a code of ethics for the Great Lakes Basin Ecosystem (Schaefer 1989). An awareness of the importance of ethics to the future of the Great Lakes is evident, and considerable groundwork has been undertaken in anticipation of such a development. The method for developing an ethics code and the form it should take are relevant for discussion. Through the creation of a code of ethics, the Commission will elevate discussion of the problems in the ecosystem to a moral level and may thus be able to further mobilize the collective thinking, feeling and will of the people towards the resolution of challenges to progress under the Agreement.

The Commission’s upcoming biennial meeting in Traverse City, Michigan would provide an excellent setting within which to initiate discussion of this endeavour, with a view to its completion by the 1993 meeting.

Therefore, it is recommended that:

- a code of ethics to guide human activities and involving young people, be developed for the Great Lakes Basin Ecosystem, under the auspices of the IJC.
3. HUMAN AND ECOSYSTEM HEALTH

In the past five years there has been an improvement in the understanding of the actual effects of persistent toxic substances that have been observed in fish, wildlife and humans. Chapter 6 of Appendix B of the 1987 Water Quality Board Report (International Joint Commission 1989g) included detailed information on the status of populations of three top predators: bald eagles, mink and otters. In 1989, the joint publication of “Great Lakes, Great Legacy?” by the Conservation Foundation (United States) and the Institute for Research on Public Policy (IRPP, Canada) for the first time brought together much of the literature on the various effects of persistent toxic substances on organisms exposed through Great Lakes foodwebs. In 1989, the Cause-Effect Linkages Workshop (International Joint Commission 1989c), hosted by the Council of Great Lakes Research Managers, explored the scientific basis for causality and documented the effects of persistent toxic substances on two fish species, one reptile species, various bird species and two mammal species, including humans. The Canadian government has compiled the evidence of the effects and levels of persistent toxic substances in its 1991 publication “Toxic Chemicals in the Great Lakes and Associated Effects.”

Two different kinds of effects are being attributed to persistent toxic substances. The traditional concern has centered on carcinogenesis. Various fish species from a variety of polluted areas in the Great Lakes basin have exhibited a high incidence of tumors. More recently there has been a growing appreciation of the role of persistent toxic substances in affecting embryonic development and survival. Effects on embryos include an increased incidence of deformities and mortality as well as subtle effects such as feminization and abnormal behavioral development.

In 1990, the Science Advisory Board set up a Biological Effects Subcommittee to advise on changes occurring in populations of organisms as a result of exposures to persistent toxic substances. The subcommittee held four successful roundtables on the following species: bald eagle and osprey, double-crested cormorant, lake trout and other salmonids, and mink and otters. Roundtables have proved a useful format, not only for establishing the current state of knowledge of the status of a species and the factors affecting it, but also for identifying future research needs. Recognized experts on various aspects of the species were identified and requested to attend the roundtables and, in some cases, loose, organizational structures have been formed to coordinate future research and approaches to funding agencies. Future work of the Biological Effects Subcommittee may include consideration of tumors in fish, embryonic feminization, biochemical markers and belugas.

3.1.1 Bald Eagles

The Bald Eagle Workshop was convened on February 12 and 13, 1990, by the Biological Effects Subcommittee (International Joint Commission 1990f). The purpose of the workshop was to evaluate the bald eagle as an indicator species for the Great Lakes Basin Ecosystem. The workshop presented the latest information on the status of the bald eagle within the Great Lakes basin. Data from field studies, monitoring programs and rehabilitation efforts were presented; they outlined known and suspected impediments on the road to full recovery.

The progress toward recovery of the bald eagle population within the entire Great Lakes basin has paralleled the improved status of the species across North America except in shoreline locations. Primary credit has been attributed to the decline in contaminants, particularly DDT and metabolites in eagles and their prey base. Contributing to the improving status have been an aggressive program by natural resource agencies in the management/protection/enhancement of eagles and their habitat, and programs for public awareness,
involvement and education. These efforts have resulted in a documented improvement in adult survival, productivity and numbers of breeding areas on jurisdictional and regional bases.

Mortality and injury to non-nesting eagles (impacts with vehicles, structures, etc.) continue to be dominated by trauma. Necropsy results show that lead and dieldrin poisoning are secondary to trauma as causes of death of Great Lakes eagles. Trapping and shooting are secondary causes of injury to eagles. Shooting injuries are closely associated with the opening of waterfowl seasons. Successfully rehabilitated eagles are released back into the wild when possible, and are being monitored for subsequent survival and reproductive efforts. Hacking of eaglets in Ontario and fostering of eaglets in Ohio have been highly successful in fledging eaglets along the shorelines of Lake Erie. However, it is too early to determine whether these efforts will result in the return of these birds to Lake Erie as breeding adults.

Despite this improvement, the bald eagle subpopulation located along the Great Lakes shorelines, connecting channels and embayments is lagging behind the recovery of inland eagles. No bald eagle breeding areas are known to exist along the Lake Superior shoreline of Minnesota or the entire shoreline of Lake Ontario. Only one nest is known on the Lake Huron shoreline of Ontario, though there are increased observations of immature adults along the Bruce Peninsula shoreline and there are seven known nests between Thunder Bay and Sault Ste. Marie on the Lake Superior shoreline. Furthermore, shoreline eagles in Wisconsin and Michigan produce fewer young per occupied nest and have lower success rates in reproduction than eagles in adjacent inland areas. In Michigan, Ohio and southwestern Ontario, the coastal subpopulation is composed of a higher percentage of young adult pairs than in inland populations. These young, inexperienced pairs exhibit lower rates of productivity for the first two years than older, more experienced pairs. However, experienced Great Lakes pairs (3+ years) in Michigan and Ohio have reproductive outcomes similar to inexperienced pairs (one to two years), and are significantly less productive than inland experienced pairs. Furthermore, Great Lakes breeding pairs along the Lake Michigan and Huron shorelines of Michigan exhibit near total reproductive failure by the fifth year of occupying a breeding area. This phenomenon may account for the suspected higher turnover rates among adults along the Wisconsin, Michigan and southwestern Ontario shorelines. In Wisconsin, the lower reproductive rates of coastal eagles may in part be due to higher rates of nestling mortality than in inland areas. As a result of these reproductive differences between inland and coastal subpopulations, it is postulated that the shoreline subpopulation is unable to sustain itself and is being maintained by surplus immigrants from inland areas.

At present, there is a strong link emerging between the poor reproductive success of shoreline eagles and persistent toxic chemicals. In Wisconsin, there is a correlation between contaminated, addled eggs and areas with waterfowl consumption advisories. In Michigan and Ohio, concentrations of total PCBs, p,p'-DDE and dieldrin are significantly higher in addled eggs recovered from shoreline nests than in those from inland nests. Additionally, concentrations of these contaminants are inversely correlated to two measures of productivity for four shoreline reaches and two inland realms. Nests along the Lake Michigan and Huron shorelines exhibited the lowest reproductive rates and the highest contaminant residues in addled eggs (Table 3.1). This association between poor productivity and elevated egg residues, is consistent with a nationwide study in the United States which correlated egg residues of <4.0 µg/g total PCBs, <1.0 µg/g p,p'-DDE and <0.1 µg/g dieldrin (fresh wet weight) with normal reproduction. In Wisconsin, contaminants were detected in higher concentrations in eaglet carcasses recovered from Lake Superior shoreline nests than from inland nests. For eaglets surviving to the near-fledgling state in Michigan, blood sera concentrations of PCBs and p,p'-DDE were six times higher in Great Lakes eaglets than in inland eaglets. Similarly, eaglets on Lake Erie shorelines have levels of contamination four to six times higher than in interior Michigan. These results call into question the viability of these fledged young to survive to adulthood and to be recruited into the breeding population.
ADDLED EGG RESIDUES (mg/g Fresh Wet Weight) PER OCCUPIED BREEDING AREA

<table>
<thead>
<tr>
<th>LAKE BASIN/REGION</th>
<th>PCBs</th>
<th>p,p'-DDE</th>
<th>Dieldrin</th>
<th>No./Fledged Young</th>
<th>%/Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Huron</td>
<td>107.5</td>
<td>41.5</td>
<td>2.35</td>
<td>0.36</td>
<td>27.3</td>
</tr>
<tr>
<td>Lake Michigan</td>
<td>55.5</td>
<td>30.5</td>
<td>2.05</td>
<td>0.65</td>
<td>42.3</td>
</tr>
<tr>
<td>Lake Erie</td>
<td>25.3</td>
<td>4.8</td>
<td>0.52</td>
<td>0.76</td>
<td>51.2</td>
</tr>
<tr>
<td>Lake Superior</td>
<td>13.5</td>
<td>6.2</td>
<td>0.35</td>
<td>0.84</td>
<td>55.2</td>
</tr>
<tr>
<td>Mich.-Upper Peninsula</td>
<td>10.3</td>
<td>4.1</td>
<td>0.32</td>
<td>0.97</td>
<td>60.5</td>
</tr>
<tr>
<td>Mich.-Lower Peninsula</td>
<td>9.3</td>
<td>3.1</td>
<td>0.13</td>
<td>1.14</td>
<td>71.1</td>
</tr>
</tbody>
</table>

These elevated organochlorine residues in Great Lakes bald eagles is further consistent with the elevated levels of these contaminants in other Great Lakes biota. The bald eagle’s position as an upper trophic level predator causes it to bioaccumulate these persistent chemicals from a diverse prey base. Studies in Wisconsin and Michigan suggest that Great Lakes eagles forage on a higher percentage of avian prey, particularly aquatic feeding birds such as gulls, waterfowl and colonial waterbirds, than do eagles nesting inland. This avian prey is itself elevated in organochlorine compounds above those levels found in the fish and other aquatic organisms upon which these species forage. Turtles, which are highly contaminated, are a significant food item for birds nesting in southwestern Ontario near Lake Erie. These additional trophic levels have contributed to some of the highest organochlorine residues in addled eggs and blood ever encountered in eagles.

The toxicological significance of PCBs for developing bald eagle embryos was evaluated by means of PCB congener-specific analysis and the H-4-ⅡE bioassay (Tillitt et al, in press) on two addled eggs from Michigan. One egg was obtained from a nest along the northern Lake Michigan shoreline of Big Bay de Noc, and the other from the western Lake Superior shoreline of Thunder Bay. Congener-specific analysis provides a measure of the total toxicity possible via a summation of the concentrations of the individually-detected congeners, expressed as 2,3,7,8-TCDD equivalents. Equivalents are the concentration of each congener multiplied by its respective dioxin equivalency factor, laboratory-derived measures of a congener’s ability to induce a hepatic enzyme response, relative to the most toxic dioxin, 2,3,7,8-TCDD (Water Quality Board 1989). The enzyme potency of dioxin-like compounds correlates well with known toxic responses, such as teratogenicity, growth retardation and immunosuppression in laboratory animals.

The H-4-ⅡE bioassay method is a direct in vitro measure of hepatic enzyme induction, relative to 2,3,7,8-TCDD, for the dioxin-like mixture of PCB congeners in a sample. This extract assay takes into account interactions (synergism, antagonism, etc.) among the individual congeners, the degree of which is approximated by the difference between the two measures of total toxicity.

Table 3.2 gives the results of the two methods compared with total PCB, measured using standard methods. The extract bioassay results are consistently lower than equivalents derived from analytical chemistry, suggesting some biological antagonism. The TCDD equivalents come almost exclusively from one PCB congener, IUPAC 126 (3,3’,4,4’,5-), from both sites. All four analyses showed significant contamination by PCBs. To place these data in perspective, 2-5 μg/g total PCB is the lowest observable effect level in studies of bird reproduction, including laboratory chickens as well as Forster’s terns and bald eagles on the Great Lakes. At the other end of the spectrum, 1,000 pg/g injected into the eggs of white leghorn.
chickens completely inhibits the hatching of chicks (100% mortality). A lowest observable effect level for white leghorn chicken embryos, injected with actual 2,3,7,8-TCDD, is 6.5 pg/g in the egg contents, excluding the shell. If bald eagles are as sensitive as chickens, which the total PCB data seem to indicate, then PCBs occur in eagles at embryotoxic concentrations. Work is underway to analyze the entire archived set of addled eggs from Michigan and Ohio.

Table 3.2

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>TOTAL PCBs</th>
<th>TCDD EQUIVALENTS ATTRIBUTABLE TO PCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STANDARD METHODS (OC SCAN)</td>
<td>CONGENER SPECIFIC PCB ANALYSIS (H4-II-E)</td>
</tr>
<tr>
<td>Lake Huron</td>
<td>96 µg/g</td>
<td>98 µg/g</td>
</tr>
<tr>
<td>Lake Michigan</td>
<td>51 µg/g</td>
<td>83 µg/g</td>
</tr>
</tbody>
</table>

Aside from contaminants, there are habitat, prey-base, management and other factors which may impede eagle recovery within the basin. While the species has shown a degree of adaptability in the requirements of a breeding habitat relative to disturbance, it is not known if Great Lakes subpopulations are limited by the lack of breeding habitat along certain shoreline reaches. Habitat Suitability Indices are being developed by several agencies to assess the extent of suitable shoreline breeding habitat, with emphasis on assessing historical nest sites. The survivorship of birds in the period of four to five years spanning fledging to adulthood is largely unknown in the life history of bald eagles. Observations from Ohio suggest that human disturbance may reduce the survival of newly-fledged eaglets during this important life stage when foraging behaviors are being learned. Along some shoreline reaches, juvenile habitat may be limited. In Michigan, inland breeding areas, which are accessible to anadromous fish runs from the Great Lakes, have lower measures of productivity than shoreline breeding pairs. Proposals to extend anadromous fish further inland threaten to compromise currently productive breeding areas. These inland eagles can also be affected by management programs proposed to enhance a sports fishery, but which alter the prey base of the eagle through roughfish removals.

In conclusion, populations of eagles integrate many aspects of their environment. They rely on suitable breeding habitat and a diverse, contaminant-free prey base. Population and breeding performance depend on several different components of habitat quality. With the eagles as an indicator species, an entire suite of physical habitat and water quality factors needs to be present for success. As an integrator of these factors, the eagle can reflect the state of the coastal environment of the Great Lakes as a whole. Therefore, the species serves as an effective indicator of overall habitat quality by integrating contaminant and habitat features. The future presence of bald eagles throughout the basin should reflect the ability of the Great Lakes to support all levels of consumers, including humans.

On the above basis, it is recommended that:

- the SAB 1989 recommendation to the Parties be implemented to develop ecosystem objectives that specify the number of pairs of bald eagles (*Haliaeetus leucocephalus*), their productivity, and egg and brain residues, associated with the virtual elimination of persistent toxic substances from the Great Lakes and interconnecting channels.
The second roundtable was one of a continuing series of working sessions on double-crested cormorants (*Phalacrocorax auritus*) initiated in December 1987 by Dr. James Ludwig of Ecological Research Services and the staff of the Canadian Wildlife Service. During the past four years, research and monitoring of Great Lakes populations of double-crested cormorants have shown that this species is one of the most reliable organisms as an indicator of the levels, trends and effects of persistent toxic substances. Research in 1974 on herring gulls (*Larus argentatus*) in the lower lakes and in 1983 on Forster’s terns (*Sterna forsteri*) was undertaken to investigate whether the observed reproductive failure characterized by embryo mortality, edema and congenital deformities might be caused by chick-edema active compounds such as 2,3,7,8-TCDD and PCBs (reviewed in Gilbertson et al., in press).

This initial research related the signs of chick-edema disease in herring gull embryos from Lake Ontario to 2,3,7,8-TCDD and the signs in Forster’s tern embryos from Green Bay, Wisconsin mainly to 3,3’,4,4’,5- and 2,3,3’,4,4’-pentachlorobiphenyls. Similar effects have been documented in colonies of double-crested cormorants throughout the Great Lakes basin. Figure 3.1 shows the incidence of bill deformities in colonies in different parts of the Great Lakes (Fox et al., in press). The occurrence of deformities in colonial, fish-eating birds seems to be a relatively recent phenomenon, that started in the 1960s. It has proved difficult to find uncontaminated colonies, but reference sites have been surveyed in Alberta and Saskatchewan. The incidence of bill deformities in colonies in Lake Nipigon, Lake Winnipegosis and the North Channel of Lake Huron are not significantly different from the incidence on the Prairies. The incidence in colonies in Lake Ontario, Lake Superior, Georgian Bay in Lake Huron and Beaver Island in Lake Michigan are significantly elevated. The highest incidence was found in colonies in Green Bay, Wisconsin. It should be noted that Saginaw Bay, Michigan is still too toxic to support a population of nesting double-crested cormorants. Thus, no estimate of the incidence of bill deformities is possible at that location.
The improvements in analytical techniques and the development of interdisciplinary, collaborative work between United States and Canadian researchers has led to advances in relating the causes of embryo mortality in cormorant populations to specific compounds. A highly significant dose response relationship between egg mortality on a colony basis, and dioxin equivalents in samples of eggs from the colony has been documented by Tillitt et al. (in press). Most of the dioxin equivalents is contributed by 3,3',4,4',5- and 2,3,3',4,4'-pentachlorobiphenyl. These improvements in analytical techniques and in methods of interpreting biological data have supplanted conventional PCB analyses using technical formulations as standards and expressing the results as total PCBs.

Populations of double-crested cormorants in the Great Lakes are increasing dramatically. This phenomenon can be attributed to a variety of factors, including relative protection from human disturbance, lack of predators and restoration of eggshell thickness with decreasing DDE levels. This population increase has been maintained despite the occurrence of Newcastle disease and the associated mortality of adult birds. However, the fact that populations of a wildlife species are expanding is normally interpreted by wildlife resource managers as a sign that the members of the species are healthy and that, therefore, no intervention is warranted. Double-crested cormorants have become an important indication of the status of the restoration of the Great Lakes impaired by releases of persistent toxic chemicals. The fact that certain colonies of double-crested cormorants continue to exhibit a high incidence of embryo mortality and congenital deformities argues for increased regulatory intervention to deliver the policy contained in the Water Quality Agreement concerning the virtual elimination of discharges of persistent toxic substances. Indeed, the absence of congenital deformities and elevated embryo mortality in double-crested cormorant colonies could be used as an indicator of the effective delivery of this policy.

On the above basis, the Science Advisory Board recommends that:

- the Parties develop an ecosystem objective for the double-crested cormorant *(Phalacrocorax auritus)* with particular reference to embryo mortality, incidence of deformities and eggshell thickness and associated levels of persistent toxic substances.

### 3.1.3 Lake Trout Roundtable

On September 24 and 25, 1990, the Biological Effects Subcommittee of the International Joint Commission and the Great Lakes Fishery Commission co-hosted a Roundtable on Contaminant-Caused Reproductive Problems in Salmonids (International Joint Commission 1990a). The main focus of the workshop was to gain a clearer understanding of the role which toxic contaminants play in the inability of salmonids to maintain naturally-reproducing populations in the Great Lakes.

Populations of lake trout (*Salvelinus namaycush*) declined to near extinction in the 1940s due to the combined effects of overfishing, sea lamprey (*Petromyzon marinus*) predation and habitat destruction. In response to the decline in the number of lake trout, efforts were begun to stock the Great Lakes with hatchery-reared fish and to control the population of sea lamprey. These actions restored the number of lake trout, but have not resulted in self-sustaining populations of these salmonids. Toxic substances, which became common in the Great Lakes basin at about the time stocking and lamprey control programs were begun, are thought to be a factor in the continued reproductive failure of these fish. Other salmonid fishes such as the Pacific salmon (*Oncorhynchus tshawytscha*; coho, *Oncorhynchus kisutch*) were planted in the Great Lakes in the late 1960s in response to the overwhelming numbers of forage fish present, particularly alewife (*Alosa pseudoharengus*). These species grew well in the lakes and created a valuable sport fishery. All of these salmonids rely on hatchery inputs to maintain
populations, with limited natural reproduction occurring in some areas. While intense sport fishing, limited habitat and sea lamprey still affect the capability of these fish to be naturally self-sustaining, persistent organic contaminants may be a limiting factor as well.

There are a number of reasons why persistent organic contaminants are suspected as a cause of the continued reproductive failure of salmonids. The position which salmonids hold near the top of their food chain, combined with their relatively long life span and high fat content, cause them to efficiently bioaccumulate toxic substances from their environment. These species also produce a large egg, with a high-lipid yolk material, that carries a significant dose of organic contaminants as the first food for developing young.

One of the main reasons for organizing the roundtable was the realization that a number of Great Lakes scientists have observed similar anomalies in early-life development (eggs and sac fry) of lake-produced salmonids. Observations of swim-up mortality syndrome have been reported in lake trout and steelhead trout (Oncorhynchus mykiss) from Lake Michigan and Lake Ontario, and chinook salmon from Lake Ontario. Pre-hatching mortality has been found in embryos of chinook salmon and lake trout from Lake Michigan. Different researchers also reported finding blue-sac disease in lake trout from Lake Ontario and in lake trout exposed in the laboratory to 2,3,7,8-tetrachlorodibenzo-p-dioxin. In regards to the swim-up mortality observed in Lake Michigan lake trout, Dr. Mac (1990) stated: “Several characteristics of this syndrome point to the possibility of contaminants being involved. The syndrome occurs at the end of yolk absorption when body levels of contaminants are highest; the behavior of afflicted fish resembles a condition brought on by DDT exposure; livers of affected fish show MFO (mixed function oxydase) induction; and the occurrence of the syndrome has been restricted to several salmonine species but only in Lakes Michigan and Ontario, the two most contaminated lakes.”

In the laboratory, researchers have illustrated a cause-effect linkage between contaminants and reproductive failure in salmonids (Peterson and Walker, 1990). It would seem to follow that persistent organic contaminants are at least in part to blame for the inability of salmonids to maintain self-sustaining populations in the Great Lakes. No scientific field study, however, has been able to directly correlate specific contaminants existing in the Great Lakes with salmonid reproductive failure.

Participants of the roundtable agreed that the complexity of the problem has presented the major barrier to answering the question of whether or not contaminants are influencing the reproductive ability in wild fish. In the laboratory, variables affecting fish reproduction can be limited to a great degree; in the field this limitation is not possible. Factors that affect population size, spawning-habitat quality, normal spawning behavior, as well as other factors that affect gamete quality, such as genetics and nutrition, influence reproductive success in the field. With very little natural reproduction occurring by lake trout in the lakes, it is extremely difficult to point to any one reason, or to separate the various putative causes. For lake trout, reproductive failure is most likely due to a combination of various factors, of which contaminants may contribute to a varying degree in different lakes.

A more complete understanding of the cause of salmonid reproductive failure in the Great Lakes requires some new approaches to the problem. To accomplish this task, participants in the roundtable established a work group which will meet biannually. This concept will allow researchers to share ideas and information, as well as coordinate research efforts so as to maximize resources. Participants in the roundtable expressed the need to concentrate research efforts on field studies, using an epidemiological approach. Individuals at the workshop also emphasized the need to more clearly define the problem; gain a stronger knowledge base on the basic physiology and biochemistry of salmonids; evaluate the effects of multiple contami-
nants; utilize other applicable Great Lakes species for comparison, study how fish process different contaminants in their eggs and examine the fate of chemicals in the eggs themselves.

While the role of persistent organic chemicals in the inability of salmonids to maintain a self-sustaining population in the Great Lakes is not fully understood, there is substantial evidence which indicates that these chemicals are a factor in this problem. The creation of the work group and the reorienting of research programs will expand our understanding of the problem.

The assembling of a group of experts in contaminants and salmonid reproduction for the two-day roundtable was an attempt to foster discussion and cooperation on future research. Through the sharing of information and ideas, it was intended that some insight be gained by the participants regarding the reproductive problems of salmonids in the Great Lakes. The roundtable brought closer an understanding and eventual solution to the problems which the workshop addressed.

The existing objective for lake trout in Lake Superior was developed as a general ecosystem objective.

On the above basis, it is recommended that:

- the Parties develop an ecosystem objective for lake trout that specifically relates the incidence of embryo mortality, fry survival and developmental anomalies in samples of eggs of fish exposed to persistent toxic substances.

### 3.1.4 Mink and Otter Roundtable

On March 5 and 6, 1991, the Biological Effects Subcommittee of the International Joint Commission, the Canadian Wildlife Service and the Ontario Ministry of Natural Resources co-hosted a roundtable on mink (*Mustela vison*) and river otter (*Lutra canadensis*) (International Joint Commission 1991b). The discussion at the roundtable centered on the usefulness of mink and otter as biological indicators of ecosystem health in the Great Lakes basin, with a focus on the role of persistent toxic substances in reproductive impairment of these two mammals.

Mink and otter are being discussed as possible biological indicators because of the position they hold in the food web and their great sensitivity to PCBs and related toxic substances. As consumers of fish, these two mammals are subject to high levels of environmental contaminants, which bioconcentrate up the aquatic food chain.

- **Population Status of Mink and River Otter**

**Mink**

Almost all population data for mink and otter in North America have been compiled from trapping records. The applicability of these records for estimating population size is limited by a number of factors which influence harvest levels, including pelt price, demand and trapper effort and experience.

In a number of coastal areas bordering Lakes Erie, Michigan and Ontario fewer mink were trapped than in areas further inland. This distribution of mink is consistent with a contaminant effect since those animals living closer to the water would be expected to consume more aquatic prey and, therefore, be exposed to higher levels of chemicals. Along the Upper Mississippi, the mink harvest declined in the early 1960s, but has since been slowly increasing. In Oregon, the number of mink trapped between the years 1949/1952 and 1989/1990 dropped
by 84% along the Columbia River. Both the Upper Mississippi and the Columbia River have been shown to have high contaminant levels.

**Otter** In Europe, otter populations have been estimated by a series of precise field surveys carried out by biologists and trained volunteers. Dr. Christopher Mason explained that otters were widespread throughout most of Europe in the 1950s, but had suffered a severe decline by the 1970s. Population levels of otters in the Great Lakes basin are not well documented; there seem to be areas where suitable habitat is available but no animals have been trapped.

- **Factors Affecting Mink and Otter Populations**

There are a number of biological factors which could affect the abundance and distribution of mink and otter in the Great Lakes basin, including habitat quality and quantity, over-trapping, parasites and disease. Chemicals may mediate cold temperatures, delayed implantation in otters, and the kidney worm parasite in mink and thereby affect abundance.

Dr. Christopher Mason explained that, although the use of dieldrin in England coincided with the decline in otter populations of that country, several lines of evidence indicate that PCBs were a more likely cause of the decline and failure to recover. He presented data which showed that food containing .25 ppm PCB caused reproductive failure in mink, and stated that current PCB levels in the tissues of otters are sufficient to cause the same effect in this species.

High PCB body burdens have been found in mink collected in the late 1980s from coastal areas along Lake Ontario and Lake Erie. Similarly, high PCB and Mirex levels have been detected in mink collected in the late 1980s from sites bordering the Salmon River, New York State, where spawning-run salmonids stocked in Lake Ontario are available as food. The livers of 25 out of 51 otters collected by trappers in Michigan in 1986 and 1987 had mean liver concentrations of .3 ppm PCB.

Mink fed 0.134 mg PCB/kg body weight/day of contaminated carp from Saginaw Bay had poor reproductive success. PCB inhibits the development of the apical gland on the necks of PCB-exposed kits and thereby reduces the amount of maternal attention, leading to higher kit mortality.

Mercury is suspected to be a cause of mortality of mink and otter. Healthy mink contain about 2.2 μg/g. Lab-poisoned mink were found to contain 24.0 μg/g of Hg, while Great Lakes mink poisoned in the wild had a level of 58.2 μg/g. Healthy otters had levels of 1.6 μg/g. Lab-poisoned otters were documented containing 33.4 μg/g of Hg, and wild-poisoned Great Lakes otters contained 96.0 μg/g.

- **Summary of Discussion Sessions at Roundtable**

The purpose of the Great Lakes Water Quality Agreement is to restore and maintain the integrity of the waters of the basin ecosystem. To this end, there are policies that the discharge of toxic substances in toxic amounts is prohibited and the discharge of any or all persistent toxic substances should be virtually eliminated. The roundtable participants discussed whether mink and otter could be used as indicators of the restoration of the integrity of the waters of the basin ecosystem.

Assessment of the distribution of mink and otter and of the factors affecting their health and abundance has been limited by scientific as well as institutional constraints. Responsibility for the assessment of stocks of mink and otter rests with state and provincial governments under their mandates for managing fur-bearing animals. Generally, wild mink and otter stocks
are sufficiently abundant for the purposes of trappers and, thus, research and monitoring of populations would appear not to be warranted. Agencies responsible for managing fur-bearers tend not to be the agencies responsible for environmental quality. Thus, implementation of the idea of using fur-bearers as indicators of environmental quality will require some creative institutional mechanisms to ensure appropriate allocation of budgets and personnel.

If institutional constraints can be overcome, the scientific constraints can be addressed. Survey techniques must be developed to assess the age structure, range, distribution, abundance, habitat requirements and reproductive health of these species, particularly along the Great Lakes shorelines. In addition, biological research is needed on the dietary habits, disease and parasite status and the relative sensitivity of these species to persistent toxic substances. Finally, it may be possible to undertake measurements of specific biochemical lesions induced by contaminants by sampling live, wild animals. After these studies and institutional changes have been undertaken it will be possible to assess whether mink and otter are reliable indicators of the restoration of the integrity of the waters of the basin ecosystem.

On the above basis, it is recommended that:

- the Parties investigate the feasibility of developing ecosystem objectives relating the status of mink and otter populations to exposures to persistent toxic substances.

3.1.5 Liver Tumors in Brown Bullheads and White Suckers

In 1987, the Water Quality Board reported on the results of various surveys of the incidence of tumors in brown bullheads and white suckers in the Great Lakes and connecting channels. Further details were included in Appendix B of the 1987 Water Quality Board report (International Joint Commission 1989d) under the specific sections on the conditions of the lakes and connecting channels. A brief update was included in the 1989 Water Quality Board report, together with a statement that “research into the relationship between tumors and chemical exposure is urgently needed.” In 1989, Dr. Paul Baumann presented a paper using epidemiological criteria on “Liver Tumors in Brown Bullheads,” at the Cause—Effect Linkages Workshop. In 1990, agreement was reached on the criteria that should be used to interpret the provisions contained in Annex 2 of the 1987 Protocol concerning “Impairment of Beneficial Uses.” In listing or delisting Areas of Concern, the fourth category of impairments concerns “Fish Tumors or Other Deformities” and there is agreement that an area could be listed as an Area of Concern when “the incidence rates of fish tumors or other deformities exceed rates at unimpacted control sites or when survey data confirm the presence of neoplastic or preneoplastic liver tumors in bullheads or suckers.” Despite advances that have been made in linking the occurrence of tumors in fish to the presence of environmental carcinogens, there is still debate among scientists about some anomalous findings.

Liver neoplasms were first documented in wild fish in 1964 (Harshbarger and Clark, 1990). The condition was observed in white sucker (Catostomus commersoni) and brown bullhead (Ictalurus nebulosus) taken from Deep Creek Lake, Maryland (Dawe et al. 1964). Since then an increasing number of fish tumor epizootics have been documented in North America. The rate at which liver tumors are currently occurring in Great Lakes fish (documented at 60% in one region) has generated great concern. According to Mac and Smith (1988), the expected incidence rate of liver tumors in fish living in clean water is less than 2%; the authors state that any rate of liver tumors is “cause for concern.” Many experts in this field feel that the incidence rate should be zero for fish at clean sites (Hickey et al. 1990) based on the fact that no reasonable hypothesis has been proposed for why any liver cancer should occur in uncontaminated wild fish.

Recently, however, there has been a significant advance in linking liver and skin cancer in fish to environmental carcinogens. Harshbarger and Clark (1990) have reviewed the
incidence of neoplasms in fish in North America and have made the following observations concerning why they think that there is a causal linkage between tumors in fish and exposure to environmental chemicals.

- The initial discovery of epizootic liver neoplasms in 1964 (Dawe et al. 1964) occurred after the onset (approximately 1940) of the exponential growth of industries producing synthetic organic chemicals. There is no documentation of liver tumors in any wild fish species sampled prior to 1940 (Dr. Harshbarger, pers. comm.).

- Virtually all of the two to three dozen known carcinogens tested with one or more fish species have consistently produced liver tumors (Hoover 1984; Couch and Harshbarger, 1985; and Metcalfe 1989). This phenomenon implies a strong correlation between contaminants and the development of liver tumors.

- The 15 species with epizootic liver tumors are all bottom feeders for at least part of their life history. During this period they are exposed to contaminated sediment. In virtually every case, the fish with the tumors are clustered in areas where environmental chemicals are concentrated or where there is an obvious point source (e.g. effluent outfall, waste dump site, military/industrial/municipal development). As further evidence, the decommissioning of a coking plant in 1984 was followed by a decline in the prevalence and severity of liver neoplasms in Black River bullhead in the vicinity of the outfall (P.C. Baumann, M.J. Mac, S.B. Smith, J.C. Harshbarger, unpublished data).

- Fish liver tissue contains the enzymes necessary to metabolize indirect-acting carcinogens to the reactive electrophilic metabolites. These metabolites are capable of producing DNA adducts in fish tissue (Dunn et al. 1987; Varanasi et al. 1989).

- There are several lines of evidence from carcinogenesis experiments involving contaminated sediments:
  - Extracts of sediment from the Black River, Ohio and the Buffalo River, New York painted or fed to brown bullheads in the laboratory caused tumors and hyperplasia of skin and liver similar to lesions found in the wild (Black 1983). Extracts from both locations also caused skin tumors in mice.
  - Winter flounder held four months in tanks with contaminated sediment (from Central Long Island Sound dumpsite) and fed contaminated blue mussels (Mytilus edulis) exhibited a number of preneoplastic lesions (Gardner et al. 1987; 1988). These lesions were similar to those observed in winter flounder caught near the dumpsite, itself.
  - Extracts of sediments from Hamilton Harbour in western Lake Ontario injected into rainbow trout sac fry induced liver tumors (Metcalfe et al. 1988).

- Spontaneous liver tumors are exceedingly rare in wild fish from clean habitats and in control fish in carcinogenicity experiments.

On the above basis, Harshbarger and Clark (1990) concluded that hepatocellular neoplasms are strongly correlated with exposure to chemical carcinogens and that epizootics involving liver tumors in brown bullheads and white suckers indicate poor water quality in areas where tumor-bearing fish are found.

Further grounds for thinking that neoplasms are caused by exposure to environmental chemicals are provided by recent biochemical studies involving the formation of DNA adducts with environmental carcinogens. This phenomenon provides a plausible biochemical mecha-
nism for the involvement of environmental carcinogens in the development of liver tumors in fish. The ability to understand the biology at the fundamental level of a molecule of a persistent toxic chemical interacting with a strand of DNA to produce liver neoplasms provides further evidence of a causal linkage between the contaminants in the Great Lakes and the occurrence of liver tumors in fish species. Maccubbin et al. (1988) found that the level of DNA adducts in the polluted waters of the Buffalo River and the Detroit River was five to six times higher than in control fish and noted that "these results directly demonstrate chemical interaction with DNA which is generally considered to be the first step in chemical carcinogenesis."

Information on the frequency of liver tumors in brown bullheads and white suckers was chosen for several reasons. As bottom feeders, these species are exposed to considerably higher concentrations of contaminants than are pelagic fish. In addition, the majority of information on tumour frequency in the Great Lakes relates to bullheads and white suckers since they have been studied most commonly in Great Lakes tumor surveys. The incidences of liver tumors are reported since they are more strongly correlated with chemical exposure than are tumors for other parts of the body.

- **Brown Bullheads**

  Figure 3.2 indicates the frequency of liver tumors and the chemical composition at each site. In 1982, 125 brown bullheads from the Black River, Ohio were analyzed histopathologically (Baumann 1990). Sixty percent of these fish had liver neoplasms and 38.4% had liver cancer. In addition, no bullheads older than five years were found in the Black River, while 18% of the population of brown bullheads from a control site were ages six and seven (Baumann 1990). The lack of fish above age five in the Black River is consistent with the hypothesis that contaminants are inducing cancer in these fish (Dr. Baumann, pers. comm.). Bullheads from the Black River have been found to contain significantly elevated levels of PAHs when compared with bullheads from control sites (Black 1984). Black (1984) states that “it is likely that PAH exposure represents the primary etiologic factor that produced the liver pathology observed in the Black River bullheads.”

  Elevated liver tumor rates have been documented in a number of rivers and creeks in the vicinity of Buffalo, New York. A liver tumor incidence of 35% (neoplastic and preneoplastic) was documented in bullheads from the Love Canal-102nd Street dump site in 1986 (Hickey et al. 1990). A lower liver tumor incidence (5% neoplastic and preneoplastic tumors) was observed in 1987 brown bullheads at this same site, but the authors state that this condition might have been an artifact of the technique used to analyze liver specimens (Hickey et al. 1990). This same study reported that less than 1% of brown bullheads in Black Creek had liver tumors. The Niagara River Toxics Committee found concentrations of PAHs, PCBs and the dioxin isomer 2,3,7,8-TCDD to be high in Niagara River brown bullheads (Hickey et al. 1990).

  Liver tumor incidence rates of 20% have been measured in both the brown bullheads from Cayuga Creek (Government of Canada 1991) and the brown bullheads from the Buffalo River (Baumann, unpublished data). Cayuga Creek empties into the Buffalo River, which enters Lake Erie near the head of the Niagara River. The Buffalo River has been described as one of the most heavily polluted waters in the United States (Black et al. 1980). Black (1983) found substantial PAH levels in Buffalo River sediments.

  Brown bullheads have been found with liver tumor rates of 3% in the Detroit River (Maccubin et al. 1985) and 2% in Hamilton Harbour (Government of Canada 1991). Both the Detroit River and Hamilton Harbour are Areas of Concern and contain contaminated sediments (International Joint Commission 1989d).
Liver Tumor Frequency in Brown Bullhead Populations of the Great Lakes

Anomalous results have been found in liver tumor surveys of brown bullheads at Munuscong Lake, which is connected to the channel joining Lake Superior to Lake Huron. Liver tumors were observed in 6.3% of the brown bullhead population sampled from Munuscong Lake (Baumann, unpublished data). However, brown bullheads between the ages of one and four had no liver tumors. Brown bullheads, ages five and six, had rates of incidence of liver neoplasm of 6.7 and 5.9%, respectively; the liver neoplasm rate increased to 12.5% in fish, age seven; and 16.7% in fish, age eight. Baumann (1990) noted that "a positive correlation between fish age and tumor frequency is compatible with the hypothesis of a chemical etiology, in which a latent period between initiation and tumor development would be expected." No high levels, however, have been found of any of the chemicals which are suspected of inducing liver tumors (Baumann, pers. comm.). To account for these anomalous findings, Baumann and Harshbarger noted that tumor-bearing fish collected from Munuscong Lake might have been initiated in the polluted waters of the St. Marys River before migrating downstream about 26 km to Lake Munuscong. High-sediment PAH levels have been measured in the Saint Marys River (Smith, pers. comm.). Alternatively, the relatively low frequency of liver tumors and the older ages of fish in the Munuscong brown bullhead population could have resulted from a chronic exposure to low levels of contaminants (Baumann, pers. comm.). For example, low levels of chemicals from ship traffic or from Chippewa County International Airport could be bioconcentrated in the food chain (Harshbarger, pers. comm.). The disturbance of sediments from boat traffic could expose fish to tumor-inducing contaminants. Clearly, further work needs to be undertaken on fish migration and the presence of carcinogens before conclusions can be reached on this epizootic and its cause.

Another anomalous situation occurs in the Cuyahoga River, Ohio where brown bullhead exhibit the same general trend of an increasing incidence of liver tumor incidence with the
increasing age of the fish. Brown bullheads ages one and two had no liver tumors (Baumann, unpublished data). Between the ages of three and five the liver neoplasms increased from 6.1% to 60%. However, six-year old brown bullheads had an incidence of over 25% liver tumors, and bullheads age seven had no tumors. This anomaly might be explained by the migration of older fish from other areas or it may represent an artifact of the small sample sizes used (only five fish age six to seven years). If we combine all of the age classes, 9.4% of the brown bullheads from the Cuyahoga River exhibited liver tumors. The Cuyahoga River is a highly industrialized area and a high level of polynuclear aromatic hydrocarbons has been measured in the areas where tumor frequency is elevated (Baumann and Mac, 1988). Clearly, further research is required to investigate the possibility of the migration of older fish and the mortality of fish with tumors.

White Suckers

White suckers with an elevated frequency of liver tumors have been sampled from the following rivers which empty into Lake Ontario (see Figure 3.3); Forty Mile Creek (0.0%), Grindstone Creek (1.2%), Spencer Creek (3.4%), Sixteen Mile Creek (7.4%), Humber River (4.7%), Rouge River (3.5%), Ganaraska River (6.0%) and Trent River (0.7%) (Fisheries and Oceans Canada; Cairns and Fitzsimons unpublished data). At one Lake Huron site, South Baymouth, no liver tumors were found in the white sucker population (Government of Canada 1991). There is little information available on contaminant levels in the sediment from any of these rivers and none on PAH levels. Fish from all five of these rivers spend the majority of the year living in Lake Ontario itself, and can travel many miles away from the river mouth (Dr. Smith, pers. comm.). In the waters of Lake Ontario, white suckers may be exposed to high levels of persistent toxic substances. Spencer Creek, for example, empties into Cootes Paradise, connected to Hamilton Harbour, where the sediments have been shown to contain considerable levels of PAH (Metcalfe et al. 1988). Metcalfe et al. (1988) induced liver tumors in rainbow trout by exposing them in the laboratory to sediment samples from Hamilton Harbour. Further research is required to investigate whether the frequency of liver tumors in white suckers is a result of exposure to chemicals in the five rivers or in Lake Ontario.
Conclusion

There are several methodological and institutional constraints on the successful use of these fish species as reliable indicators of the incidence of tumors in fish in the Great Lakes basin. There is a lack of consistency in the frequency of sampling, treatment of samples, in diagnostic techniques, classification of tumors and in reporting. Thus, there is a priority need for the development of an acceptable protocol for estimating and reporting the incidence of liver tumors in selected fish species in the Great Lakes basin. There is a chronic shortage of funding for this kind of research. Thus, there is a priority need for a long term commitment of resources for researchers to conduct comprehensive field surveys of the incidence of liver tumors in these fish species. The Biological Effects Subcommittee intends to host a roundtable on tumors in fish to address these methodological and institutional constraints so that reliable information on the incidence of fish tumors can be obtained for review and evaluation of the progress being made in restoring the waters of the Great Lakes impaired by releases of environmental carcinogens.

3.1.6 Beluga Whales in the Gulf of St. Lawrence

Beluga whales (Delphinapterus leucas) inhabited the St. Lawrence estuary before the last ice age. A century ago there were probably more than 5,000 animals in the Gulf of St. Lawrence, a body of water that supported an active fishery (Reeves and Mitchell, 1984). In the past two decades there has been a growing appreciation of the precarious status of the Gulf population. Population estimates in the 1980s ranged from 350 (probably unreliably low) to 500 (Sergent 1986; Beland et al. 1988) and the reproductive rate was about a third lower than that in Arctic populations. Recent estimates range (visibility uncorrected) from 427 ± 60 animals in 1988 to 527 ± 268 in 1990, based on photographic aerial surveys (Kingsley 1991). Though hunting had largely ceased by the 1950s, the population failed to increase and in 1979, the population was listed as endangered.

In the late 1980s, the Canadian Federal Government set up an Ad Hoc Committee for the Conservation of the St. Lawrence belugas ( Fisheries and Oceans 1987); published an interdepartmental action plan (Fisheries and Oceans Canada and Environment Canada, 1988) and held workshops on research and on disturbance of belugas (Fisheries and Oceans 1989). From these discussions three main issues emerged: what was the status of the population, the age structure, trends and genetic fitness; had habitat changes, such as hydroelectric developments or tourism pressure, limited the population; and had pollution, particularly by toxic chemicals, caused the failure of the population to increase? Results from this research plan were the subject of a symposium and workshop held in March 1991.

Arrangements were made for the collection of dead beluga whales and, to date, 40 animals have been autopsied. The most frequent lesions involve ulcers and tumors of the digestive system and buccal region. The incidence rate for tumors in the 40 animals is 40% (Martineau et al. 1988; Beland 1991). Geraci et al. (1987) reviewed the international literature on tumors in cetaceans (whales, dolphins and porpoises). In all the world’s literature only 52 tumors have been described, indicating how unusual the situation is in the beluga population in the St. Lawrence estuary.

Interpretation of these results in relation to possible causal agents is complicated by the presence of two kinds of pollutants in the whales from two different sources. Analysis of samples of beluga tissue has revealed polynuclear aromatic hydrocarbons and organochlorine compounds. The source of the polynuclear aromatic hydrocarbons is, undoubtedly, the aluminum refineries at Arvida and Chicoutimi at the head of the Saguenay Fjord (Martineau et al. 1988). Martineau et al. (1988) concluded that as these agents probably contaminate the
beluga whale food web, they have to be considered as a possible aetiological factor for the high frequency of tumors seen in this population. The occurrence of benzo[a]pyrene (BaP) adducts in the DNA of the brains of three beluga whales provides incontrovertible evidence that these particular animals had been exposed to BaP and had metabolized it to the carcinogenic form, which subsequently became covalently bound to the DNA of brain tissue. DNA adducts are an integral part of the process that culminates in overt malignancy.

The source of the organochlorine contaminants has been more difficult to locate, however, the presence of Mirex in the whales indicated that a substantial proportion of the organochlorine chemicals must originate from Lake Ontario since Mirex was manufactured by Hooker Chemical at Niagara Falls, New York. The most likely vector for these organochlorine chemicals is the American eel (Anguilla rostrata), which seasonally migrates from the Great Lakes, down the St. Lawrence River to the Gulf and out into the Sargasso Sea (Dutil et al. 1985; Beland and Martineau, 1988). An initial indication that there were extremely high levels of organochlorine contaminants in belugas was obtained in 1970 when a juvenile was collected that contained 827 ppm DDT and 800 ppm PCB in the body fat (Sergent 1980). Since then many samples have been analyzed that show that: a) males have higher levels than females, which tend to lose organochlorine chemicals through lactation, and b) organochlorine levels increase with age (Martineau et al. 1987). These animals contained among the highest levels of these pollutants ever recorded for cetacean samples taken anywhere in the world (Wagemann and Muir, 1984; Martineau et al. 1987). Martineau et al. (1988) concluded that conditions such as gastric ulcers, squamous metaplasia of mammary glands, histological evidence of activity in the mammary glands of two immature animals and probable immunosuppression in three animals are consistent with chronic organochlorine toxicity. Consequently, it is suggested that contamination by organochlorine compounds is contributory to diseases of the St. Lawrence beluga whales, thus helping to explain the failure of the population to have recovered after the end of commercial hunting a few decades ago.

The levels of PCBs in males collected in 1988-89 (107 ± 71 mg/kg wet weight) were significantly lower (p <0.05) than those in males collected between 1982-85 (185 ± 79 mg/kg) (Muir et al. 1991). Slightly higher levels of DDT and metabolites were found in males sampled in 1988-89 (117 ± 62 mg/kg) than in those reported earlier (91 ± 58 mg/kg) (Martineau et al. 1987). No changes in levels of DDT or PCB were detected in females. The blubber of belugas from the estuary contains a variety of organochlorine chemicals, including various chlordane-related compounds, toxaphene, hexachlorobenzene, hexachlorocyclohexanes as well as Mirex (Muir et al. 1991).

Recent analyses have been undertaken to determine the “TCDD equivalents” for coplanar PCBs, dibenzofurans and dioxins in five male and five female belugas. About 36% of the “TCDD equivalents” was attributable to the 3,3′,4,4′,5-pentachlorobiphenyl (IUPAC No. 126). The rest of the TCDD equivalents was accounted for by 2,3,3′,4,4′-pentachlorobiphenyl (IUPAC No. 105) and 2,3′,4,4′,5-pentachlorobiphenyl (IUPAC No. 118) (Muir, pers. comm.). On the basis of a comparison of chemical analytical results for Arctic belugas, seals and narwhal and Great Lakes birds and fish, Muir et al. (1991) suggested that cetaceans possess enzymes with a high activity for the metabolic degradation of 3,4-substituted PCBs and 2,3,7,8-substituted PCDDs as well as PCDF. Similarly, the levels of dioxins in St. Lawrence beluga are exceeded by those found in marine mammals on the west coast (M. Kingsley, pers. comm.).

Finally, recent information from an autopsy has shown that a 26-year-old beluga found dead was an hermaphrodite, having both male and female organs (St. Lawrence National Institute of Ecotoxicology 1989). The significance of this finding should be reviewed in relation to other Great Lakes evidence of endocrine dysfunction and anatomical anomalies (see below).
3.1.7 Embryonic Feminization Leading to Abnormal Sexual Development

Field studies of herring gulls nesting in colonies on Lake Ontario (Fox and Weseloh, 1987) and Lake Michigan (Shugart 1980) in the 1970s showed an abnormally high incidence of large clutches of eggs. Herring gulls normally lay two or three eggs, but nests were found with four, five or even six eggs in one nest. These supernormal clutches of eggs were laid by two females, who had paired and were most prevalent in Lake Ontario colonies in 1977, declining rapidly during subsequent years. These findings implied that the sex ratio in the colonies was skewed towards females.

Herring gulls take at least four years to come to sexual maturity. This phenomenon suggests that the birds which were being recruited into the colonies at that time corresponded with the young hatched in the late 1960s and early 1970s. This period of time corresponded with high concentrations of organochlorine chemicals, particularly DDT and PCB, and poor hatchability (Gilbertson and Hale, 1974). These compounds are known to be estrogenic (Bitman and Cecil, 1970). Fry and Toone (1981) showed that the injection of DDT into gull eggs caused the feminization of male embryos, which developed ovarian tissue and oviducts. Fry examined 17 formalin—preserved, near—term embryos and newly-hatched chicks collected in 1975 and 1976 from Lake Ontario herring gull colonies. Five (71%) of the seven males were significantly feminized and five (50%) of the 10 females had abnormally enlarged oviducts.

The concentrations of DDE and related residues in herring gull eggs collected in 1975/76 were about one-half of the levels in eggs collected in 1971. Thus, it is possible that many of the genetically male embryos were significantly feminized during the peak period of DDT contamination in Lakes Ontario and Michigan. If the majority of males in these numerically weak cohorts were feminized and incapable of reproducing, then the effective sex ratio in these colonies in the late 1970s was seriously skewed towards females. A detailed study (Fry et al. 1987) concluded that nests with supernormal clutches of eggs occur in gull breeding colonies when the sex ratio of breeding adults is skewed towards females and when nest sites are available for female—female pairs or polygynous trios. Fry and Toone (1981) noted that the feminization of male avian embryos markedly affects the reproductive behavior of the birds when they mature.

There are several other environmental contaminants that alter endocrine function including 2,3,7,8-tetrachlorodibenzo-p-dioxin, (Umbreit and Gallo, 1988; Romkes and Safe, 1988) lindane, hexachlorobenzene, Mirex, toxaphene, 2,4-dichlorophenoxyacetic acid (2,4-D), synthetic pyrethroids, methoxychlor, atrazine, simazine and endosulphan (Colborn 1991a).

Environmental contaminants can cause demasculinization or defeminization through a variety of mechanisms. They can act as mimics of steroids and either stimulate steroid response in a tissue or organ or block steroid expression by reacting with the receptor site.

There are biochemical indications that one of the sites of action of 2,3,7,8-TCDD is the hypothalamus. Alteration of this gland by TCDD may result in a variety of endocrinological effects, associated with exposure to TCDD (Russel et al. 1988).

Embryos require a certain level of specific hormones in the developing brain at critical neonatal periods for normal sexual differentiation of brain development in the resulting adult. If the developing brain is not exposed to these critical levels at the right time, the effect, though not apparent until after puberty, is irreversible (Dieringer et al. 1979).

The history of the past 20 years of toxicology research on the Great Lakes has shown that information derived from wildlife studies has direct application to humans. There is a need to undertake research to investigate whether exposure to nonsteroid estrogenic compounds has had an effect on normal human sexual maturation.
3.1.8 Biological Markers

Previous reports have established that concentrations of organochlorine chemicals in fish and wildlife in the Great Lakes basin were among the highest in the world. Research over the past 25 years has demonstrated that high levels of certain organochlorine chemicals were associated with effects on fish and wildlife and had serious consequences for populations of some organisms. The Cause-Effect Linkages Workshop (International Joint Commission 1989e) used epidemiological criteria to reliably relate the effects observed in wild populations with specific chemical substances or modes of action. Though habitat changes, overharvesting and persecution may contribute to population changes, the following species have been shown to be affected by specific organochlorine chemicals: bald eagle, herring gull, double-crested cormorant, Forster's tern, lake trout, mink, otter and snapping turtle. The great success of the Fifth Biennial Meeting of the International Joint Commission was in focusing attention on reproductive and developmental effects and in linking the effects observed in fish and wildlife to effects in humans.

Levels of organochlorine chemicals have been declining during the past 15 years, and, as predicted, populations of several of the species that were seriously affected by the chemicals have gradually increased. Even populations of bald eagles, the most highly exposed organisms in the Great Lakes food webs, have increased in areas such as Lake Erie, where levels of organochlorine pollutants have sufficiently declined. The same chemicals that caused the original damage are, however, still being released. In addition, there are large reserves of waste organochlorine chemicals in landfill sites. These compounds are now migrating slowly towards the waters of the Great Lakes in such locations as the Niagara River and they have the potential to cause a repetition of the serious effects observed in the 1960s and 1970s. The Parties have begun to develop consensus on what species should be used as ecosystem indicators, particularly for Lake Ontario habitats. The challenge in the future will be to devise methods of monitoring that can be used to protect the Great Lakes and prevent serious biological injury, rather than to rely on restoration after damage has occurred. By the time overt effects are seen in the field, the situation is already out of control. A proactive approach requires that we develop more sensitive indicator methods, that can give a warning long before overt effects are detectable.

In the past 20 years there have been enormous advances in understanding the ways in which organochlorine and other chemicals exert their toxicological effects at the biochemical levels. There is even knowledge of the shape, size and charge distribution of specific receptor sites on molecules that are specific sites of action of toxic substances with similar modes of action. Many of these molecules and toxicological processes are common to fish, birds and mammals, including men. Thus, monitoring these biochemical processes can, not only warn of increasing levels of persistent toxic chemicals with specific modes of action, but also warn of the specific dangers to humans from exposures to these substances.

The following three biochemical parameters measured in eggs or embryos of herring gulls could be developed for systematic analysis and reporting: aryl hydrocarbon hydroxylase (Ellenton et al. 1985), highly carboxylated porphyrins (Kennedy and Fox, 1990) and vitamin A (Spear et al. 1990). Abnormal vitamin A storage and porphyria have also been documented in adult herring gulls (Fox et al. 1988, Spear et al. 1986). In addition to these direct biochemical measures on biota collected from the Great Lakes, bioassay methods have been developed to measure the specific biological activity present in contaminated samples. For example, cell cultures of a rat hepatoma have been used to measure the activity of dioxins, dibenzofurans and planar PCBs in extracts of environmental samples (Tillitt et al. 1991). Similarly, in fish, induction of hepatic mono-oxygenase activity has been used as a biological indication of exposure to environmental contaminants (Haasch et al. 1989).
One disadvantage of the biochemical approach is that the results of the measurements are difficult for the lay public to relate to and, thus, lack public appeal. People can relate to the restoration of the bald eagle populations to the shorelines of the Great Lakes because of declining levels of organochlorine pollutants. It is, however, much more difficult to get the public enthusiastic about declining levels of an enzyme such as ethoxyresorufin O-deethylase, even though this enzyme is a specific marker for several of the chemicals that caused the failure of the bald eagle to recover from the effects of DDT and dieldrin in the 1950s. As levels of chemicals decline and affected species recover and overt effects disappear, novel methods will be required to provide interpretations of these biochemical measures that are accessible to the lay public.

During the next biennial cycle, the Biological Effects Subcommittee intends to host a series of roundtables on various biochemical indicators that are specific for the chemicals that have caused injury to fish and wildlife resources. These roundtables will probably result in recommendations on the kinds of biochemical parameters that should be routinely measured and reported by the Parties. The roundtables will document long-term trends in specific kinds of biological activity, caused by changes in exposures of Great Lakes fish and wildlife to toxic chemicals. These biochemical parameters, if routinely measured, can act as an inexpensive and effective early warning of changes in trends of persistent toxic chemicals, that have injured fish and wildlife populations and human health during the past four decades.

3.2.1 Preamble: How Do We Define Health and Threats to Health?

Men as a rule find it easier to depend on healers than to attempt to live wisely.

Rene Dubos. The Mirage of Health

Rene Dubos, a medical researcher on the causes of human disease, advocated prevention rather than attempts to cure disease after the fact. He viewed the process of living as a continual interplay between the individual and his environment. This is another way of saying that humans depend on air, food, drinking water and warmth as much as bacteria, elephants and rosebushes. Dubos, a strong believer in the unity of nature, noted that harmonious interplay becomes a struggle when we unwisely weaken the forces of nature. The result: environmental deterioration is accompanied by disease and disability.

In the Great Lakes region, a battle rages against persistent chemical contamination from organochlorines and heavy metals. Both wildlife and humans suffer similar expressions of harm, particularly to their reproductive and developmental processes. The complex biology of germ cell formation and development of the fetus are easily disrupted by the intrusion of foreign chemicals. Wildlife experts since the 1960s have documented the impact of toxic substances on reproductive processes. The adverse effects appear differently in each species: fish that swim upside down, double-crested cormorants whose bills cross like twisted scissors, mink that cannot reproduce. On the human side, child development experts have detected adverse behavioral changes in children, changes resulting from interference with brain development during the fetal stage.

Should we be surprised that adverse effects due to toxic substances should surface in humans? Are we that exposed? Obviously we are not fish, but we experience contamination by persistent toxic substances as do fish and wildlife. Moreover, it would be a mistake to think that contamination can be eliminated by deleting certain foods from our diet, food such as lake...
Our bodies have become nodal hot spots. Persistent toxic substances contaminate all food by virtue of cycling through the air, land and water. Our bodies, like those of other organisms, are parts of the cycle. Persistent toxic substances bioaccumulate at each step in the food chain. When we eat predatory fish and wildlife at the top of food chains, our bodies become nodal hot spots.

Children are more vulnerable than adults to toxic chemicals. Adults, their biological development complete, deploy an array of detoxifying mechanisms that defend against toxic substances. The fetus, in contrast, feeds off its mother’s body, and operates one step higher on the food chain. Most critical, the fetus is going through a once-in-a-lifetime development, a process delicately orchestrated and timed, that can easily be upset by foreign chemicals. In short, our children are better indicators of environmental quality than adults.

Diminished human potential, resulting from exposure to toxic substances, however, remains largely hidden. Most exposed children live apparently normal lives. Subtle manifestations of human damage are unlikely to attract the attention of health authorities, unless our definition of health changes. The World Health Organization (WHO) addressed this issue 40 years ago. They offered an expanded view of what constitutes health: "Health is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity."

Whether or not one needs the services of a doctor does not define the state of one's health. Good health, according to WHO, represents more than a collection of negatives, more than not suffering any clinically-defined disorder. Subtracting I.Q. points from individuals exposed in the womb to toxic substances falls into the WHO definition of an adverse effect on health.

The WHO concept of health fits well with the ecosystem concept: everything interacts with everything else. If one accepts that notion, then one accepts the view that anything of a social, personal or environmental nature can influence the state of one's health. While personal lifestyle and social factors are recognized determinants of health, environmental factors receive less credit. The prevailing view distances human health and well-being from environmental factors. The environment is regarded as something out there, separate from humans, something that can be dealt with when time, money and resources permit.

This attitude is equivalent to saying that we are merely an audience to a planetary symphony, when, in fact, each human is a player in the orchestra along with other forms of life. Human actions interweave with those of other organisms and planetary forces. But, unlike the other players, humans now set the tone of the planetary system. The tone, increasingly, turns disharmonious. We recognize the environmental dissonance, but we attempt corrections after disharmony has been identified rather than learn to play in tune with the natural forces of the planet.

Paradoxically, the reductionist science that underpins environmental policy works best for after-the-fact solutions. Moreover, this science focuses almost exclusively on harm to humans; concern for the health of wildlife or ecosystem processes receives low priority. Government authorities prefer neat, easily-recognized, human medical problems as the criteria on which to base decisions. They want to know causes. In asking science to provide cause-effect evidence of harm to humans, authorities exclude harm to humans which fails to fit a narrow definition of threat to health.

A preventive perspective makes us ask questions that cause-effect science can seldom answer. The sciences of toxicology and epidemiology, on which environmental policy-makers have traditionally depended, were not designed to answer questions about exposure to the multiplicity of chemical contaminants that enter food chains. A preventive ecosystem approach requires us not only to look at all chemicals, but all exposure routes: air, land, water,
food. Governmental policies must recognize that science is unable to furnish hard answers for all questions.

This need for more than cause-effect science does not mean abandonment of science. Far from it. We need to learn ways of using science more creatively to help set policy objectives and priorities. In our 1989 report, we recommended that policy-makers adopt a weight-of-evidence approach to human health. One assembles all the evidence: adverse effects on wildlife, adverse effects on humans, adverse effects on ecological processes and a fundamental understanding of how biological systems, such as the reproductive system, can be harmed. As in solving a difficult crime, the weight of all the evidence together builds a basis for judgement.

The weight-of-evidence approach supports the objectives of the International Joint Commission. It provides a basis for judgements within a preventive framework, a scientific rationale for the ecosystem approach. But, it does require new types of evidence and new ways of assembling evidence. Above all, it requires a willingness to act on an integrated body of evidence rather than to wait for irrefutable evidence of a cause-effect link.

A better understanding of subtle forms of harm induced by environmental contaminants is key to accepting the weight-of-evidence approach. The Board’s Health Committee has set an objective of expanding and putting on a firm scientific base, criteria for defining how toxic substances affect human health. In proceeding with its workplan the Committee accepts three ground rules: (1) that humans share with all other life forms the fate of the ecosystem; (2) that human health is more than an absence of clinically-defined disease; and (3) that the Committee generates practical recommendations to the SAB and the Commissioners.

### 3.2.2 Developmental Neurotoxicity

The Board’s Health Committee sponsored a workshop in Chicago in 1989 that explored recent information on the health effects of exposure to persistent toxic substances. Participants in this workshop concluded that neurotoxicity, particularly in children, is one of the more subtle and potentially-devastating manifestations of harm. Children born to mothers with levels of PCBs and other organochlorines only slightly above average exhibited reduced birth weight, neonatal behavioral abnormalities and poorer recognition memory in infancy as well as poorer short-term verbal and quantitative memory up to at least four years of age. Psychologists and behavioral toxicologists are showing increasing concern, expressed in an increasing number of studies. The American Psychological Association, for example, has compiled a bibliography on the psychological, behavioral and sociocultural aspects of environmental contaminants, consisting of 962 abstracts and papers over the period 1973-1989. The same association sponsored a mini-symposium on this subject at its 1989 annual meeting.

Several independent research groups plan to investigate further the effects of transplacental and breast milk transfer of chemical contaminants to infants. They plan to measure the cognitive and psychological development of young children in the Great Lakes basin. Neurobehavioral effects of environmental contaminants, however, are subtle and difficult to measure. Results would be more conclusive if experimental design could be improved. The Health Committee, therefore, organized in April 1991, a workshop that brought together leading researchers on this emerging issue (International Joint Commission 1991g). The workshop concentrated on analytical protocols for PCBs, lead and methyl-mercury; on the development of questionnaires for Great Lakes fish consumption and on questions of neurobehavioral development. The intent was to design procedures to relate exposure to neurobehavioral toxicity.
Participants in the workshop developed four major conclusions pertinent to the health risks of Great Lakes populations:

- human exposure to toxic substances is a serious health concern
- further research is not needed as a basis for preventing the input of persistent toxic substances to the Great Lakes Basin Ecosystem
- research is required to understand better the health risks of persistent toxic substances, especially to subpopulations at special risk
- studies of the health effects of persistent toxic substances on individuals must be conducted ethically and must include a sensitivity to communication and interpretation of results, particularly when few options are available to avoid further contamination and when there is no feasible way to reduce existing body burdens of lipophilic toxic substances.

3.2.3 Innovative Approaches for Evaluating Human Health in the Great Lakes Basin, Using Wildlife Toxicology and Ecology

The adverse effects of pollutants on wildlife can foretell how the same pollutants could affect human populations. Species of wildlife eating near the top of the food chain suffer the severest impacts from persistent toxic substances. The most common impact is on reproductive systems (Table 3.3). Sixteen top predator species have experienced such problems, with resulting population declines. The list includes double-crested cormorants, herring gulls, common terns, ospreys, Beluga whales and mink. The declines seen in the 1970s and early 1980s, however, seem to have been reversed although the reproductive problems of fish-eating birds continue, notably in specific regions, such as Saginaw and Green Bay.

Reproduction is one of the most complex of all biological processes and it is not surprising that traces of toxic substances interrupt or interfere with it in some way. Toxic effects unfold in both males and females. Studies with lake trout and predatory birds reveal that changes in the sperm and ova of exposed parents result in poor survival of the young. Embryos that live exhibit altered body metabolism, low body weight, immune suppression and behavioral changes. Similar changes have been observed in wild mammals.

Eating higher up on the food chain becomes increasingly hazardous due to the biomagnification of toxic substances. PCBs, dioxin and other organochlorines accumulate in the fats of plants and animals. Each species has a higher concentration of organochlorines than in its food.

Fish-eating birds live at a top level. The eggs of herring gulls, for example, contain 25-million times the concentration of PCBs found in lake water. Bald eagles eat gulls and have an even higher concentration. If there are no other factors involved, the success of the bald eagle in reproducing (and in not suffering disease) should be a good predictor of the reduction of PCBs and other organochlorines in the Great Lakes basin.

Analyses of bird eggs collected over the last 20 years generally show that concentrations of selected organochlorine compounds, after an initial period of decline, have levelled off. The concentrations, however, are still unacceptably high compared with IJC objectives and the United States Food and Drug Administration's levels of concern in fish. Moreover, a decline in the total amount of persistent toxic substances does not necessarily imply a decline in toxicity. PCBs, for example, consist of 209 congeners, some more toxic than others. Most analytical data apply only to total PCBs. The fact that some congeners are accumulated more rapidly than others leaves open the question of whether or not there has been any reduction in total toxicity.
The adverse effects of exposure to Great Lakes pollutants in both wildlife and humans show a remarkable consistency. First, adults may show no adverse effects of exposure, yet harmful effects show up in offspring. Second, cancer does not appear to be a major factor in controlling population size. Third, trying to link an observed adverse effect with a single toxic chemical is generally impossible. Both humans and wildlife are exposed to the full range of toxic substances.

Population, Organism and Tissue Effects in Great Lakes Animals
(observed effects that have been reported in the literature)

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LEGEND: 1 Population Decline  4 Metabolic Changes “Wasting”  7 Target Organ  10 Immune Supression  13 DNA Adducts
2 Reproduction Effect  5 Deformities  8 Behavioral Changes  11 Generational Effects
3 Eggshell Thinning  6 Tumors  9 Hormonal Changes  12 Enzyme Induction

The similarity of adverse effects in wildlife and humans supports the important role of wildlife as environmental "canaries" or monitors of environmental quality. Animal monitors have an advantage over the traditional chemical analysis of water and air samples because they integrate adverse effects from the total range of toxic substances.

Conclusion:

The traditional public health approach to monitoring for cancer and unusual birth outcomes is too blunt to capture the subtle reproductive effects of Great Lakes contaminants. Subtle health effects observed in wildlife provide clues for the design of experimental approaches for determining if the same or similar effects occur in human populations.

3.2.4 Effects of Persistent Toxic Substances Transferred from Mothers to Children

Studies on wildlife and laboratory animals suggest that resistance to the effects of toxic substances is least in early stages of life. This concept applies equally to humans and was recently the focus of an evaluative report (Gobas 1990) commissioned by the Health Committee...
Health advisories for P633 in human milk have been set arbitrarily.

Health advisories for PCBs in human milk have been set arbitrarily.

Background

Organochlorines, including PCBs, DDT, dieldrin, dioxins (TCDD) and dibenzofurans, are among the most persistent toxic substances in the Great Lakes. They accumulate in body fat. Human adults, by virtue of diets that include carnivores that reside high up in the food chain, become enriched in these chemicals. Nursing women pass the accumulated chemicals into their milk, in effect, putting their babies one step higher on the food chain. The potential for harm to the developing baby has raised considerable concern among authorities. This concern has led to the monitoring of human milk.

The Gobas report reviewed 12 breast milk surveys conducted in the Great Lakes basin. Whereas concentrations of DDT and DDE in breast milk have decreased four- to five-fold since 1968 (DDT was banned in 1973), levels of PCBs have not fallen over the same period. The Great Lakes region, however, is not significantly more or less contaminated with PCBs, DDT and dieldrin than are other parts of North America or Europe.

Health Advisories

The Great Lakes states and Ontario have established health advisories for PCBs in human breast milk. Advisories for other contaminants have not been established. All these jurisdictions, except Wisconsin, have set an advisory at 50 ppb of PCBs for whole milk. Wisconsin set an advisory at 100 ppb. Interestingly, the surveys show a fairly uniform level of PCBs in the breast milk of mothers living in the Great Lakes basin. The average is about 26 ppb.

The Gobas (1990) report concluded that current health advisories do not adequately reflect available scientific information on the toxic effects of PCBs. It cited studies, based on a limited number of samples of nursing rhesus monkeys (Allen et al. 1980; Barsotti and Miller, 1984) who had 50 ppb of PCBs in their milk. One-half of their infants died within four months of birth and the surviving offspring had deficits in hyperlocomotor activity and memory more than three years after weaning (Levin et al. 1988). Arnold et al. (1991) found a dose-dependent effect on reproductive parameters after feeding rhesus monkeys daily doses of 0, 5, 20, 40 and 80 mg/kg body weight of PCBs over a 2-1/2 year period.

The customary practice of extrapolating data from animal experiments to the human situation is to start with the animal “no-effect” level, in this case less than 50 ppb, and divide it by a factor of 100, or even 1,000, to arrive at a “safe” level for humans. This accepted practice has not been applied in the case of PCBs in mothers’ milk. We conclude that the 50 and 100 ppb levels of concern in health advisories for PCBs in human milk have been set arbitrarily and are not based on scientific studies of perinatal effects or risk assessments on children.

Toxicity of Mothers Milk: Balancing Positive and Negative Influences

The question which many mothers ask, knowing that there are toxic substances in breast milk, is whether or not they should breast feed. Scientific information fails to provide a clear answer. It is known that the milk is contaminated, not only with PCBs, but with the range of persistent toxic substances found in the Great Lakes. The specific question that we ask is whether these substances are harmful at the levels found in breast milk.

Biomagnification plays a role in the transfer of PCBs and other organochlorines from mother to child, resulting in elevated body burdens of chemicals in the child. At birth, baby and mother generally have the same level of PCBs, indicating that PCBs transfer freely and...
passively through the placenta. Once the baby starts feeding on mothers' milk, the transfer becomes active. That is, the baby concentrates the PCBs. After six to nine months of breast feeding, the level of PCBs in the baby can reach four times that in the mother. The level keeps rising the longer the mother breast feeds. The question then arises: When does breast feeding raise the level of PCBs in the infant to a toxic level? If we had the answer to this question, physicians could advise nursing mothers on a suitable duration for breast feeding. Research on this question is needed.

Evidence of the toxic effects of PCBs in humans was obtained in two studies of accidental poisonings, which occurred in Taiwan and Japan. In the Japanese incident, the victims had consumed rice oil containing 2 to 3,000 ppm of PCBs. Thirteen infants were born to exposed women: one was stillborn; four were undersize; ten had dark skin pigmentation; four had pigmented gums; nine had conjunctivitis; and eight had jaundice. Nine years later, these children still suffered neurological and developmental impairment.

Infants are particularly susceptible to neurological damage, a condition detectable in groups with levels of PCBs only slightly greater than those characteristic of the general population. One such group consists of families in Michigan who had histories of eating fish from Lake Michigan. The fish were contaminated with PCBs and many other persistent toxic substances. Investigators used the levels of PCBs in the blood as a convenient marker for the whole range of contaminants. Children born in these families and breast fed for more than one year showed a decrease in spontaneous activity compared with children of mothers who did not have histories of eating large quantities of Great Lakes fish. These and related results were attributed to intra-uterine effects, rather than to breast feeding. This kind of toxic effect is subtle, hard to quantify, yet has the potential to create long-term ill effects on the development and wellbeing of these individuals.

When assessing the toxicity of breast milk, the nutritional value of the milk and other factors need to be considered. Breast milk offers clear advantages to mother and child in terms of bonding, transfer of immunities and, of course, superior nutrition. The Ministry of Health of Ontario, for example, states that "the known benefits of breast feeding are felt to exceed any potential disadvantage and women are encouraged to breast feed their infants." This statement was, however, made before evidence of serious perinatal effects came to light. Moreover, mothers may have transferred most of the potentially-damaging body burden of toxicants to their infants during the fetal stage. Concerned mothers in most states and Ontario can have their breast milk analyzed free of charge, but most citizens, physicians and, surprisingly, officials of health departments— are unaware of the service and, further, may lack the training to interpret the results. There is a communication issue here. Better public information and education programs are needed.

Screening nursing mothers for subclinical abnormalities, such as high levels of PCBs in serum or breast milk for which effective treatment is unavailable, could by itself provoke adverse health effects. Some women could suffer guilt, depression or interrupted relationships with their infants. Thus, an ethical clinical policy in this regard demands high quality evidence that net benefit accrues to the child before mothers are advised to discontinue breast feeding earlier than they might wish. The significant benefits of breast feeding for children could well outweigh the ill effects from contamination with organochlorines, yet a definitive answer is not on hand.

**Breast Milk Contamination as a Surrogate for Transfer of PCBs from Mothers to Fetuses**

That mothers deliver persistent toxic substances to children is a serious health concern. It indicates a problem that has to be addressed at an ecosystem level. Mothers are contaminated because they live in contaminated ecosystems. Water, air and foods carry detectable amounts of toxic substances, many of which are not easily eliminated from the
body. They lodge in the body fat, accumulating year by year. The mothers, in turn, transfer these toxic substances from their body fats to children, in utero and in breast feeding. The main source of PCBs for mothers is food, especially when enriched with heavily contaminated Great Lakes fish.

The primary concern of the Board here is not whether mothers should or should not breastfeed their babies. That is a health issue that must be evaluated by others in terms of broader concerns than just toxic substances. The Board's primary concern is to develop a process that will more people and governments to action, using the levels of toxic substances in mothers' milk as a surrogate for the concentrations of toxic substances in mothers and hence, for the transfer of toxic substances from mothers to fetuses.

Over the past 15 years, the Board has repeatedly alerted the governments of the United States and Canada to the harmful effects of persistent toxic substances. The governments themselves have recognized the requirement in the Great Lakes Water Quality Agreement to eliminate the inputs of persistent toxic substances. Nevertheless, old problems remain and new problems keep arising.

Why?

Evidently, because the need for new attitudes and behaviour in relation to the production and use of persistent toxic substances has not yet meaningfully penetrated human consciousness.

Using the presence of persistent toxic substances in mothers' milk as a surrogate for the placental transfer of persistent toxic substances will not allow parents to prevent intra-uterine harm during the first pregnancy but it could cause people to reflect on the implications of contaminated ecosystems to children. The issue is not breast feeding, but how to avoid contaminated ecosystems caused by the long-range transport of persistent toxic substances in the atmosphere. This is not a problem that any nation or area can solve on its own. Collective action is needed. The purity of mothers' milk could be the needed stimulus for action. For this reason, the Board urges the adoption of a two-pronged strategy on the part of governments and citizen groups: on the one hand, continued promotion of the benefits of breast feeding, and on the other, concerted action to lower contamination levels in mothers' milk.

The Board recognizes that, even if all organochlorine pollution stopped today, contamination of the environment and mothers' milk would persist well into the 21st century. Research and better controls are needed to address these public health issues now. Answers are needed to provide advice to governments, the public and special groups so that health risks from exposure to persistent toxic substances can be reduced.

3.2.5 Conclusions

The weight of evidence shows that persistent toxic substances, particularly organochlorines, found in the Great Lakes basin contribute to a broad spectrum of adverse human health problems. Fetuses and infants, particularly, are at serious risk.

In arriving at this conclusion, the Board cites the following evidence:

- Great Lakes pollutants cause reproductive failure and neurobehavioral deficits in fish and wildlife.
- PCBs and related organochlorine chemicals are known to be harmful to humans. Children born to mothers exposed to high levels of PCBs in rice oil in Japan and Taiwan exhibited incapacitating health and behavioral effects. These effects are seen in children ten years after the mothers' one-time exposure.
Contamination of Great Lakes fish with PCBs and other persistent toxic substances is associated with neurobehavioral deficits in infants and young children.

Infant rhesus monkeys exhibit adverse health effects at parental exposure levels of PCBs roughly comparable to those of human mothers in the Great Lakes basin.

Ambient levels of persistent toxic substances in the Great Lakes are not decreasing as rapidly as in the 1970s. The level of DDT and its metabolites has actually increased over the last five years.

3.2.6 Recommendations

1. **Recognizing:**
   - the accent on toxic substances in the Great Lakes Water Quality Agreement
   - the urgency for eliminating persistent toxic substances voiced by the International Joint Commission in its Fifth Biennial Report
   - that at any given moment in the Great Lakes basin, 500,000 fetuses lie in the wombs of mothers where they are particularly vulnerable to harm from persistent toxic substances
   - that the harm which these citizens of the 21st century experience can linger for the rest of their lives

   **It is recommended that the IJC declare that persistent toxic substances, particularly organochlorines, are a hazard to human health in the Great Lakes basin.**

2. **Recognizing:**
   - the need for scientifically-based criteria and objectives for persistent toxic substances in mothers’ milk
   - the positive benefits of breast feeding
   - the directness of the bonding between parents and children

   **It is recommended that the levels of persistent toxic substances in mothers' milk be used as a surrogate for the transfer of persistent toxic substances from mother to fetus; that scientific criteria and objectives be developed for acceptable levels of persistent toxic substances in mothers' milk and that the goal of the Parties be to achieve virtual elimination of persistent toxic substances, especially organochlorines, from human beings.**

3. **Recognizing:**
   - that persistent toxic substances affect the health of human populations in the Great Lakes basin
   - that information is needed to identify routes of contamination, especially via food, in respect to dietary exposure
   - that communities and individuals more highly exposed to persistent toxic substances need to be identified more clearly

   **It is again recommended that the Parties establish a coordinated, multidisciplinary binational program to more clearly understand and to prevent injurious health effects of chemicals designated as priority chemicals by the International Joint Commission.**
4. REMEDIAL ACTION PLANS

- **Reporting requirements have changed seven times**

  Reporting requirements have changed seven times. In response to Annex 1, Section 6 of the 1972 Agreement, Great Lakes states/province, under the aegis of the Water Quality Board, the Commission and the Water Quality Board identified and classified specific areas of non-compliance, such as harbors, river mouths and parts of the connecting channels, first as "problem areas," later as "Areas of Concern."

  For almost two decades the classifications of these affected areas have changed several times and reporting requirements have been changed at least seven times. In 1975 there were 63 such areas; at present, there are 43.

  The present reporting process, which was established in 1985, involves three stages: problem definition, remedial measures and restoration of beneficial uses. At present, most Remedial Action Plans (RAPs) are in Stage 1 and there have been deficiencies in those reports.

- **The Commission repeatedly expressed its concern about lack of progress**

  The Commission has consistently expressed its concern about the lack of progress in RAPs in all of its five biennial reports. In its last report (International Joint Commission 1990d), the Commission said that "RAPs are not merely a planning process ...." For the most part, however, they have been only a planning process. The Commission's views were echoed in the 1987 Great Lakes United report: "We don't need any more study, we want action now." In its Fifth Biennial Report (International Joint Commission 1990d), the Commission concluded that "If RAPs are to be effectively implemented, they may require the force of law."

- **Stage 2 reports should include a timetable for load reduction**

  One of the reasons for success in reducing phosphates from point sources in the Great Lakes was that a timetable for load reductions was established.

  A 1991 report on a program for zero discharge by the National Wildlife Federation and the Canadian Institute for Environmental Law and Policy recommends "a timetable for load reductions ...." This recommendation was echoed by a January 1991 Thunder Bay RAP report which said: "There should be clear timetables for priority pollutants."

- **The data available to develop load reductions is sketchy and needs to be improved**

  Data on loadings of pollutants from various types of sources to Areas of Concern are very sketchy in spite of nearly two decades of study. Loading data for the most conventional types of pollutants is only partly available, as indicated by a March 1991 (Crickman, unpublished) report concerning six Areas of Concern recently prepared under contract for the International Joint Commission (IJC). That report showed reductions in conventional point source pollution loadings from four Areas of Concern and significant increases for two. It is apparent from the report that data are not adequate to describe the loadings from combined and storm sewers. Such loads are usually very significant.

- **Stage 2 reports should link remediation action to compliance with relevant regulatory processes**

  For example, the Crickman report indicates that "pollutant loadings were already calculated and recorded for the Canadian facilities, while only raw data was available for the facilities in the United States." Section 303 (d) of the 1972 U.S. Federal Water Quality Act requires that "each state shall identify those waters ... for which effluent limitations are not stringent enough ... and establish ... the total maximum daily load..." The Act requires states
to rank such waters by priority and submit the list to the U.S. Environmental Protection Agency (U.S. EPA). If the U.S. EPA disapproves the list, it must prepare its own list and load limits.

A broad range of laws and regulations require cleanup of the problems found in Areas of Concern. They need to be fully identified, incorporated into the process and invoked. Violations of laws and regulations should be included in the Stage 2 report.

- **The Stage 2 process needs to separate three types of problems based on the complexity of the solution**

In 1989, the Water Quality Board said that Remedial Action Plans are taking longer than expected "because of the complexity of problems and solutions."

Remedial Action Plans represent a mix of conventional and complex problems, and problems which may require further research. Therefore, and in order to prevent a further delay in dealing with conventional problems, it is essential that the Stage 2 process separate the remedial schedule into the following categories:

- **Conventional Pollution Problems**
  These include treatment of municipal sewage (including illegal discharges of raw sewage, or sewage that has less than secondary treatment), pollution from combined and storm sewers, the same as the above for industrial wastes, radioactive wastes, dredging disposal sites, and the discharge of toxics from point sources.

- **Non-Conventional Pollution Problems**
  These include polluted sediments, pollution caused by navigational dredging, groundwater pollution causing surface-water pollution, nonpoint source pollution (including agricultural pollution), localized air pollution and pollution caused by a pattern of leaks and spills.

- **Research and Pilot Studies**
  These include pollution problems where scientific and technical knowledge is inadequate to assure corrective steps, e.g. situations where it is difficult with existing knowledge and experience to decide how to deal with certain in-place pollutants and where the correction will require research and/or pilot studies.

- **Conventional pollution problems should be put on a fast track, that is separate from and does not await the reporting scheme**

The existence of sophisticated reporting schemes associated with Areas of Concern has tended to delay addressing some conventional pollution problems associated with Areas of Concern.

- **Stage 2 reports need to include budgets and sources of funds**

Another reason for the success of the program to reduce loads of point source phosphate is that the program identified the cost of the project.

Therefore, it is necessary to combine the timetable for reduction of loadings to the projects in the three categories (above) with specific workplans and budgets for the design, construction and operation of mitigation processes as well as with staffing at all levels of government to carry out the programs and research.

In areas where enforcement steps have been underway for some time and have not been successful, there is a need to review and revise an enforcement strategy.
For example, in cases involving publicly-owned treatment works, the courts have had success by transferring responsibility to newly-created institutions.

- **Public participation is essential but cannot become a substitute for good government**
  While a good public participation process is essential for the success of the RAP effort, it can lead only to disenchantment if government does not respond decisively. The public participation process can enhance cooperation among the stakeholders, including government. It can help resolve conflicts and help set goals for remedial action and finance, but it cannot and should not be expected to replace the leadership responsibility of government. The increased familiarity among stakeholders and government should not be allowed to interfere with or defer enforcement actions against serious violations of law and regulations where timely corrective action is not underway.

- **Technical support can greatly enhance the public participation process**
  Public participation can be greatly enhanced by independent technical support. In a number of environmental programs, technical support that is independent of government and industry is being provided to public participation efforts involved with large and scientifically complex projects. The budget for the Remedial Action Plan should provide for such support.

### 4.1.1 The Ecosystem Approach

The Agreement and the Commission have put much emphasis on the “ecosystem approach” in the entire RAP process. There is a need to define what is meant by that approach and to make it an essential element in the diagnostic part of the RAP process. It should include at least the notion of teamwork among all government agencies which have a stake in the process.

Financial constraints may require deferring the full ecosystem approach in the implementation of the Remedial Action Plan. When that situation occurs, the ecosystem approach should be used establishing priorities for programs, projects and budgets.

### 4.1.2 Summary and Recommendations

The Commission has repeatedly expressed its concern about the lack of progress in connection with Remedial Action Plans.

The complexity suggests and it is recommended that the problems and solutions be divided in accordance with their degree of complexity to achieve a strategic planning approach similar to that used in the control of point sources of phosphorus.

It is recommended that conventional pollution problems be put on a fast-track, that is separate from the present Remedial Action Plans.

This approach would require, and it is recommended that specific time tables for load reductions of pollutants be linked to budgets and regulatory actions.

It is recommended that in Areas of Concern, early consideration be given to implementation of Stage 2 recommendations with attention to:
- economic sanctions (e.g. elimination of government contracts and purchasing agreements with polluters)
- legal innovations (e.g. use of injunction)
- effective enforcement techniques, particularly for those areas where violations of laws and permits have existed for many years and where traditional enforcement methods have not achieved regulatory compliance
It is clear that none of these considerations will change the pace of this program, unless there is stronger leadership and commitment by governments at all levels to eradicate these serious injuries to the Great Lakes Basin Ecosystem.

The Commission, responding to initial Remedial Action Plans, has commented that, as part of taking a comprehensive ecosystem approach, relevant socio-economic and institutional aspects should be integrated into the documents, pointing, for example, to current practices in environmental impact assessments.

In practical terms, an assessment of socio-economic factors is seen as essential in order to evaluate remedial options and provide funding commitments to plan implementation over time. This knowledge would also provide a basis for determining the role and the participation of all levels of government and the private sector involved in clean-up initiatives.

In September 1990, the Science Advisory Board conducted a roundtable (International Joint Commission 1990c) to examine socio-economic considerations relevant to RAPs, particularly current approaches, promising initiatives and future directions. As part of this effort, a framework was presented for assessing RAPs with respect to the integration of socio-economic factors within a systematic and comprehensive ecosystem approach, as required under Annex 2, paragraph 2(a) of the Great Lakes Water Quality Agreement (GLWQA). The framework focused on three factors:

- the socio-economic dimensions of problems which could cause an area to be designated as an Area of Concern
- the socio-economic forces driving those activities causing degradation or inhibiting restoration of beneficial uses
- the feasibility of other solutions to the problems of the past and of sustainable development strategies for the future

Human activities were viewed essentially as having contributed to environmental degradation in terms of a downward spiral. As degradation starts, options are foreclosed and beneficial uses that require high levels of environmental quality can no longer be maintained. These uses begin to be replaced by those that do not require any natural integrity in order to be sustained until the economy becomes inextricably linked with activities that impinge on the ecosystem. There are opportunities not only to stop the downward spiral through remedial actions, but to reverse the direction. That is, there are opportunities to create an upward spiral where improved environmental quality and amenities attract new and higher-order economic activities. There are many locales of the Great Lakes basin where this reversal is, in fact, occurring (e.g. the waterfront redevelopment projects, both underway and planned for many urban areas in the U.S. and Canada and the large order of investment that these projects represent). As traditional, smokestack industries in the Great Lakes region become more information-intensive, and the service economy continues to emerge and evolve, it is clear that the quality of life and the unique attributes of the Great Lakes will become increasingly important. Quality of life includes, in large part, environmental factors, such as human health concerns, in terms of proactive aspects such as “healthy cities”, as well as recreational and aesthetic considerations. These factors contribute, in turn, to new commercial opportunities and monetary benefits. In terms of tourism alone, these factors contribute to the value of an industry that ranks among the top five in every Great Lakes state and province. In economic terms, the cost of environmental degradation is the “opportunity cost”, which is the value of these potential benefits (and avoided costs) that become no longer attainable because of environmental degradation.
Environmental costs, effects on income and nonmonetary benefits can all be quantified in theory in terms of a monetary economic value. In practice, however, there are many methodological difficulties in quantifying these values (see SAB 1987 Report, 3.1.1 Valuing the Benefits of Environmental Improvements). While full quantitative evaluation of environmental benefits may present difficulties, it is important that implicit values be assigned to benefits and addressed, even if on the basis of the participatory process rather than on the basis of economic calculation. The integration of benefit evaluation and goal setting into the participatory processes of RAPs has several advantages: (1) it can help to animate and motivate these processes; (2) it puts benefit evaluation into an overall context in which it is most comprehensible and relevant; (3) it draws involvement in, and support for, the RAP from diverse stakeholders, and through them, from large sections of the public. Survey methods can be used to reflect where values of the general public concur with, or diverge from, those of participating stakeholders.

With regard to the question of who should pay the costs of remedial action, it was suggested that the general rule be adopted that the "polluter pay." The principle that polluters should pay for the environmental costs of their pollution has the economic advantage that it creates the correct incentives to reduce pollution at its sources. It also encourages the true costs, including environmental ones, to be reflected in the prices of the products and services.

Figure 4.1 illustrates the current and extended scope of RAPs. Currently, remedial actions are directed to bringing about ecosystem enhancements that would allow the Area of Concern to be delisted. The scope of the process can be broadened as shown to consider explicitly socio-economic changes and ultimate benefits (and costs) in the Area of Concern, which are consequent to remedial actions and ecosystem enhancements. The stippled feedback lines (above, and connecting, the boxes) indicate that planning of remedial actions and follow-on investments is an iterative process in which actions can be modified according to the effects that are predicted or realized from these actions.

In terms of the "polluter pays principle", polluters should be made responsible as far as possible for the costs of remedial actions to achieve the required ecosystem enhancements (for delisting the AOC). Obviously, the costs of follow-on investments must be borne by those who undertake them. Nevertheless, the value of remedial actions derives from the inherent value of the consequent ecosystem enhancements, and from the value of the opportunities (options) for beneficial follow-on investments that are thereby made possible.

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Current and Extended Scope of RAPs

Current scope of RAPs

Scope of RAPs integrating socio-economic considerations

Figure 4.1
4.2.1 Current and Proposed Scope of RAPs

The proposed framework for integrating socio-economic factors was considered with a view to the information needs of RAP developers as well as the requirements for reviewers and committees involved in RAP assessment. The framework was developed on the basis of a series of tables, each comprising an assessment informed by prediction or commitment:

- effects of remedial actions on use impairments over time
- funding commitments relative to each remedial action in terms of industry, local government and private sector requirements
- investment income and employment, with and without the RAP in terms of each major income sector, including those industries most affected by remedial action.

As the Parties begin to develop Stage 2 RAPs (Annex 2, paragraph 4 (d, iii)), it will be critical that cost estimates and benefit valuation be used to evaluate and select remedial and regulatory measures. Recent cost estimates prepared by the Northeast-Midwest Institute, Ontario Ministry of the Environment and Statscan/Institute for Research on Public Policy indicate that several (tens of) billions of dollars from both public and private sources will be required for plan implementation. These high estimates do not include allowances for:

- the replacement and maintenance of the municipal water and sewage handling and treatment infrastructure that will be required to meet rising environmental standards, to replace aging facilities and to provide for population growth. The immediate concern under this heading is for the combined sewer overflows, an issue that is central, but not limited to, the Areas of Concern
- rehabilitation and maintenance of degraded areas both adjacent to the Great Lakes and inland in the basin, currently not included on the list of 43 Areas of Concern
- accidental spills, discharges and other forms of catastrophes, whether induced by humans or occurring in nature

Seen from the perspective of the wealth of a region with a gross annual product in excess of one-trillion dollars (U.S.), and spread over time, the cost estimates were not viewed as overwhelming or a cause for diversion from the eventual goal of Great Lakes cleanup. Roundtable participants agreed that increased efforts must be made to present the cleanup challenges in Areas of Concern in a positive light by focusing on benefits as well as costs. Demonstrating the economic payoff associated with remedial action allows Great Lakes cleanup to be presented as a sound socio-economic investment rather than as a drain on limited public cleanup funds. As such, it was noted that the preparation of a user’s guide to benefit assessment for RAP developers and public advisory committees would encourage the application of relevant methodologies, provide for improved submissions and address important implementation aspects.

The Board supports these conclusions and recommends that socio-economic considerations relevant to RAPs receive increased attention by the Parties, particularly those plans at Stage 2 in the planning process, and that increased efforts be directed at developing a comprehensive understanding of the social, economic and ecological implications and effects of remedial actions. The Board encourages the Parties to provide for improved communication among the citizens in Areas of Concern and RAP coordinators in order to share common approaches concerning underlying values and benefits from remediation as well as costs. The Board notes the importance of the Commission and the Parties continuing the tradition of RAP Coordinator’s Forums as one means of accomplishing a consistent, overall approach to RAPs for the entire Great Lakes basin.
Lakewide Management Plans (LWMPs) represent a mid-point in an evolving process to address the adverse impacts of critical pollutants on the boundary waters of the Great Lakes system. The general principles presented in Annex 2 of the Great Lakes Water Quality Agreement (GLWQA) stipulate that LWMPs must embody an ecosystem approach; assess problems, and determine and implement remedial actions that address critical pollutants; and ensure that the public is consulted throughout the process. They further specify that LWMPs should identify threats posed to human and aquatic health from critical pollutants; determine load reductions and remedial sources; and specify institutional responsibilities and an assessment of effectiveness.

Two schools of thought have emerged with respect to the focus and scope of LWMPs. One subscribes to a narrow interpretation of Annex 2 and views LWMPs as "Critical Pollutant Plans." The other endorses a broad interpretation, viewing LWMPs as a comprehensive, systematic planning framework within which many activities are pursued, including but not limited to, the control of critical pollutants. It is the view of the Board that the latter best reflects the ecosystem orientation of the Agreement and, therefore, recommends that Annex 2 initiatives reflect this broader interpretation.

The question of how to best incorporate an ecosystem perspective into a LWMP is made clear in the non-Annex 2 initiatives and addressed by the Canada—United States Framework for Lakewide Management Plans for Critical Pollutants (Governments of Canada and United States, 1989). It is recommended that the Parties address this issue as Annex 2 LWMPs are developed, beginning with the explicit recognition of how Agreement initiatives are to be linked.

It is recommended that the Canada-United States Framework for Lakewide Management Plans for Critical Pollutants be further developed to include:

- a recognition of the linkage between the development and implementation of Lakewide Management Plans, Remedial Action Plans (RAPs), Watershed Management Plans (WMPs), Fishery Management Plans (FMPs) and the goal of Virtual Elimination under the Agreement
- specific reference to joint institutional roles and responsibilities for the development and implementation of Lakewide Management Plans
- criteria and procedures for evaluation
- an ecological perspective that assesses the role of processes such as the internal cycling of lake contaminants and fish predation on the prospects for achieving ecosystem objectives through reductions in toxic loading
- recognition that LWMPs are a comprehensive, systematic planning framework, which is not solely limited to the control of critical pollutants, if an ecosystem approach is to be achieved.

An important requirement of Annex 2 stipulates that LWMPs assess program aspects pursuant to Article VI (Annex 2, 6(a), (iii)) and in this regard there is a need to review and evaluate the effect of the current regulatory, legislative and program regime affecting the open lakes in order to contribute to the historical record called for as a general principle under paragraph 2(b). As in the case of RAPs, there is a need for a critical assessment of the effect of the current regulatory approach in terms of the adequacy of both reporting and compliance, that implements any federal, state or provincial legislation, such as the (U.S.) Federal Water Pollution Control Act, the Canadian Environmental Protection Act, the (Canada) Fisheries Act and the Ontario Environmental Protection Act.
of the effect of the current regulatory approach in terms of the adequacy of reporting and compliance be addressed in a Stage 1 LWMP. In order to implement this recommendation, the Canada-United States Framework should be amended to explicitly provide for a comprehensive program review under Section V, Operational Elements.

5.2 Linkages Among LWMPs, RAPs and Watershed Management Plans

The guidance provided by the Parties in a document entitled Lakewide Management Plans Review Criteria states that LWMPs and RAPs “are intended to be complementary” in their geographic coverage of the waters of the lakes that are impaired due to human activity. It specifies that, in most cases, use impairments within nearshore waters will be addressed by RAPs, but if nearshore problems are caused by critical pollutants, they can be addressed in a LWMP. It also specifies that within designated Areas of Concern, Critical Pollutants should be addressed in RAPs from two perspectives: (1) the impairments which they may be causing locally and (2) the extent to which they contribute to lakewide problems. How and to what extent LWMPs address problems in nearshore areas, will depend upon the nature of the problem. In the case of activities completed or underway, i.e. RAPs for Areas of Concern, Niagara River and Lake Ontario Toxic Management Plans, Phosphorus Loadings Plans, Fishery Management Plans and initiatives to address Point Source Impact Zones (PSIZ), the Parties in developing LWMPs will take fully into account and build upon initiatives taken.

Information about non-RAP management planning in a whole watershed (to address nonpoint sources of critical pollutants coming from priority hydrologic areas, as specified by Annex 13 of the 1987 Great Lakes Water Quality Agreement) and/or coordination of existing watershed management initiatives with RAP implementation or with the LWMP process, are needed prior to the completion and adoption of RAP Stage 2 remediation strategies. For example, institutional arrangements (i.e. watershed management authorities or conservation districts) that could be used to implement remedial action strategies targeted at critical pollutants exist in most of the Areas of Concern (AOCs) and could provide one basis for coordination.

5.3 Institutional Design, Coordination and Public Participation

The management structure for LWMPs is led by a working committee composed only of the parties and jurisdictions. It is anticipated that public participation will be incorporated through a Lake Wide Advisory Council that represents basin interests. The Review Criteria provide for the public to be “fully consulted” and to be involved in the development and implementation of the LWMPs. However, the U.S. Environmental Protection Agency and Environment Canada jointly chair the councils (except for Lake Michigan), and membership is intended to be restricted to senior representatives of the United States and Canadian private sector and nongovernmental organizations (NGOs). The potential for coordination between RAPs and LWMPs, using the Advisory Councils as a vehicle may be limited to the extent that council representatives are directly connected to RAPs or authorized to represent them. The Lake Michigan Federation has been working to expand opportunities for citizen input on the Lake Michigan LWMP. Public access to the LWMP process needs to be expanded using the RAP process needs to as a model and providing for the full participation of diverse jurisdictional and stakeholder interests, including those representing the AOCs, the Great Lakes Fishery Commission (GLFC), binational nongovernmental organizations and others with interests in the whole lake system.

The development of public participation programs in RAPs was recommended in the 1989 Science Advisory Board (SAB) Report. It is again recommended that LWMPs design a program
of public participation at the outset of the process, in consultation with the affected public. It is further recommended that a manual, such as The Manual on Public Involvement in Environmental Assessment: Planning and Implementing Public Involvement Programs be adopted as a basis for public participation programs in LWMPs, with the goal of achieving “joint planning” as defined in the manual. This manual was developed by the Federal Environmental Assessment Review Office (Canada) on the basis of advice from experts in Canada and the U.S. on the development of public participation programs.

A critical component of the LWMPs is the development of a strategy or a set of actions which will achieve the virtual elimination of persistent toxic substances from the lakes. There is agreement that the aim should be to reduce contaminant concentrations in water, sediments and organisms throughout the lake system with the expectation that the quality, function and value of the ecosystem will improve, and human health can be better assured. It is less clear how this objective can be achieved because there is usually not a clear linkage between the nature and cost of a proposed remedial measure (such as installation of improved effluent treatment) and the benefit in terms of lower concentrations in, for example, fish or drinking water.

The mass balance approach attempts to provide this linkage in quantitative terms by establishing the fate of the chemicals of concern as they partition and accumulate throughout the lake, becoming susceptible to a variety of transformation processes, such as biodegradation, and transport processes, such as evaporation and sedimentation. Chemicals behave differently, thus, there is a need to devise a “generic” mass balance approach, which can be applied to treat the individual characteristics of each chemical of concern. Essentially, the mass balance of modeling approach seeks to provide the link between the amounts of a chemical currently in the lake, the expected future inputs or loadings, and the future amounts and concentrations throughout the biotic and abiotic compartments of the lake. It seeks to do for chemicals in lakes what the accountant does for cash in a corporation.

There is currently some effort throughout the Great Lakes basin to develop, test, improve and validate mass balance approaches. Some have focused on the role of the atmosphere as a source, while others have examined Areas of Concern such as Green Bay or the Bay of Quinte, or whole lakes, such as Lake Ontario. A variety of approaches is being tested and it seems likely that a series of models will emerge, ranging in scope, complexity, cost and fidelity, from which selections can be made and lake-management strategies drawn as desired.

These models have the potential to clarify the relative roles of current inputs from industries, municipalities and nonpoint sources including the atmosphere and transfer from already-contaminated sediments. Proponents of more intense modeling efforts think that if simple, reliable models can be devised, they can be used as a basis for a decision support strategy which identifies clear loading reduction targets and justifies benefits in terms of lower concentrations. Many think that the lack of an overall strategy containing these targets has been a major factor in the slow remediation which has occurred in the 1980s.

As a result of a consideration of the present status of mass balancing efforts and their potential benefits in terms of improved decision-making, it is recommended that essential information on the loadings, pathways and fate of the critical, persistent toxic chemicals be obtained as a priority so that practical mass balance models of critical classes of pollutants can be developed and priority can be assigned to source control in LWMPs for each lake.
The concept of employing a comprehensive and systematic ecosystem approach to eliminate use impairments identified in Lake Michigan is intuitively appealing and was widely supported at a recent roundtable cosponsored by the GLFC and the SAB. Implementing the concept will require improved coordination between environmental and fishery managers, with a view to planning goals, program development and remedial action.

The roundtable participants addressed many operational needs in terms of Lake Michigan, recognizing the opportunity to apply the experience from Lake Michigan to the other lakes. Many of the recommendations of the roundtable support the foregoing conclusions of the Board. In addition, however, it was recommended that each LWMP incorporate objectives for reductions in toxic substances that will eliminate deformities and reproductive problems in fish, fish-eating birds, reptiles and mammals, and the International Joint Commission (IJC) and the GLFC ensure that the peer review process is part of LWMPs and FMPs. It was also concluded that the leadership role of the IJC and the GLFC was important in itself, as a means of fostering an ecosystem approach for the Great Lakes. It is anticipated that the proceedings of the roundtable will be published by the GLFC as a special publication (Number 91-3) and will be available by the fall of 1991.
In the spring of 1986, the Technological Committee of the Board began a series of four workshops to address the topic of the Human—Machine Interface (International Joint Commission 1988), which, it thought, was the fundamental cause of most spills. From the workshops emerged a better understanding of what we need to do about spills and how devastating a major spill would be for the people and the ecosystem of the lakes.

There are five reasons why a major spill of a toxic chemical on the open waters of the Great Lakes would be a catastrophic event and why spill prevention is so important.

- **The Great Lakes are Traps**
  The hydraulic retention time of the lakes is not expressed in terms of days, as in the case of a flowing stream; or weeks, as in the case of an estuary, but decades. The retention time of Lake Michigan is 100 years; the retention time of Lake Erie, 2.8 years.

- **Large Volumes of Toxics are Being Shipped by Vessel**
  Large volumes of petroleum and other toxic chemicals are being shipped by vessel on the waters of the Great Lakes.

  A recent draft report by the State of Michigan indicates that Michigan ports handled 2.4 million short tons of petroleum products in 1987. During that year, five-million short tons passed through Michigan waters. The largest, single category is gasoline, which is both toxic and carcinogenic.

  During the same year, 5.4 million short tons of hazardous chemical products were shipped through Michigan waters and 432,000 short tons of hazardous chemical products were handled at Michigan ports. The volume of these products is huge and the danger is comparable.

  The advent of Superfund and the Resource Conservation and Recovery Act (RCRA) and similar laws in Canada has greatly increased the distances which hazardous wastes are being shipped. While this phenomenon presents a hazard for land transportation, it is a much more serious hazard for water transportation.

- **Water Transportation in its Present Form is Accident-Prone**
  Compared with commercial aviation, the water transport system uses obsolete practices, which are accident prone and present a high probability of a catastrophic event.

  This point is best expressed in Chapter 6 of the book "Normal Accidents," by Yale Professor, Charles Perrow. Among his conclusions, appears the statement: "Marine transport appears to be an error-reducing system, where perverse interconnections defeat safety goals as well as operating deficiencies."

  Water transport in its present form exposed those who depend on the Great Lakes for their drinking water to an unacceptable level of risk.

  The high standards which we traditionally apply to the protection of drinking water sources elsewhere, do not, for historic, economic and political reasons, apply to the Great Lakes. In many drinking-water reservoirs, recreational uses are prohibited, let alone the transportation of hazardous substances.
At a time of serious budget limitations, any prevention program needs to target high priority issues first.

Present data systems are highly fragmented and unreliable.

• **Major Open Lake Spills Cannot be Cleaned-up Because Contingency Planning Will Not Work for Such Spills**

A spill of a toxic chemical in the open waters of the lakes could not be cleaned up and could do serious, irreversible damage to the ecosystem and especially the drinking water supply which serves 30 million people. Experience has shown that at best only about 20% of the oil in major spills in open waters can be cleaned up.

Therefore, contingency planning, as provided in the Great Lakes Water Quality Agreement, is not a viable option for chemical and major oil spills in the open waters because (as confirmed by the Carnegie-Mellon Report, 1989) major oil spills cannot be cleaned up. The same is true for chemical spills.

**It is recommended that the Commission urge governments to give spill prevention a higher priority than contingency planning**

• **Setting Priorities for Spill Prevention - A First Step**

As indicated in the Technological Committee reports on the Human-Machine Interface, spill prevention is a complex subject. It includes such diverse topics as vessel manning, navigation, drug abuse, fatigue, excessive automation and a broad diversity of other topics relating to human behavior and technology.

In order to set priorities, reliable data is needed about the relative importance of these causes of spills. Such data is not now available.

While the operation of such a data system is not a major task, only the International Joint Commission (IJC) has the binational posture to carry out this assignment for the entire Great Lakes basin.

**It is recommended that a basinwide spill data system be established to monitor the number and causes of spills on the Great Lakes.**

**It is recommended that a goal be established for reducing the number of marine transport spills by one-half every three years**

Once there are good data to help set priorities for spill prevention programs, a goal can be established for reducing the number of spills by one-half every three years. That type of management goal will encourage the implementation of effective preventive measures. It would gradually reduce the serious risk of a catastrophe.

**It is recommended that Great Lakes transportation policy be reviewed and evaluated in terms of three questions:**

- **What is the safest mode of transport for oil and toxic substances?** That question examines the level of risk inherent in alternative modes of transportation, such as highway, railway, pipeline and water and relates transportation risks to economic and geographic considerations.

- **Would a single, binational Great Lakes Coast Guard be feasible and more effective than the two systems currently in use?** Does it make sense to have two separate Coast Guards on the Great Lakes and connecting channels in view of the narrow and swiftly flowing streams?
- **How can marine transport be made safer?** Would, for example, the installation of better navigation command and control systems and a shift to safer forms of transportation for hazardous substances be a wise policy? The engineering and human requirements to make the transportation system safer should be addressed in the answer to that question.

The present form of water transport of toxic chemicals on the Great Lakes, using inappropriate and obsolete forms of navigation control systems, presents the people and the ecosystem with the high probability of a chemical catastrophe.

Contingency planning should promptly be changed to spill prevention.

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6.2 **Summary**

The present emphasis on contingency planning is inappropriate and leads to a false sense of security.
7. POLLUTED GROUNDWATER

There shall be no man or woman dare to wash any unclean linen, wash clothes, or throw out the water or suds of foul clothes in the open streets within the fort or within 40 feet of the same nor rinse and make clean any kettle, pot or pan, or suchlike vessel within 20 feet of the old well or new pump, nor shall anyone aforesaid within less than a quarter of a mile from the fort, dare to do the necessities of nature, since by these unmanly, slothful and loathsome immodesties, the whole fort may be choked and poisoned.

Sir Thomas Gates, Lt. General of Virginia, May 25, 1610
(probably the first North American instance of a contaminated water well resulting in a groundwater pollution prevention ordinance)

- Groundwater problems have not been addressed

It has been ten years since the Commission alerted Governments to the serious problem of toxic and hazardous substances in the Niagara River and the threat posed by contaminated groundwater from abandoned or improperly-operated hazardous waste facilities being released into the river. It has been eight years since the Science Advisory Board recommended increased attention to groundwater contamination and escalated the mapping of contaminants so that policy decisions on cleanup progress could be based on facts. These recommendations have not been implemented and the public remains in the dark on the basinwide significance and ramifications of groundwater contamination.

- The Great Lakes Water Quality Agreement has not been implemented

Annex 16 of the 1987 Protocol to the Great Lakes Water Quality Agreement contains commitments by the U.S. and Canada to: (1) identify sources of contaminated groundwater; (2) map hydrogeological conditions in these areas, (3) develop comparable approaches for characterizing this contamination and most importantly, (4) control sources of contamination and the contaminated groundwater itself. Unfortunately, as noted in the International Joint Commission's Water Quality Board 1989 Report, the Parties have not provided the type of groundwater quality data which the International Joint Commission (IJC) needs to evaluate progress. The record of the November 1990 meeting of the Parties indicates that no progress has been made in establishing a binational groundwater work group due to the loss of key people. The Science Advisory Board views this lack of progress with deep concern.

- Groundwater and the Great Lakes

Groundwater aquifers and surface water bodies both are part of the continuum of the hydrologic cycle. What is dumped, spilled or injected into or onto the ground often will end up in our lakes, in our fish and on our dinner tables.

Preliminary estimates are that direct groundwater discharge into the lakes through the bottom sediments is about 18% of the contribution by tributary stream flow into the lakes or about $84 \times 10^6 \text{ m}^3/\text{day}$. Recent calculations of direct groundwater discharge into Lake Michigan from a small segment of the coastline along the Door Peninsula of Wisconsin alone totalled $66,000 \text{ m}^3/\text{day}$. Direct groundwater discharges into the Great Lakes from the State of Michigan total about $76 \times 10^6 \text{ m}^3/\text{day}$. These estimates do not include groundwater inflow to all streams (approximately half of annual streamflow derives from groundwater influx) or the direct groundwater discharge into upland lakes and wetlands in the basin.
Approximately 70,000 synthetic organic chemicals are in common industrial and commercial use in North America and that number increases by about 1,000 every year. Almost no health research has been done on most of them.

- **Groundwater pollution of the Niagara River**
  Dioxin (TCDD) may be the most toxic chemical known. It induces cancer and birth defects in experimental animals in parts-per-trillion concentrations. Recent studies have shown that measurable amounts of dioxin are present in the livers of stillborn human infants, clearly demonstrating the transplacental intrauterine transfer of dioxin from mother to fetus. Previously, breast feeding was thought to be the method of transfer from mother to infant. It is estimated that two tonnes of dioxin were discarded in the Hyde Park dump near Niagara Falls, New York, and that it is now flowing with the groundwater and a plethora of other toxic compounds toward the Niagara Gorge. About 178 kilograms (394 pounds) of organic compounds derived from disposal sites near Niagara Falls discharge into the Niagara River with groundwater every day, a clear violation of the Boundary Waters Treaty. Individual chemical constituents of this flux are unknown, but the contribution of pollutants from groundwater to the river probably equals the contribution from all point sources combined.

- **Transboundary groundwater migration**
  Approximately 200 hazardous waste injection wells are currently operational in North America. Between 1958 and 1975, 7.7 billion litres of liquid industrial waste were injected into just nine deep wells in the Sarnia, Ontario (Chemical Valley) area. The petrochemical waste from the Sarnia area is thought to have been injected into a high porosity, high permeability dolomite bedrock strata at high pressure and high injection rates. It is speculated that the injectate has displaced chloride-rich, formation water into overlying fresh water aquifers in Michigan via fracture networks, abandoned oil and gas exploration holes and/or faults.

- **Great Lakes groundwater is very susceptible to contamination**
  Groundwater is under siege, not just from the industrial polluters that grab the headlines, but also from the traditional town dump, the cropland at the edge of town, the service station on the corner, the dry cleaning establishment up the street and the septic system next door. Approximately 70,000 synthetic organic chemicals are in common industrial and commercial use in North America and that number increases by about 1,000 every year. Almost no health research has been done on most of them. These novel chemicals, produced by chemical splicing or molecular engineering, have never before existed and no natural system has ever been previously exposed to them. Of the more than 200 documented, chemical constituents of ground water, approximately 175 fall into this group. Those occurring most often in randomly-selected public groundwater supply systems were trichloroethylene (TCE) and perchloroethylene (PCE), commonly used dry cleaning and industrial solvents and degreasers. Both exhibit the worst possible characteristics for any groundwater contaminant in that they are soluble, mobile, toxic and persistent (PCE, a possible carcinogen, is resistant to degradation by bacteria in groundwater systems; however, over time, it is transformed to vinyl chloride (VC), an even more potent carcinogen). TCE has been recently shown to readily transfer from tap water to indoor air, especially in shower stalls, with considerable enhancement of the inhalation exposure route.

  An effective means of portraying the susceptibility of groundwater to contamination on a basinwide scale is to utilize GIS (Geographic Information System) spatial analysis. Figure 7.1 illustrates a generalized county-by-county assessment of the susceptibility of groundwater to pollution in the Great Lakes basin. A detailed GIS evaluation of the potential for groundwater contamination potential on a township, municipal or regional scale is urgently required.

- **Pesticides in Groundwater**
  Persistent toxic pesticides occur in groundwater. About 500 million kilograms of pesticides are produced each year in North America. Recent U.S. EPA surveys (U.S. Environmental Protection Agency 1990a; 1990b) estimate that over 10% of community water system wells contain detectable levels of one or more pesticides and that approximately 61,000
rural, domestic wells contain at least one pesticide which exceeds either a Maximum Contaminant Level (MCL) or a Lifetime Health Advisory Level (HAL). Ten other pesticides were detected in many of the wells surveyed. Five of these: alachlor, atrazine, dibromochlorophane (DBCP), \textit{gamma-}HCH (Lindane) and ethylene dibromide (EDB) were found to exceed MCL/HAL in some rural domestic wells. The most frequently-detected pesticides in the national survey were atrazine and DCPA acid metabolites, a byproduct of Dacthal. Dacthal metabolites were also the most commonly found pesticide in Michigan groundwater supplies.
Figure 7.2 illustrates the counties of high DCPA usage counties in the Great Lakes region of the U.S. Dacthal has recently been discovered bioaccumulating in fish tissue from Siskiwit Lake on Isle Royale in Lake Superior. The herbicide apparently arrived on the island via atmospheric deposition. Virtual elimination of persistent herbicides, such as atrazine and Dacthal, should be pursued in accordance with pollution prevention initiatives.
Health Effects of Viruses in Drinking-Water Supplies

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Nature of associated illnesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echovirus</td>
<td>Meningitis, diarrhea, respiratory disease, fever</td>
</tr>
<tr>
<td>Poliovirus</td>
<td>Paralysis, meningitis, fever</td>
</tr>
<tr>
<td>Coxsackievirus A</td>
<td>Meningitis, herpetic angina, respiratory disease, fever</td>
</tr>
<tr>
<td>Coxsackievirus B</td>
<td>Myocarditis, meningitis, fever, respiratory disease, pleurodynia</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Infectious hepatitis</td>
</tr>
<tr>
<td>Norwalk Virus</td>
<td>Vomiting, diarrhea, fever</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Vomiting, diarrhea</td>
</tr>
<tr>
<td>Adenovirus</td>
<td>Respiratory disease, eye infections, gastroenteritis</td>
</tr>
<tr>
<td>Astrovirus</td>
<td>Gastroenteritis</td>
</tr>
</tbody>
</table>

- **Nitrate in groundwater**
  Typically more than half of all drinking water wells in the basin contain measurable nitrate (above 0.15 mg/L). About 2% (as many as 250,000 wells) are estimated to contain nitrate in excess of the Maximum Contaminant Level of 10 mg/L. It is, therefore, viewed by most researchers as the top groundwater contamination problem in the Great Lakes basin.

  Nitrates in our groundwater are derived from naturally-occurring organic nitrogen, atmospheric deposition, nitrogen fertilizers, septic systems and agricultural activities, such as feed lots, dairy farms and the poultry industry. Approximately five trillion litres of waste water is discharged by septic tanks annually in North America. Nitrates in groundwater do not adsorb; are very mobile and are not degraded. Epidemiological research has associated nitrates with human birth defects, high blood pressure and certain cancers. Chronic health effects are unknown.

- **The population at risk**
  Table 7.2 details the populations of the Great Lakes states and Ontario who are completely reliant on groundwater for their drinking water supply. The most densely-populated, industrialized areas in the basin are characterized by large numbers of waste disposal sites. Figure 7.3 is a GIS portrayal of the concentration of hazardous waste sites. The high concentration of sites in the vicinity of the densely populated areas around Chicago/Gary, Detroit, Cleveland, Erie and on the Niagara frontier is noteworthy. Clearly, groundwater quality has the highest potential to be jeopardized in these areas.

Canada is unique among industrialized nations for the lack of federal government leadership in groundwater protection/management. This situation is most often attributed to constitutional divisions of authority, the federal deficit and the fact that groundwater management has a very low priority in Canada.

In Canada, groundwater resources and protection (as with most natural resource activities) vests with the provincial rather than the federal government. Exceptions are federal lands and facilities (e.g. Indian reserves, Canadian Forces bases) and those impairments which fall under the Boundary Waters Act (International Joint Commission 1909), the Pest Control Products Act and the Atomic Energy Control Act. However, even with a mandate to address groundwater issues in these areas, no federal initiative will proceed without provincial...
consultation because of potential and often delicate jurisdictional implications. Along with the interjurisdictional difficulties, the fact that most groundwater users are rural residents with dispersed political influence, the lack of comprehensive provincial groundwater protection legislation, lax enforcement of existing regulations and the underfunded, understaffed federal presence all contribute to inadequate groundwater protection and clean up efforts in the basin.

### Table 7.2

**Estimated Populations in the Eight Great Lakes States and Ontario Who Depend on Groundwater as a Primary Water Supply**

<table>
<thead>
<tr>
<th>JURISDICTION</th>
<th>POPULATION (millions)</th>
<th>THOSE DEPENDENT ON GROUNDWATER (millions)</th>
<th>(percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>11.9</td>
<td>10.7</td>
<td>90</td>
</tr>
<tr>
<td>Minnesota</td>
<td>4.2</td>
<td>3.2</td>
<td>75</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>4.8</td>
<td>3.2</td>
<td>67</td>
</tr>
<tr>
<td>Indiana</td>
<td>5.5</td>
<td>3.2</td>
<td>59</td>
</tr>
<tr>
<td>Michigan</td>
<td>9.2</td>
<td>4.6</td>
<td>51</td>
</tr>
<tr>
<td>Ohio</td>
<td>10.8</td>
<td>5.4</td>
<td>50</td>
</tr>
<tr>
<td>Illinois</td>
<td>11.6</td>
<td>5.6</td>
<td>48</td>
</tr>
<tr>
<td>New York</td>
<td>17.8</td>
<td>6.2</td>
<td>35</td>
</tr>
<tr>
<td>Ontario</td>
<td>9.3</td>
<td>2.8</td>
<td>25</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>85.0</strong></td>
<td><strong>45.0</strong></td>
<td><strong>53</strong></td>
</tr>
</tbody>
</table>

A case in point is the recently announced federal “Green Plan,” under which Canada will provide Ontario up to $75 million over a six-year period for groundwater studies and clean up. This amount is insufficient to adequately clean up one known site of PCB-contaminated groundwater at Smithville, let alone hundreds of other sites ($20 million has been spent so far on alternate water supply alone, due to groundwater contamination near Elmira, Ontario).

As every government official unfortunate enough to have had the experience of trying to cope with visceral public alarm and outrage when drinking water wells become contaminated will attest, prevention of pollution and wellhead protection legislation are the keys to viable groundwater management. The compilation of basic hydrogeological information is a mandatory prerequisite to drafting such legislation.

Similar institutional barriers interfere with effective groundwater contamination remediation and prevention programs in the United States portion of the basin. Federal legislation has created federal/state regulatory programs for active, hazardous site restoration and abandoned site remediation. These programs have suffered from micromanagement, lack of trained staff, high staff turnover because pay is so low in state and federal agencies, and bureaucratic/legal impediments. The active, site corrective action program under the Resource Conservation and Recovery Act (RCRA) has started slowly and the majority of Superfund money has been spent on legal fees and technical studies rather than on the prevention or remediation of groundwater pollution. Neither of these programs has been preferentially targeted for the Great Lakes basin where they are desperately needed. As a consequence, plumes of toxic substances continue to leak from many of the 4,000 abandoned sites and thousands of active sites in the basin.

Even more significant is the lack of use of authority under Superfund for natural resource claims that could be used to clean up contaminated sediments in harbors of the basin that are
Areas of Concern. Lack of cooperation by the Justice, Commerce and Interior departments and the U.S. EPA means that billions of dollars that could be used to remediate contaminated sediments in AOCs (from upstream, historical surface or groundwater releases of pollution) are not being collected from the industries which released the toxic pollutants. This phenomenon has serious ramifications for the lack of clean up and the associated human health risks from eating Great Lakes fish. These institutional barriers and the significance of groundwater contamination should be the subject of a special report to governments from the IJC. Action is needed now before more toxic substances ooze into surface waters from contaminated groundwater.

Comprehensive groundwater protection programs have not been implemented in the U.S. Each state prepared a strategy for protection, with federal EPA funding under the Clean Water Act, but state legislation creating effective state/municipal partnerships in protecting groundwater has not been enacted.

The prevention of groundwater contamination is far more logical, simple and cost-effective than an attempt to correct a problem, a problem that may have been in existence for decades.

Groundwater cleanup costs are staggering; scrubbing crude oil off beaches is “child’s play” in comparison.
It is recommended that:

- The Parties and jurisdictions adopt and implement the recommendations of the SAB Technological Committee Workshop on Assessing the Potential for Great Lakes Contamination via Groundwater (October 1989, University of Waterloo) (International Joint Commission 1989a), restated as follows:
  
  - Using Geographic Information System computer technology, collate all hydrogeological data
    -- existing data on land use, surficial materials, recharge/discharge zones, depth to bedrock, bedrock geology, variable groundwater flow regimes and aquifer utilization in the Great Lakes basin
    -- additional data, including surface water flow systems, differentiated by perennial and intermittent streams; pertinent man-made infrastructure, such as abandoned sewer lines and wells; specific sources of contamination, categorized by source type, such as organic versus inorganic or natural versus anthropogenic; direct discharge of contaminants with groundwater through lake bottoms and many other hydrogeological parameters are urgently required for the basin.
  
  - Develop a directory of hydrogeological expertise as a resource for conducting the required studies
  
  - Produce a single, comprehensive, “state-of-the-knowledge” report, incorporating case histories of significant pollution of the Great Lakes by contaminated groundwater and examples of the transboundary movement of contaminants should be prepared by the International Joint Commission to illustrate the significance of the problem.
  
- Coordinate a United States/Canadian groundwater initiative so that resultant databases are fully integrated and compatible. Project management could be provided through the auspices of the IJC.

- the Government of Canada and the Province of Ontario give priority to implementing the recommendations of the 1990 “Groundwater in Canada” report, published by the Science Council of Canada, including efforts to address:
  - the lack of comprehensive regulations for groundwater protection and management
  - minimal groundwater research activity
  - the lack of activity in continuing educational retraining in groundwater science
  - the manpower shortage and “brain drain”

- the Government of the United States give priority to addressing management and training questions related to Superfund and RCRA, and to taking steps to apply Superfund resources to appropriate Areas of Concern

- the Commission issue a Special Report to the Parties, urging action in remediating groundwater contamination and in establishing effective groundwater protection programs in partnership with provincial/state governments

- the United States and Canada promote the use of alternative agricultural practices in the Great Lakes basin, such as low input farming, sustainable agricultural systems and integrated pest management, as national demonstrations for protecting groundwater and controlling nonpoint source pollution
Since the Board’s last report, several initiatives undertaken by a variety of agencies have increased the Board’s level of optimism about the future of Great Lakes education in the region. The Commission agreed with the Board that incorporating the information on the Great Lakes Basin Ecosystem in existing school curricula throughout the basin is essential to ensure that “children understand the importance of a healthy ecosystem to our future.” Indeed, many of the Board’s 1989 recommendations to the Commission concerning Great Lakes education efforts were included in the Commission’s Fifth Biennial Report.

Since the release of the Commission’s report, Ohio and Ontario have passed legislation mandating that environmental education be integrated into school curricula. The U.S. Congress passed the National Environmental Education Act, which commits the federal government to developing teacher training and environmental education programs. These policy initiatives are encouraging and show that voices emphasizing the importance of environmental education are being heard at all levels of government.

Even more heartening, more and more educators are becoming excited about the opportunities to include an ecosystem approach to water management in their teaching settings, and are becoming involved in efforts to incorporate the topic into their state, provincial or even local education guidelines.

- In Ontario, a proposal called “Great Lakes Alive” has been developed by educators to provide boat tours and environmental action days in Lakes Erie and Ontario, using sponsorship funds from corporations and other interested organizations.

- The Interactive Rouge River Water Quality Monitoring Project (outlined in the Board’s 1989 report) is expanding into waterways in several Areas of Concern, including Saginaw River and Bay, Clinton River and Cuyahoga River, and in other areas, such as the Grand River and Turkey Creek in Ontario.

- The educational program in Traverse City, using the schooners Malabar and Madeline, received national recognition from the National Geographic Society in its hour-long program on the Great Lakes. The program is quickly growing in popularity.

- In the Commission’s live-by—satellite videconference, “Teachers Making a Difference” (International Joint Commission 1990b), participants learned about the wide variety of ways that educators and students are becoming involved in Great Lakes education programs and curricula.

- In 1990 alone, more than 5,000 copies of the Directory of Great Lakes Education Material (International Joint Commission 1989h) were distributed, by far the Board and Commission’s most popular publication.

Another basis for optimism is the Board’s Educators Advisory Council, developed in early 1990. Members from each state and province in the region meet semi-annually to develop and hold teacher training workshops in their respective states and provinces, and to share ideas and opportunities to further the goal of incorporating the Great Lakes into all curriculum guidelines and objectives.
During 1990 and the first half of 1991, workshops were organized and held by Education Council members, with support from Regional Office staff, in Minnesota, Wisconsin, New York, Ohio, Illinois, Indiana and Pennsylvania, and two were convened in Ontario. While these workshops varied in length and format, each provided a key opportunity for educators to learn about Great Lakes issues and to become more aware of how these issues can be used in the learning setting to teach a variety of concepts.

The Educators Advisory Council has come to some important conclusions concerning the state of Great Lakes education and what efforts are still needed to ensure its incorporation into state/provincial and local curriculum guidelines and objectives. First and perhaps most importantly, members of the Educators Council agree that teachers will integrate the Great Lakes into their curricula, in a variety of subject areas, once they are confident in their own level of knowledge. In-depth, week-long workshops, held in a different part of the basin each summer and/or at one specified location, could help teachers to develop the essential level of awareness and confidence in the subject matter. In addition, however, the Educators Council considers that preservice experience in Great Lakes and environmental issues is an important missing link that could help educators gain the valuable knowledge and confidence to incorporate these topics into their teaching settings.

On the above basis, the Board recommends that:

- the Great Lakes states and provinces develop environmental programs and courses in education facilities of universities and colleges that focus on issues relevant to the Great Lakes Basin Ecosystem.

The *Directory of Great Lakes Education Material* can continue to be revised and expanded on a biennial basis with funds provided to distribute the manual to educators in each school district in the basin. A computer network that focuses on a particular Great Lakes topic each semester could provide useful information on materials, programs and events related to that topic for each teacher to use and incorporate into his lessons as applicable.

The Educators Advisory Council views these options as essential components in a coordinated strategy that incorporates information on the Great Lakes Basin Ecosystem into established curricula. The Educators Council also concludes that the best assurance that these efforts will be coordinated to form a unified, basinwide strategy is through the development of a Great Lakes Education Clearinghouse. The clearinghouse could serve as a regional mechanism to accomplish several goals:

- provide centralized access to curriculum guides, publications, films and videotapes, mailing lists and other educational materials
- market, distribute and evaluate Great Lakes education materials and their use
- coordinate the creation and implementation of annual, week-long workshops in various parts of the basin
- assist states and provinces in developing curriculum guidelines and objectives
- subscribe and contribute to existing computer networks for educators in a variety of fields and arenas
- encourage a partnership approach to Great Lakes education with government agencies, businesses and industries, professional teacher associations and citizen groups

Therefore, the Board recommends that:

- the Parties, in coordination with the state and provincial governments provide adequate financial and human resources to create and maintain a Great Lakes Education Clearinghouse that will serve the functions already outlined and assist in ensuring that the Great Lakes become an important component of curricula in a variety of subject areas.
The wetlands of the Great Lakes basin are a vital regional resource, which performs a variety of functions essential to maintaining a healthy ecosystem. Wetlands are among the most productive areas of the Great Lakes, and support diverse plant and animal communities. They provide spawning habitat for a number of economically important fish species, resting places and nesting sites for migratory birds, as well as permanent habitat for a variety of aquatic plants and animals. Other benefits of undisturbed wetlands include enhanced nutrient recycling, water purification, flood hazard reduction and erosion control along shorelines, and the recharging of groundwater supplies. Although a number of the above attributes are not immediately obvious to humans, and the processes identified may occur over extended time periods, Great Lakes wetlands represent a significant ecological and economic resource.

9.1.1 The Destruction and Degradation of Wetlands - Urgent Action is Required

Despite their worth, the wetlands of the Great Lakes continue to experience irretrievable losses in both quantity and quality. For example, in southern Ontario, an estimated 80% of original wetland area has been converted to other uses and continued loss is occurring at a rate of 1-2% per year. The remaining isolated wetlands act as refuges for many rare plant and animal species, which, upon continued destruction of their habitats, will become extinct. Additionally, economic benefits, which depend on the existence of relatively large areas of wetlands for optimum return, have become significantly reduced.

On a basinwide scale, approximately 70% of the original wetlands are gone, with similar consequences. Drainage of extensive areas for agricultural use is responsible for most of this loss. In addition, large areas of coastal wetlands were destroyed to make way for urban and recreational development (e.g. residential housing, waterfront development, construction of marinas and ports).

Quality of the remaining wetlands is also being impaired. Those areas located adjacent to industrialized urban areas are threatened by toxic contaminants and inadequately-treated municipal wastes. Such pollution may result in toxic chemical contamination of the food chain, and significant alteration of the biological community. Moreover, the recent invasion and rapid spread of purple loosestrife (Lythrum salicaria) poses an additional danger. The proliferation of this resilient plant is altering emergent plant communities by replacing native plant species at an alarming rate. At its present rate of spread, the loosestrife invades 1,900,000 ha of wetlands each year in the United States.

The extensive damage already sustained and the rate of continuing destruction of wetlands require immediate action to prevent further declines in the quantity and quality of wetlands.

9.1.2 Are the Governments of the United States and Canada Responding?

It has become clear that, in order to reverse the destruction of this resource and effectively protect and restore wetlands, it is necessary to gain a detailed understanding of their function and benefits to both humans and the entire ecosystem. This understanding, along with rehabilitation efforts, requires a significant commitment on the part of the U.S. and Canadian governments.
Over the last two decades, the role of wetlands in the Great Lakes Basin Ecosystem has received increased attention by governments and conservation groups in both countries. In Annexes 7 and 13 of the amended Great Lakes Water Quality Agreement (1987), the Parties agreed to identify and preserve, and if necessary, rehabilitate significant wetland areas in the Great Lakes Basin Ecosystem, which are threatened by urban and agricultural development, dredging and waste disposal activities.

Since 1987, some progress has been made by both countries in the areas of wetland identification, description and classification; in the identification of institutions, mandates, policies and programs concerned with wetland protection and in the classification of wetland stresses and the factors leading to loss of wetland habitat. These efforts and ongoing programs were summarized in the Water Quality Board's (WQB) 1989 Report on Great Lakes Water Quality. As reported in 1989, implementation of the 1986 North American Waterfowl Management Plan (NAWMP) would provide $23 million over 15 years for wetland protection, enhancement and restoration under the Eastern Habitat Venture Plan. The NAWMP identified the lower Great Lakes - St. Lawrence River as priority, endangered waterfowl habitats.

9.1.3 Recommendations of the WQB (1989) - A Progress Report

In its 1989 report, the WQB made recommendations promoting the monitoring of wetland losses, the identification of contaminant sources, and the evaluation of government legislation and policy, and called upon the Science Advisory Board (SAB) to provide direction and advice about wetland research.

Significant progress has not been achieved in the establishment of inventories of wetland loss. However, ongoing efforts in the development of computer-based Geographic Information System databases appear promising for assisting in the preparation of such inventories. Similarly, little progress has been made in establishing linkages between contaminants in wetlands and point and nonpoint sources.

Governments of both countries are reviewing policies and legislation concerning wetlands. In the U.S., a revised draft of the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (1989) was released for review by the U.S. EPA, the U.S. Department of Agriculture and the U.S. Army Corps of Engineers in May 1991. The White House has withheld its endorsement of the revised manual and the U.S. Fish and Wildlife Service is actively campaigning, along with many environmental groups, against the revised version. The controversial issue has split Congress and is described as one of the most intensively lobbied and complex environmental issues of the decade. The outcome of this process will significantly influence the number of areas designated as wetlands, and the degree of protection from agricultural and other development. If the proposed revised wetland classification system is passed, some states may experience a 90% decline in the total area of wetlands protected under the original 1989 legislation.

In Canada, the federal 1990 Green Plan largely ignored wetlands, allocating only two paragraphs to the topic. In January 1991, the third draft of the Federal Policy on Wetland Conservation was released, promoting the policy of no net loss of wetlands on federal lands, wetland enhancement and rehabilitation, and recognition of sound, sustainable management practices in forestry and agriculture. However, at this time, no policies or legislation concerning wetland preservation and management exist in Canada.

Similarly, in the Province of Ontario, direct legislation concerning wetlands is not in place. The proposed policy statement on wetland classification and protection is currently awaiting approval by the Minister of Natural Resources, and subsequently, by the Ontario legislature, for inclusion in the Planning Act.
In summary, little progress has been achieved regarding the first three recommendations of the WQB. Federal legislation and policies on wetlands remain a controversial, many-faceted issue in both countries. The development of progressive, environmentally-acceptable wetland policies by the Parties in the near future seems unlikely.

9.1.4 Current Wetland Research and Research Needs for the Great Lakes

The Science Advisory Board and the Council of Great Lakes Research Managers established an ad hoc workgroup, directed it to prepare an inventory and assessment of current research, and to identify and establish priorities for wetland research needs. Results of these activities are summarized below.

Research specific to wetlands is being conducted by relatively few organizations, with a total funding of $900,000, and is frequently a collaborative effort. Projects are generally short in duration and rarely extend beyond political boundaries. The focuses of current research activity in the Great Lakes region are wetland stress and wetland function, accounting for 78% of the funding. Much less effort is being dedicated to studies of wetland restoration, management techniques, wetland status and the interrelation of wetlands and humans.

Areas of wetland research requiring study were identified using information from a variety of sources (e.g. literature reviews, communication with environmental agencies, evaluation of conferences, colloquia), and were classified on the basis of generalized areas of research. The identified needs were then assigned high, medium or low priority within each class, and recommendations were made.

9.1.5 Recommendations - Research Needs for Great Lakes Wetlands

The following recommendations outline wetland research needs of high priority identified by the Workgroup, and, in part, reiterate those of the WQB (International Joint Commission 1989d).

- **Wetland Function**
  Research into the internal functioning of Great Lakes wetlands be encouraged to determine their contribution to the basin ecosystem

- **Wetland Status**
  The inventory of the current status of wetlands be determined utilizing advanced technologies and standardized techniques.

- **Wetland Stress**
  Both natural and human-induced stresses on wetland integrity be investigated and the individual and synergistic implications of these stresses on wetland community dynamics be identified

- **Wetland Restoration and Management**
  Further research be conducted into wetland creation and restoration techniques and incorporated into comprehensive management strategies to protect wetland integrity

- **Wetlands and Humans**
  Effective educational means be developed to identify, quantify and more effectively communicate the functional and aesthetic values of wetlands to humans
9.2 Heritage Protection

In the 1989 report, the Science Advisory Board (SAB) identified the need for Heritage Area Security Plans within the context of the Great Lakes Water Quality Agreement (GLWQA) and recommended that:

The Parties consider developing a new annex to the Great Lakes Water Quality Agreement concerning Heritage Area Security Plans that incorporates formal recognition of the planning process to conserve pristine locales in the coastal zone.

This recommendation was based upon:

- two studies funded by the Donner Canadian Foundation and the SAB, which gave an overview of known, significant natural areas, protected and unprotected, in the coastal zone
- the Ecological Committee's cosponsored consultation meeting to assess work already underway, especially in the Lake Huron and Lake Superior basins. One of the committee's recommendations was to compile information on implementing measures and determining ways to link the goal of protecting natural heritage areas to the GLWQA as well as to other binational agreements
- a goal to develop a "palustrine/terrestrial natural community classification scheme" for use in Ontario and a multijurisdictional system of protecting nearshore and coastal zone sites around the lakes as a practical expression of "anticipate and prevent" strategies to stop further ecosystem degradation. Such a program that focuses on high quality, often visually-attractive components of the Great Lakes Basin Ecosystem would raise public awareness and interest
- a recognition that wetlands inland of the Great Lakes may be crucial to the maintenance of ecosystem health and, therefore, the results of recent inventories of wetlands should be analyzed to identify inland/upland wetlands of particular importance

The implementation of the 1989 recommendation would not only help protect examples of healthy ecosystems within the basin, it would also help secure important reference areas and monitoring sites. These sites could be used to help assess progress towards meeting ecosystem objectives as spelled out under Annex 2 of the Agreement, to help strengthen the rationale for protecting significant wetlands as called for in Annex 13, and to develop norms for some of the criteria specified in Annex 2(1c) for the listing and delisting of Areas of Concern.

In its Fourth Biennial Report (International Joint Commission 1989b) in 1989, the Commission made five recommendations to the Parties concerning the need for ecosystem benchmarks, biological monitoring and the need for the latter to include monitoring at all important trophic levels within the ecosystem. In 1990, The Nature Conservancy (TNC) and the Nature Conservancy of Canada initiated a joint project, with funding from the Joyce Foundation, to develop the Great Lakes Heritage Data Network. It is modeled after TNC's "Biological and Conservation Data (BCD) System," used by State Natural Heritage Programs, and it also identifies species and communities that could be used as indicators of ecosystem health and water quality. The Conservancies have sought advice and suggestions from the SAB on this undertaking.

The BCD system was adopted by Quebec in 1989 and by Ontario in 1991. When fully developed, the two provincial conservation data systems can be linked electronically with those for the eight Great Lakes states to provide, for the first time, a Great Lakes - St. Lawrence perspective on opportunities and priorities for the conservation of biodiversity and for identification of having the most potential value as ecosystem benchmarks or for biological
monitoring sites. In 1991, in cooperation with the nature conservancies, the Center for the Great Lakes launched a binational "Great Legacy Program" to foster stakeholder involvement in developing, promoting and implementing a strategy to conserve natural areas along the Great Lakes - St. Lawrence. The project will draw upon the Great Lakes Heritage Data network for guidance. The SAB recommends that the Commission and the Parties endorse these initiatives as ones in keeping with the intent of the Agreement.

In the Fourth Biennial Report, the Commission also noted that "biosphere reserves," a special designation of recognition from the United Nations Educational, Scientific and Cultural Organization's (UNESCO) "Man and the Biosphere" (MAB) Program, have an important potential role to play as possible benchmark areas in the Great Lakes. Currently, there are three biosphere reserves associated with the Great Lakes: Isle Royale in Lake Superior, Long Point on the north shore of Lake Erie and the Niagara Escarpment in Ontario, including the Bruce Peninsula National Park and Fathom Five Marine National Park in Lake Huron/Georgian Bay.

The designation of these areas signifies that they offer good examples of ways in which conservation objectives can be balanced with development. The term “biosphere” refers to the association of the designated area with the MAB program, and “reserve” means that there are some protected sites within the biosphere reserve. The designation does not interfere with legal mandates, private property rights or management policies which are in place. The designation signifies that the arrangements appear to be sufficient for developing the three main roles of biosphere reserves: conservation of ecosystems and important species of plants and animals; demonstration of sustainable land/water/resource management practices; and promotion of various research, monitoring and educational activities directed towards local or regional issues of conservation and sustainability.

A cluster biosphere reserve is appropriate for situations where not all of the roles for a biosphere reserve can best be carried out on contiguous lands. Thus, the cluster is a multiple-site arrangement, that includes one or more protected areas, research sites, education facilities and various demonstration projects, that are all within the same bioregion. If there is sufficient coordination and communication among the program activities based in the different sites, the cluster arrangement can fulfill the roles expected from a biosphere reserve. This approach is being taken in the United States, notably through the prototype Southern Appalachians (Cluster) Biosphere Reserve.

During the past year, Canada/MAB and U.S./MAB (the respective national committees for the MAB program) have noted the mutual benefits to be had from bringing the MAB perspective and the Great Lakes research and management experiences together. The concept of a multiple-site cluster biosphere reserve, which could help strengthen cooperation for research, monitoring, education, training and the recognition of demonstration projects (such as RAPs) related to the restoration and maintenance of ecosystem health of the Lakes, is being considered by members of the two national committees.

Given the Parties’ agreement on the lake ecosystem objectives and ecosystem health indicators for Lake Superior (Supplement to Annex 1(3a), and Annex 11(4a) and the Commission’s recommendation in its Fifth Biennial Report that “The Parties designate Lake Superior as a demonstration area where no point-source discharge of any persistent toxic substance will be permitted” (International Joint Commission 1990d, Part II, Persistent Toxic Substances Threaten Human Health, Recommendations 1-7, page 9), the cluster biosphere reserve concept could help strengthen cooperative efforts to meet these objectives. Canada/MAB and U.S./MAB are invited to consider this cooperation as a priority for bringing MAB into the Great Lakes. Binational initiative, together with the work of the MAB committees, is needed in order to realize the opportunity presented by this mechanism for protecting heritage areas of the Great Lakes.
It is recommended that:

- the Parties address the potential of the cluster biosphere reserve concept, together with Canada/Man and the Biosphere and U.S./Man and the Biosphere, in terms of Lake Superior as a priority for further extending Man and the Biosphere into the Great Lakes.
At an IPM monitoring location in Essex County, a program coordinator is checking a pheromone trap to determine insect pest levels. IPM substitutes information technology for chemical technology.

In its 1987 Report (International Joint Commission 1987c), the Great Lakes Science Advisory Board (SAB) of the International Joint Commission accented the need for strategies to anticipate pollution problems and ensure prevention. A policy of anticipation and prevention is proactive, and ultimately, more effective than reacting to pollution once it has occurred. Such a policy has gained increasing favour and has been endorsed by organizations such as the World Commission on Environment and Development, Environment Canada, the U.S. Environmental Protection Agency in addition to the International Joint Commission.

This policy can be applied to agriculture, especially to the control of chemical pesticides contributing to nonpoint pollution, through the development of Integrated Pest Management (IPM) programs. Twentieth-century agriculture has become increasingly dependent on chemical technology for crop production, while the "on farm" and external costs of this technology have impinged on the integrity of ecosystems. A basinwide accounting for pesticide use is unavailable, but certain areas illustrate the degree to which conventional agriculture is dependent on chemical pest control. In the Lake St. Clair region alone, an estimated 7.7 million lbs. (3.5 million kg) of pesticides are applied annually to land in the United States and Canada. This area has great potential to transmit the chemicals via surface runoff, fine particulate matter carried by wind or water, and infiltration to groundwater. Approximately 60% of the Canadian area exhibits a high risk of pollutant transfer to groundwater systems, while the potential for surface water contamination is approximately 70% for the same area. By using pesticides more efficiently and developing nonchemical options, IPM aims to avoid such problems.
In May 1989, the Board conducted a survey of Great Lakes jurisdictions to review and evaluate the development and potential of their IPM programs, and included a section on IPM in its 1989 Report under “Emerging Issues” (International Joint Commission 1989c). The survey population consisted of state and provincial IPM coordinators of jurisdictions and selected agricultural producers within the Great Lakes basin. The survey was not designed to research a scientifically-determined sample, but rather to obtain the best information possible from knowledgeable respondents. Critical aspects of the survey included program goals and definition, program support, research activities, coordination, implementation and adoption. Producers were also surveyed on their approaches, perceptions and constraints.

Many agricultural commodities are produced in basin jurisdictions. Consequently, there are different priorities when setting objectives for IPM programs. Feasibility and acceptability govern what can be achieved. Thus, the challenges of pest management are perceived differently and the policy initiatives associated with each jurisdiction range widely. Because IPM is subject to broad interpretation, its practice and potential also range widely. IPM has been defined as:

"... the optimization of pest control in an economically and ecologically sound manner, accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, animals, plants and the environment."

(Dover 1985)

In defining IPM or in outlining the objectives for their programs, jurisdictions generally refer to an efficient pest management system as one that minimizes environmental impact while optimizing producer profits. A consideration of economic thresholds was important to all respondents. The availability or development of a variety of different types of pest control were described by all Great Lakes provinces and states, except Ohio, Illinois and Indiana. IPM coordinators in Michigan, Minnesota, Ontario, Quebec and New York specified nonchemical options, such as biological and cultural methods. Quebec had the only program that had the stated objective of eventually replacing pesticides by other means. Other objectives worth noting include Ohio’s efforts to involve agricultural chemical dealers in their program and to expand multidisciplinary research; New York’s attention to farming systems and multidisciplinary research; Michigan’s use of selective pesticides; Minnesota’s desire to foster development of the crop consulting industry; and Ontario, Illinois and Minnesota’s designs to provide IPM information and training to farmers. Pest resistance, selective pesticides, the crop consulting industry and information delivery to farmers were of interest in the IPM programs in most jurisdictions.

An important conclusion and recommendation from the survey was that research into IPM should concentrate on interdisciplinary efforts that develop options to chemical controls and should reconcile the development of the agro-ecosystem with related concepts, such as sustainable and organic agriculture, multiple cropping, conservation tillage and low-input farming. Recognizing the ramifications of pesticide use and the pressures which producers face from pesticide restrictions and pest resistance, IPM coordinators have identified nonchemical approaches as essential, but relatively undeveloped components of IPM systems. They also described the lack of such strategies as the fundamental impediment to IPM adoption by the farming community.

Basin respondents clearly indicated that current funding and overall support for IPM is inadequate. Basin programs have not attained the level of sophistication necessary to include aspects of interdisciplinary research that, for example, view the development of agricultural systems within the context of pest management and societal goals governing land and water
management, resource conservation, environmental protection or socio-economic development. Despite many inadequacies, however, IPM has attracted a small proportion of producers in basin jurisdictions. Progress to date has been modest, yet it indicates the potential benefits that could be attained in the future with increased resource commitments.

The concept of IPM is not restricted to agricultural practices, and recently has been extended to the management of sea lamprey (*Petromyzon marinus*) by the Great Lakes Fishery Commission. The application of IPM to Great Lakes pests responds to three major issues faced by the Great Lakes Fishery Commission:

- demand for improved program effectiveness through the definition of an acceptable level of control (economic thresholds)
- concern with continued reliance on chemical control and the need for biological options, such as current research into the effects of release of sterile males
- impact of the expansion of the salmonid fishery on exotics, relative to the rehabilitation of natural lake trout populations — the level of control of sea lamprey for a “put-grow-and take” fishery is lower than that necessary to protect naturally-reproducing species, such as lake trout (Koonce et al. 1990).

The relevance of IPM to the Great Lakes Fishery Commission (GLFC) involves a consideration of the effects of sea lamprey populations in relation to ecological, social and economic constraints based on an “economic injury level.” This level represents a population abundance of a pest, where the costs of additional control do not produce commensurate benefits. If the pest population is larger than the injury level, undertreatment occurs, and the opposite condition indicates overtreatment. By employing IPM principles, control specialists attempt to suppress pest populations to predetermined levels of abundance. This approach contrasts significantly with the existing sea lamprey control program, where maximum suppression is attempted within budgetary and technological constraints (Koonce et al. 1990).

IPM applies knowledge and other strategies today so that remedial measures will not be required tomorrow. It has the potential of minimizing chemical dependence through the reduction in use and replacement of pesticides and, more importantly, through the design of agro-ecosystems. The goal of protecting valuable surface and groundwater resources can be realized through a reduction in the widespread dependence on the indiscriminate use of chemicals in agriculture by substituting information technology and research for conventional chemical technology with its inherent problems.

The term “ecosystem” in the Great Lakes Water Quality Agreement, may suggest pristine natural environments. The largest, single land use in the basin, however, is composed of a highly-diverse, human-made agro-ecosystem. It is important to recognize agriculture as managed manipulations of natural components of the environment, and it is essential that human activities contribute to the integrity of the Great Lakes Basin Ecosystem. Agricultural systems that are modeled on ecological processes are more likely to achieve integration with the natural ecosystem and to be sustainable. The Board endorses four recommendations from the findings of the survey:

- **basinwide guidelines, outlining development goals for Integrated Pest Management programs, be established by the Parties under the Agreement and evaluated periodically by the Commission in its role of providing advice and recommendations to governments**
- **governments at all levels increase their resource commitment to all aspects of the development of Integrated Pest Management**
- all basin jurisdictions adopt Integrated Pest Management as their official state or provincial pest management policy, and government agencies with responsibility for pest management, implement Integrated Pest Management policies and practices and apply them to their own operations.

- research on Integrated Pest Management concentrate on interdisciplinary efforts that develop options to chemical controls and reconcile the development of the agro-ecosystem with related concepts, such as sustainable and organic agriculture, multiple cropping, conservation tillage and low input farming.
The International Joint Commission (IJC) in its work under the Great Lakes Water Quality Agreement, beginning with the Lower Lakes References in the 1960s, has used strategic planning and management on only one occasion, in connection with point sources of nutrients on the lower lakes.

Because of the rising level of expectations in connection with other programs, such as nonpoint sources, toxic substances, persistent toxic substances and municipal publicly-owned treatment works (POTWs), there is a need to develop management strategies so that the goal of a healthier ecosystem for the Great Lakes can be attained.

A review of five major programs under the Great Lakes Water Quality Agreement shows that a management strategy was used successfully for point sources of phosphates on the lower lakes.

In that connection, the IJC developed targets for a reduction in loadings with timetables and financial requirements. As a result of the development of this strategy, the goals of that program have been attained on a timely basis.

11.1 The Need for a Great Lakes Strategy to Implement the Great Lakes Water Quality Agreement

A strategic approach was used on only one occasion, point sources of phosphates; and that was a success.
- **Nonpoint Sources**
  In connection with nonpoint sources, extensive scientific, technological and regulatory studies are inconclusive with the result that the implementation of the program is limited and sketchy and there is no overall strategy.

- **Toxics**
  In connection with toxics, a draft strategy, which serves as a model for the rest of the world, was developed by the Toxic Substances Committee of the Water Quality Board (International Joint Commission 1987d), but was not implemented. The development of an overall toxics strategy will form an important part of the work of the current Joint Task Force on the Virtual Elimination of Persistent Toxic Substances.

- **Areas of Concern**
  The Commission and the Water Quality Board have changed the reporting requirements for Areas of Concern seven times since first identifying them in the 1970s, but no implementation strategy was ever developed.

- **New Programs**
  The Commission has initiated work on Lake Superior in connection with the virtual elimination of persistent toxic substances.

The time has come to develop an overall Great Lakes strategy.

### 11.1.1 What is a Strategic Plan?

- **Problem Statement**
  Strategy begins with a statement of the problem, possibly in relation to a lake or group of lakes.

- **Scientific Analysis**
  The next step is a scientific analysis of the obstacles to resolving the problem and a statement of other solutions. In the case of the phosphate work, there were, at the time the strategy was initiated, some doubts about the validity of the scientific basis for the use of phosphorus to control eutrophication. Certainty is never complete. Sometimes it is necessary for the Commission and Governments to take risks.

- **Load Reduction Plan**
  Once the scientific foundation has been developed to the point of implementation, and such is certainly now the case in connection with nutrients, toxic substances, persistent toxic substances and pollution from municipal publicly-owned treatment works, we need to set load reduction plans based on risk assessment.

  A loading reduction plan includes a work plan, dates and reduction goals by jurisdiction and source.

- **Implementation Program**
  Once the load reduction plans for a lake or areas of lakes have been established, implementation strategy needs to be developed to determine whether the primary thrust of the program should be regulatory, educational or economic incentives. Experience with the success of the present programs should provide important criteria for the selection of strategies to be used. Very little evaluation has been done in this area. Once the priorities have been set in terms of criteria, we need to examine laws, regulations and programs to see if they are adequate or if they need to be supplemented. It is important that laws and regulations be consistent across the region, or at least compatible from
state-to-state, province-to-province and between federal governments. Then the question of funding in terms of a financial plan, needs to be addressed.

Post-Hoc Evaluation

Once the plan is underway, evaluations need to be conducted in order to see whether problems have emerged which require special attention in order to keep the program on target.

In reviewing phosphorus control programs for the Commission, the Board recently recommended that an international symposium be convened under the auspices of the IJC to evaluate two decades of phosphorus controls in the Great Lakes basin (IJC, unpublished).

11.1.2 Summary

Strategic planning and management has led to the success of one major IJC program, point sources of nutrients. There is a need to apply it to other programs under the Great Lakes Water Quality Agreement.

**Atmospheric deposition is now widely recognized as an important source of pollution of the Great Lakes ecosystem.**

IJC, Third Biennial Report, December 1986

Available data on a number of toxic contaminants indicate that atmospheric input is a significant route of entry into the Great Lakes Basin Ecosystem. This recognition has led the International Joint Commission (IJC) to sponsor workshops designed to assess the current status of the availability of data and scientific frameworks for estimating atmospheric loading of toxic chemicals into lakes. The importance of the atmospheric pathway is also recognized through the incorporation of an atmospheric component into the Great Lakes International Surveillance Plan and the establishment of the Atmospheric Deposition Monitoring Task Force of the IJC.

As examples of recent estimates, the total atmospheric input of lead into Lake Ontario represents more than 70% of the total load of that lake. For Lake Huron, the total atmospheric input of PCBs represents almost 80% of the total load for that lake. Approximately 90% of the annual PCB input to Lake Superior comes from the atmosphere. Consensus is emerging that, as direct discharges of toxic substances into the Great Lakes are reduced, the atmospheric pathway will become even more dominant for a large number of toxic substances.

While some of these toxic substances are generated within the Great Lakes basin, it has become evident that major sources are often outside the basin, sometimes thousands of miles away. For example, although the manufacture and use of DDT has been banned in the United States and Canada for two decades, the compound still enters the Great Lakes basin via the atmosphere in measurable amounts. The source seems to be Latin America where a reported 11,000 tons of DDT were used in 1988. Observed levels of a number of agricultural pesticides in Great Lakes fish and wildlife are also thought to originate outside the basin.

As the Commission targets activities, such as the “Virtual Elimination of Toxics” and Lakewide Management Plans (LWMPs), the problems posed by the long-range atmospheric transport of toxic substances should receive increased attention. Unless the total atmospheric
loadings of critical pollutants, and, more importantly, their sources, are well identified, the problem of their virtual elimination from the Great Lakes Basin Ecosystem will be difficult, if not impossible, to achieve. A reduction strategy must thus recognize that both national and international strategies must be developed and coordinated to deal with this issue.

Because the atmosphere serves as an important conveyor of toxic substances to the Great Lakes, it also becomes important to develop a better understanding of the role of the surface microlayer on water in serving as a point-of-entry for these substances to the food chain. The microlayer, usually less than 50 mg thick, is a physically, chemically and biologically-active zone, which serves as both a source and a sink for biogenic (naturally-occurring organic films) and anthropogenic substances. Microlayer concentrations of heavy metals, petroleum hydrocarbons, plastic particles, pesticides and PCBs may be 10 to 1,000 times higher than those in subsurface water, only a few centimeters below.

The microlayer houses a rich diversity of biological organisms (bacteria, microalgae, protozoa), known collectively as neuston. It is also an important habitat for egg and larval stages of many fish and invertebrate species. Contaminant enrichment of the microlayer at levels comparable to those that have been measured could reasonably be expected to cause damage to resident organisms, and demonstrate toxicological potential.

Because of the above considerations with respect to the Great Lakes, there is a need to address:

1. which toxic chemicals originate in the airshed outside the Great Lakes basin (long-distance transport component)
2. source reduction strategies, which include cooperative efforts on a national as well as international level
3. the need to monitor the microlayer for toxic chemicals as well as to establish the nature of the toxic threat posed to organisms that come in contact with this biologically-active zone.

11.3 Radionuclides

11.3.1 Siting Nuclear Reactors on Drinking Water Reservoirs?

There are 37 nuclear reactors in the Great Lakes basin, about half in Canada and half in the United States (see Figure 11.1 and Table 11.1). The siting of these reactors was originally motivated by proximity to areas of high-power demand and large volumes of cooling water. The Board’s concern is threefold: low level emissions as a result of operational spills, the possibility of major emissions from a catastrophe comparable to that at Chernobyl, and the implications of the aging and obsolescence of a plant and its infrastructure.

The wisdom of siting power plants on the shores of a drinking-water reservoir for 23 million people can be questioned on ecological grounds. The residence times for waters in rivers (e.g. Mississippi, Fraser, Columbia) generally ranges from weeks to months, depending on the season. In contrast, water residence times for the Great Lakes range from three years (Lake Erie) to 180 years (Lake Superior). The effects on the Great Lakes are, thus, potentially much greater and longer-lasting than on normal river courses.

Nuclear power was first produced in the Great Lakes basin in 1963. Cooling water for each reactor is drawn from the lakes and returned, contaminated by trace amounts of radioactivity.
In addition, the stations are permitted to vent radionuclides to the atmosphere. These radionuclides can enter the waters of the lake through precipitation scavenging (International Joint Commission 1983b).

While nuclear energy for the generation electricity in the Great Lakes region appears to be more environmentally-benign than the use of energy from burning coal, oil or natural gas, a full comparison of the policy choices, including a prominent role for conservation, needs to be undertaken, particularly as development in the basin becomes increasingly dependent on nuclear generation.

With the aging of plants and equipment, two issues emerge: the approach of the design life of the plant and the accumulation of high-level, radioactive nuclear fuel as waste on site. For example, Fermi 2, which has been operating for only three years, is projected to be out of storage space by the year 2004. The issue of a long-term solution for waste storage must be addressed if a legacy problem for the Great Lakes is to be avoided. The finite design life of production facilities and the issues of operations and maintenance, including waste management and the costs of decommissioning of facilities, must be included in the operating costs of nuclear plants, as is the current practice with some utilities, such as Ontario Hydro.

Joshi (1991) has recently reviewed radioactivity in the Great Lakes and concluded that there is a need to develop both a radiological objective for fish and a better understanding of the passage of radioactive isotopes through biological food chains in the Great Lakes. The Great Lakes Science Advisory Board concurs with this conclusion. Further, on the basis of the
### Table 11.1 Number and Locations of Nuclear Generating Stations

<table>
<thead>
<tr>
<th>NUCLEAR GENERATING STATIONS</th>
<th>NUMBER OF REACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Huron</td>
<td></td>
</tr>
<tr>
<td>Bruce &quot;A&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Bruce &quot;B&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Douglas Point</td>
<td>Closed</td>
</tr>
<tr>
<td>Lake Ontario</td>
<td></td>
</tr>
<tr>
<td>Darlington</td>
<td>2 (plus 2 by 1993)</td>
</tr>
<tr>
<td>Pickering &quot;A&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Pickering &quot;B&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Lake Michigan</td>
<td></td>
</tr>
<tr>
<td>Big Rock Point</td>
<td>1</td>
</tr>
<tr>
<td>Cook 1 and 2</td>
<td>2</td>
</tr>
<tr>
<td>Kewaunee</td>
<td>1</td>
</tr>
<tr>
<td>Palisades</td>
<td>2</td>
</tr>
<tr>
<td>Point Beach 1 and 2</td>
<td>2</td>
</tr>
<tr>
<td>Zion 1 and 2</td>
<td>2</td>
</tr>
<tr>
<td>Lake Erie</td>
<td></td>
</tr>
<tr>
<td>Davis-Besse 1 and 2</td>
<td>2</td>
</tr>
<tr>
<td>Fermi 2</td>
<td>1</td>
</tr>
<tr>
<td>Perry</td>
<td>1</td>
</tr>
<tr>
<td>Lake Ontario</td>
<td></td>
</tr>
<tr>
<td>Fitzpatrick 1 and 2</td>
<td>2</td>
</tr>
<tr>
<td>Ginna</td>
<td>1</td>
</tr>
<tr>
<td>Nine Mile Point 1 and 2</td>
<td>2</td>
</tr>
</tbody>
</table>

long residence times of water in the Great Lakes and the possibility of long-term sediment-water transfers of isotopes, the Board suggests a careful consideration of health and ecological issues when reviewing policy with regard to locating reactors in the Great Lakes basin.

The Board concludes that there is a need to address:

- a binational energy policy for the Great Lakes basin, with a view to the ecological implications of the various options, including conservation. Nuclear energy and fossil fuel options should be reevaluated to assess the ecological implications relative to the Great Lakes Basin Ecosystem, together with the issues of risk assessment and risk perception.

11.4 Global Climate Change

The growing awareness by the Great Lakes scientific community began perhaps in February 1985 when R.E. Munn convened a workshop in which the effects of climate on fish were assessed (Timmerman and Grima, 1985). Other papers and workshops followed (Meisner et al. 1987; Regier et al. 1990a). The choice of the Great Lakes as one of four regions for an early assessment of the potential effects of climate change by the U.S. Environmental Protection Agency’s Office of Policy, Planning and Evaluation was effective in establishing a solid start for quantitative evaluation of the uncertainties and the potential impacts in our region of responsibility (Smith and Tirpak, 1989; Smith 1991).
Ecosystems of the Laurentian Great Lakes were strongly influenced by changes in climatic factors, generated in the recent scenarios of general circulation models, perturbed with a doubling of greenhouse gases. In simulation experiments, water level (Croley 1990), ice cover (Assel 1990), water temperature and dynamics (McCormick 1990), hypolimnetic anoxia (Blumberg and DiToro, 1990) and fish distribution and production (Hill and Magnuson, 1990; Magnuson et al. 1990; Shuter and Post, 1990) all respond markedly to greenhouse-gas doubling scenarios based on the general circulation models available several years ago (Manabe and Wetherald, 1987; Hanson et al. 1988; Schlesinger and Zhao, 1988).

Climate change scenarios for the Great Lakes region indicate potential increases in annual mean temperature of 4 to 6°C and decreases in the proportion of annual precipitation occurring in summer and fall relative to winter (Smith and Tirpak, 1989; Houghton et al. 1990). In a warmer and drier Midwest, greater demand on Great Lakes water would likely occur, with increasing stress on the lakes ecosystems. Recent rehabilitation efforts, such as reducing nutrient inputs from metropolitan areas, controlling sea lamprey abundance and increasing salmonid populations, have resulted in measurable improvements in the Great Lakes Basin Ecosystems (Spangler et al. 1987). Climate warming would counter some of these successes by making the lakes more eutrophic (Blumberg and DiToro, 1990; Hill and Magnuson, 1990; Regier et al. 1990b) and by increasing the probability of invasions of new exotic species (Mandrak 1989; Johnson and Evans, 1990) and the spread of sea lamprey (Holmes 1990).

Dealing with global climate change in the Great Lakes region will require policy decisions about water level regulation, water diversion, water quality, fisheries and shoreline management (Smith 1991). The Laurentian Great Lakes are expected to respond sensitively to climate change (Magnuson et al. 1989; Regier et al. 1990a; Smith 1991), and climate changes resulting from increases in greenhouse gases are predicted to be greater in the continental interior than in coastal regions (Houghton et al. 1990). This responsiveness, coupled with the concentrated socio-economic interests in the region, makes potential climate warming a critical issue for the International Joint Commission.

The Board reiterates its conclusions from the 1989 Report for the need to address the implications of climate change relevant to the Great Lakes and that:

- a United States-Canada integrated study of the Great Lakes basin be developed as a regional pilot project for an international response to global climate change
- a joint planning group to organize and develop the pilot project be established. The recommended activity should be integrated with and built upon two major, ongoing basin efforts: the Remedial Action Plan Program for the Areas of Concern in water quality and the ongoing International Joint Commission Lake Levels Reference Study.

Finally, the Board would like to continue its emphasis on the need for a biospheric perspective in order to provide a global context for the Great Lakes Water Quality Agreement, as outlined in their 1989 report.
The Council of Great Lakes Research Managers (CGLRM) functions under the authority of the International Joint Commission. The general objective of the Council is to provide effective leadership, guidance, support and evaluation of Great Lakes research programs, tasks which involve:

- Promoting interjurisdictional and interdisciplinary planning and coordination of research
- Encouraging the preparation and dissemination of syntheses of research findings to government and nongovernment bodies and bringing policy implications of the above findings to the attention of the recipients
- Compiling and summarizing current and planned research programs
- Identifying research needs and establishing priorities
- Reviewing the impact of research recommendations made by the Council, the Science Advisory Board, the Water Quality Board and the Commission

The following chapters respond to some of the aforementioned objectives. Three major initiatives have been sponsored and successfully completed by the Council:

- Great Lakes 2000 / Futures Workshop Report Section 12.2
- Great Lakes - St. Lawrence Basin Ecosystem Framework for Decision-Making Section 12.3
- Great Lakes Basin Ecosystem Integrity Indicators Framework Section 12.4
- Inventory of Great Lakes Research Section 12.5

The purpose of this Council-sponsored workshop was to establish a framework for future natural and social science research in the Great Lakes basin (International Joint Commission 1991e). A top-down approach to ecosystem-oriented research was sought, that would provide for sustainable development into the 21st century. Three objectives were identified by the Council:

- to understand the future challenges to the research community in the Great Lakes as these challenges relate to research and research management
- to develop a consensus on the directions and priorities for research to meet those challenges
- to produce a report for research managers and government decision-makers that summarizes the merits and value of the work of the Great Lakes research community to date; sets out the scope of the demands that must be met into the 21st century and describes the level of effort and the types of research that will be needed to meet such demands

Four major conclusions and some of the recommendations of the workshop are summarized in subsequent sections.
12.2.1 A Guiding Vision for the 21st Century

A well-defined and efficient research effort in the Great Lakes basin for the 1990s and beyond requires that management and scientists share a common focus, one that reflects the vision, concerns and wishes of the population of the basin. Despite billions of dollars spent on “cleaning up” past mistakes in the Great Lakes over the last several decades, there has yet to be a clear articulation of a widely-held vision for the basin, not of what we are trying to get away from (pollution), but of what it is that we are all working toward. Without a deliberate and comprehensive statement of goals, decisions run the risk of being made on the basis of short-term trade-offs and expediency. The Great Lakes Basin Ecosystem, in turn, may deteriorate further in the 21st century.

A number of binational and regional agreements were coordinated, concerted efforts to bring about desired outcomes, such as the Remedial Action Plans (RAPs) and Lakewide Management Plans (LWMPs), arising from the 1987 Protocol to the 1978 Great Lakes Water Quality Agreement. However, the elements remain fragmented, both conceptually and jurisdictionally, and remain dictated more by reaction to past pollution problems than by the anticipation of future challenges and opportunities. And even where explicit requirements have been made, responsibilities are diffuse and accountability remains vague within government agencies and other groups in the basin.


The Council of Great Lakes Governors and the Premiers of Ontario and Quebec, with support from the International Joint Commission (IJC), and the Great Lakes Fishery Commission (GLFC) and federal agencies on both sides of the border, should begin to build a broadly-based public consensus for a decade “Great Lakes 2000.” This statement of purpose will define a social, economic, environmental and political vision for the region in the 21st century. The development of an Ecosystem Charter for the Great Lakes will provide an essential underpinning for human activities in all jurisdictions and sectors.

- **Recommendation 2 - A Vision of and for the Research Community**

The research community in the Great Lakes basin needs to interact more with the community at large if it is to deal effectively with the anticipated environmental, economic, social, technical and political challenges in the 1990s and beyond. Research managers could assist by developing mechanisms for public commentary and discussion of major scientific issues in the basin. Research should formulate long-term, research objectives, compatible with the community needs and at the same time capable of advancing science.

12.2.2 Addressing New Research

There is a need for a strategy for Great Lakes research that looks forward, influences and coordinates research of the principal agencies in the basin, and encourages more transdisciplinary and interdisciplinary work. Because of the complexities of ecosystem science and the difficulty of maintaining a long-term focus, research management requires strategic plans.

Research in the 1990s should build on the solid base of natural science, that has been established in the basin over the last several decades. Social, science, socio-economics and human health-related science need to be emphasized. Understanding the ecosystem requires
a more holistic view, particularly to support the ecosystem/sustainable development approach, with better integration of natural, socio-economic and social science work. Synthesis of research is to be emphasized.

Organizations need to better use resources and expertise in the basin, both structurally (through coordination at all three levels of government and with universities, nongovernment organizations and industry) and conceptually (through better appreciation of the roles of basic and applied research, engineering and other applied technologies). The transfer of knowledge must be accelerated among other regional and global science establishments that are working on ecosystems research and sustainable development.

Recommendation 3 - Accepting Global Leadership:
Establish An International Ecosystem Center/Network

A Great Lakes - St. Lawrence Ecosystem Studies International Center/Network should be established as a clearly-identified research entity that would:

- support holistic research and synthesis in the natural, social, health and applied sciences throughout the basin and contiguous regions

- take a futures approach, seeking to anticipate and prevent problems, and demonstrate Great Lakes Basin Ecosystem solutions regionally, nationally and internationally

- provide advice on ecosystem policy to all levels of governments, government agencies, corporations and the public on both sides of the border

- convene workshops, conferences and otherwise provide an outreach function to stimulate professional and social learning and change

- draw on outside experts who have widely-respected experience in science and culture to evaluate programs and projects and to anticipate the interests of future generations in the region

- strengthen international links in transdisciplinary ecosystem research

Recommendation 4 - Developing Ecosystem Integrity Indicators

A set of indicators of ecosystem integrity for the Great Lakes - St. Lawrence River basin should be developed, that are scientifically-sound and socially-relevant, that would provide a general sense of the state of the changes over time. Collaborate with the Great Lakes Fishery Commission and the Parties to arrive at mutually-agreeable indicators. A workshop should be held to develop this framework; the objective is to have indicators used in Lakewide Management Plans by 1995.

Recommendation 5 - Establishing Environment-Economy Linkages

Research to quantify the relationship among economic development, ecosystem stress and environmental costs should be undertaken as a priority so that decision-making in the Great Lakes basin in the 1990s can better incorporate environmental values in economic development. The work should involve the Institute for Research on Public Policy, The Center for the Great Lakes, Sea Grant, the World Bank and other institutions dealing with economic development in the basin and worldwide.
12.2.3 Mobilizing Intellectual Capital

If the pressing social, economic and environmental problems facing the Great Lakes in the 1990s are to be solved, the research community will require additional scientific resources. The development of human resources within the Great Lakes science community will expand to encompass and integrate the social as well as the natural sciences.

- Recommendation 6 - The 3 Rs: Recruitment, Replacement and Retention

Within the next two years, the managers of research institutes in the Great Lakes, in conjunction with their colleagues in surrounding universities, should develop a comprehensive, basinwide plan to double the number of trained scientists by the year 2000. The plan should explore how to establish better links among universities, industries and government laboratories, and should include better access to field facilities and equipment, and improved maintenance of and access to collections and databases.

- Recommendation 7 - Transdisciplinary and Interjurisdictional Research

Science programs developed by universities and laboratories should include exploratory and anticipatory research initiatives.

- Research managers should develop studies that bridge the traditional natural and social science disciplines and institutional mandates and cut across political jurisdictions. Over the next five years, a variety of incentives should be implemented, including measures arising from formal references to the IJC, dedicated funds, career enhancement, and fellowship programs and interchanges.

- Science programs should be expanded in scope and more deliberately linked, in part, to the development of social policies and governing statutes in the basin. Transdisciplinary teams should become involved in programs and projects as well as planning and development, such as the Remedial Action Plans (RAPs) and the Great Lakes Protection Fund.

- As the first step, the expansion of the Council of Great Lakes Research Managers should be accomplished by adding to its expertise in economics, sociology and communications.

12.2.4 Theory into Practice: Communicating and Educating

The Great Lakes research community has a special responsibility to provide easily understood and accurate information to the people who live in the basin and to decision-makers in the public and private sectors. Because of the seriousness of the issues, there is a need to develop a proactive education and communication strategy, that would establish an open dialogue between the scientific community and the public to ensure that research is responsive to needs and priorities. Researchers should drive to bring science and the results of research into the public educational system at all levels. By translating research findings into policy and legislation, the lines of communication will be improved between the research community and senior decision-makers in all sectors. Researchers should improve the flow of relevant information between different fields and institutions, and between researchers, research managers and others.
Recommendation 8 - Using an Ecosystem Vision and Charter

The decade, “Great Lakes 2000” should be a major component of a basinwide education and communication strategy. The initial focus should be on the development of a Great Lakes Ecosystem Charter through the involvement of schools, citizen interest groups, private corporations, universities and governments at all levels.

Recommendation 9 - Extension Services

Research programs in the Great Lakes basin should place greater emphasis on extension services that communicate and interpret research results for the public. To facilitate this effort, it is recommended that:

- a Great Lakes section of the National Marine Educators Association (NMEA) along with complimentary programs in similar associations

- a workshop be organized by Canadians to review how outreach services could be improved and made to resemble those offered by the U.S. Sea Grant Program and other similar organizations. The results of the workshop should be brought to the next Sea Grant meeting in order to combine forces to create an efficient, basinwide program.

Recommendation 10 - Answering to the Public

The research community in the Great Lakes should improve communication links both to and from the public that it serves. Specific measures to accomplish this objective should include:

- a clear indication in all research programs of how the results will be transmitted to the public

- a “Council of Great Lakes Research Managers Award for Excellence in Research Communication,” presented annually at the meeting of the International Association of Great Lakes Research to a research scientist working in the basin, who, by example, has best linked research activity to a wider public interest

- a formal policy statement by the Council, declaring that it supports scientists’ participation in educational programs and that such activity is recognized as an important part of research

- participation of outside interest groups, corporate leaders and public officials in the activities of the Council

- the development of a basinwide communications and education strategy through the International Joint Commission, the Great Lakes Fishery Commission, the International Association for Great Lakes Research or others

- development of training programs for scientists on communication and education techniques

Recommendation 11 - Marketing Research and the Research Community

The Great Lakes research community and the Council of Great Lakes Research Managers, in particular, develop a proactive stance to public communication. An easily-accessible
electronic “bulletin board” and other frequently-updated descriptions of research projects for the Great Lakes basin be developed and made available to all those who work with social and natural science issues in the region.

- **Recommendation 12 - Greater Community Involvement**

As part of the strategic plan for Great Lakes for the 1990s, a citizen-oriented effort be encouraged to enhance environmental reporting, to marshal public involvement and to increase opportunities for exchanging information with the research community in the basin.

The future challenges for the Great Lakes basin community are complex. There is a need for better integration of natural, socio-economic and social science research in order to cope with the multitude of issues in the basin. We must apply the ecosystem/sustainable development approach in future initiatives and maintain the development of comprehensive, basinwide plans, all the while enhancing opportunities for citizen-oriented involvement.

12.3 Great Lakes - St. Lawrence Ecosystem Framework for Decision-Making

In September 1989, the Council of Great Lakes Research Managers held a Futures Workshop “to establish a framework for future natural and social science research in the Great Lakes basin” (IJC 1990). Among the recommendations which emerged from the meeting was the need to place a greater emphasis on transdisciplinary and interdisciplinary work to address linkages between areas of research that have traditionally proceeded largely in isolation. The establishment of key linkages between major areas of research (for example, between economic, social and ecological components of the Great Lakes Basin Ecosystem) was recognized as essential for holistic policy analyses, that are thought necessary for responding effectively to growing demands on the Great Lakes Basin Ecosystem. Participants at the Futures Workshop recommended the development of a Great Lakes - St. Lawrence Ecosystem Model.

The Council endorsed the idea of investigating the development of a Great Lakes Basin Ecosystem model and early in 1990 established a Steering Committee to further develop the concept. A workshop was held December 4-6, 1990 in Milwaukee, Wisconsin to develop a detailed implementation plan for consideration and action by the Council. In this exercise, the word model was referred to as a process required for the integration of issues, information and actions; a framework for decision-making would be the outcome. The process includes stakeholder involvement, communication with a wider constituency, and an overall need to incorporate the human dimension in the exercise. It was agreed that the process will include, at some point, the use of computer models as tools to measure the resilience of the ecosystem. The development of the Great Lakes - St. Lawrence Basin Ecosystem Framework (GLSLEF) could be used to:

- help research managers, in a binational, collaborative manner, to anticipate issues and to help identify research priorities and data gaps
- develop conceptual structures which link decision-making processes at scales appropriate to different levels of model hierarchy (linkages and decision-making needs differ not only with respect to space and time, but also, the degree of interaction among economic, social and ecological components)
- provide a detailed, technical framework for the development and evaluation of a broad range of policy options for issues affecting the basin
- implement the ecosystem approach and assess ecosystem integrity in the widest sense
Both framework development and the eventual use of the tool(s) developed will serve as a basis for communication and learning among different disciplines: between researchers and research managers and among researchers, policy-makers and the public.

12.3.1 Framework Purpose

The GLSLEF should promote the development and evaluation of management and policy in the basin. To be useful, the framework should contribute to education and communication attendant on the policy formulation and implementation processes. Research requirements and science would derive from the information needs of the policy process. Ultimately, therefore, the GLSLEF must support learning and dialogue at all levels: in schools, communities, government agencies, industry, and politics in all its forms. The purpose of the ecosystem framework in decision-making is to assist society in understanding the need and mechanisms for change.

12.3.2 Framework Users

Three major groups emerge as the key users for such a framework: the science community, decision makers and the public. The science community requires a process that helps it determine the major areas of uncertainty associated with evaluating or implementing the goals of society in the basin. Development of, and experimentation with, modeling processes are proven methods of identifying research and monitoring needs and would contribute to framework development.

The user group of decision-makers, in the context of the GLSLEF, consists of those responsible for the development, evaluation and implementation of policy in the basin. These individuals operate at a multitude of levels, ranging from community to international, within both the public and private sectors. Interestingly, however, the questions which they wish answered are often very similar: “How do I get out of this problem?” or alternatively, “If I make this decision, what will it cost me and my constituency, if I am wrong?” In order to answer questions such as these, the decision-makers need a mechanism for experimentation with the options available to them and to assess potential feedback. In the development of the GLSLEF, modeling processes would provide a measure of the risk associated with the options under consideration. Although models are not reliable as predictors of the future, they have proven their ability to identify areas of vulnerability in a system and, thereby, help to answer the types of questions most often asked by decision-makers.

The public consists of people and organizations other than the researchers and decision-makers. Identifying “people” as major users of the framework is a recognition of the human dimension of the ecosystem approach. The people, as major users of the basin, are the primary motivation of concern for the health of the Great Lakes basin. It is the public’s need for security, equity, quality of life, compassion and justice that has provided the motivation for the development of the GLSLEF. Similarly, this need is reflected in the policies in the GLWQA, “to restore and maintain the biological integrity of the waters of the Great Lakes Basin Ecosystem.”

12.3.3 Framework Process

The process of building an ecosystem framework for decision-making is as important as the framework itself. A structured process of framework building includes stakeholder involvement, communication and education strategies, and the development of interdisciplinary networks.
The development of the GLSLEF, under the umbrella of the IJC, offers an opportunity to design, test and implement effective new methods of building a commitment to environmental excellence and ethics in a large and diverse public.

The framework development process must include the constituency of concerned citizens who ultimately will utilize the results of the analysis, and the decision-makers who in the past determined whether the result was relevant to their problems. One interesting new development is the concept of "policy exercises," workshop-style events at which policymakers, scientists, humanitarians and communicators work together to integrate a wide range of quantitative and qualitative input into a set of scenarios describing possible rather than predicted futures. Through the creative synthesis of model building and model analyses, a whole new set of options for change will evolve.

A necessary condition of the framework process is the need for continual adaptation. New participants will become involved over time, and new information and insight will change the framework, content and process. Any attempt to capture the scientific, social and institutional complexity of the Great Lakes basin will forever deal with the challenge of decisions to be reached under uncertainty on a grand scale. Such systems are inherently unpredictable. Recent advances in the study of complex system behavior (e.g. chaos theory) have demonstrated that the objective of highly predictable states is unreachable. It is hoped that we can establish conditions of resilience, such that the inevitable surprises are manageable and do not generate catastrophic results. Therefore, we want the framework process to identify where the system is vulnerable to a set of possible events, rather than to attempt to predict the occurrence of the events.

Coordination is needed to initiate and maintain the process described above. In order to coordinate the process, we need to define necessary steps and responsibilities; in other words we need a conceptual framework of the process. As part of the process framework, institutional support and constituent responsibilities need to be defined. The responsibility for the overall process has already been defined by the Council Steering Committee. In the long term, a permanent facility or centre could foster continuity in the framework development and use process.

12.3.4 Ecosystem Approach and Ethics

The 1978 Great Lakes Water Quality Agreement (GLWQA) between Canada and the U.S. called for an ecosystem approach to the restoration and maintenance of the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. Subsequent extensions of the GLWQA have continued to emphasize the goal of restoring ecosystem integrity, but technical interpretation of the ecosystem approach has proven illusive. The Milwaukee Workshop confronted this recurring issue, and in frustration sought an expression of the ecosystem approach in terms of socio-economic or human concerns. It was suggested that the ecosystem approach was ultimately a world view and, thus, an ethical rather than a technical problem.

The challenge of the ecosystem approach is to fit lakes and politics into the context of the ecosystem of the Great Lakes basin. Implicitly, this effort requires actions on a wide range of bio-physical, economic and social issues to make policy, management, and individual behavior consistent with publicly-held values.

Viewing the ecosystem approach as an ethical problem has the advantage that the social and economic aspects of human society may be more easily linked. All individuals residing in the Great Lakes basin ultimately share a set of core values among which is a desire for a sustainable ecosystem. This value may be thought of as security, equity, quality of life,
compassion and justice. Instrumental values translate the core values and beliefs into actions usually guided by knowledge (technical, political, etc.). Conflicts that arise due to different interpretations of knowledge and values often involve notions such as justice, equity and stewardship, and they may represent fundamental disagreement about the preference for various trade-offs (Figure 12.1).

Policy choices are often the result of trade-offs between benefits and costs or risks of adverse consequences of decisions. Tools, such as models, provide a way to formalize trade-off analysis and, thus, make decisions more objective. If policy choices are value laden, however, economic and ecological analyses of the consequences of policy choices may not capture fundamental concerns and world views. One way out of this dilemma might be to use the modeling exercise to engage in discourse about values and to view the human dimension of the ecosystem approach as a process of learning and value clarification.

Schematic Presentation of Relationships Between Values, Beliefs and Knowledge, and the Social, Economic and Ecological systems.

12.3.5 Recommendations

- **Recommendation 1 - Support to Policy and Management**

  The Great Lakes-St. Lawrence Basin Ecosystem Framework should be designed so decision-makers can easily analyze and assess the implications of policy and management decisions. The process of building the systems models of major basin issues should facilitate policy analysis and foster exploration of the significance of different initiatives in terms of their effect on the ecosystem.

- **Recommendation 2 - Interdisciplinary and Intersector Research**

  Inter-disciplinary research should be strengthened by developing new working relationships among all the relevant disciplines and sectors. Initiatives emerging out of the GLSLEF initiative could be pursued through a cooperative research/development framework, fostered by the IJC through its Council of Great Lakes Research Managers.
This effort should stress the necessary interface between research and decision-making and foster the ecosystem approach to studying and managing the basin system.

- Recommendation 3 - Application of GLSLEF

As soon as possible a systems framework approach be applied to as many of the major issues in the basin as possible. Next, the GLSLEF should be developed to integrate the sets of relatively simple, issue-based models, which incorporate dominant ecological processes. The framework would represent major linkages between subsystems of the Great Lakes Basin Ecosystem. This set of models must be capable of addressing issues at the watershed, Great Lake and basin spatial scales.

- Recommendation 4 - Cooperation and Sharing

Researchers and scholars must work together to make innovative and efficient use of existing data and models. The process must explicitly include social and economic information.

As the complexity of human impact on the environment increases, the need for effective management of our natural resources becomes increasingly critical. The nature of environmental impact has changed radically since the beginning of the Industrial Revolution, as exemplified by the increasing importance of regional (e.g. acid precipitation) and global (e.g. climate change) nonpoint sources of stress relative to point source discharges, the increasing number of potential stressors and the importance of cumulative impacts. In the Great Lakes region, as elsewhere, environmental protection has broadened from a focus on water quality standards to the broad objectives of restoring self-maintaining ecosystems and maintaining the quality of human life. To change the way in which society affects and wishes to restore and protect the environment requires improvements in the effectiveness of environmental management strategies.

There are two approaches to the evaluation of environmental degradation at the community and ecosystem levels (Norton 1988; Hunsaker and Carpenter, 1990). In the "top down" method changes in communities and ecosystems are monitored with subsequent diagnosis of problems and causative agents. In contrast, "bottom-up" methods use laboratory data on the effects on simple systems, which are then used to model changes in the more complex natural ecosystem. Routine bottom-up procedures for estimating hazard (e.g. laboratory testing with human or ecosystem surrogates, models of fate and transport) are limited in their ability to predict impacts on natural ecosystems. Simple biological test systems (e.g. single-species laboratory bioassays) might not predict effects on relatively complex systems (e.g. natural ecosystems), containing thousands of possible combinations of chemicals.

Natural ecosystems are complex, multivariate systems and are being simultaneously exposed to a multitude of stresses, the mechanisms and cumulative effects of which are poorly understood. Thus, the management of major ecosystems, such as the Laurentian Great Lakes, to achieve broad environmental and socio-economic objectives is possible only with a substantial broadening of the environmental assessment framework to encompass top-down ecosystem objectives.

Periodic, direct observation of the health of communities in their natural environment provides the opportunity to validate predictions of impact in the real world from bottom-up.
methods and provides mechanisms for implementing corrective actions into the management plan. This iterative process is described by the term "biological monitoring," the ongoing assessment of environmental conditions to insure that previously-formulated objectives are being maintained (Figure 12.2, Hellawell 1978).

12.4.1 An Objective Framework

The focus of this section is on the development of an objective framework for selecting indicators of environmental health in the context of a long-term monitoring program for the Great Lakes region. This framework is based on the ecosystem approach, first formalized by the Great Lakes Research Advisory Board (International Joint Commission 1978). This approach is conceptualized by the view of "man-within-the system" as opposed to "the ecosystem-external-to-man." Since its inception, this view has evolved steadily towards a fundamental desire to promote compatibility between and sustainability of both ecological and human systems in the region (International Joint Commission 1989d). The proposed framework supports this emerging goal by addressing the development of both biogeochemical and socioeconomic indicators of environmental health and the linkages between them.

Monitoring the Health of an Ecosystem Over Time

12.4.2 Framework for Developing a Monitoring Program

Once management goals have been specified, a framework must be developed for selecting indicators and utilizing the resulting information. Basically, everything is an indicator of something, but no one thing is an indicator of everything. Economic and ecological considerations limit the number of indicators that can be measured to only a fraction of those available. Given such limitations, it is essential that indicators are selected to maximize unique,
relevant information and minimize redundant information. Indicator monitoring should be cost-effective and supportive of management needs.

We propose a framework for indicator selection that addresses three critical questions relating to ecosystem management:

- Are stated objectives being met?
- If stated objectives are not being met, what is the cause of this noncompliance?
- How can impending noncompliance be predicted before it is actually detected?

To answer these questions, a monitoring program must fulfill multiple purposes. The first and most obvious purpose is to provide an assessment of environmental conditions to determine if goals and objectives are being achieved (Figure 12.3, Hellawell 1978). Previous work on indicator development for the Great Lakes focused on ecosystem management; it identified ecosystem parameters and processes that were useful for judging compliance with general goals and specific ecosystem objectives (Ryder and Edwards, 1985; Edwards and Ryder, 1990; Bertram and Reynolds, 1991).

**General Framework for Indicator Development**

Generally acceptable goals are used to develop a set of explicit ecosystem objectives. One or more compliance indicators are identified; they are used directly to judge attainment and maintenance of some desired condition stated in an ecosystem objective. Early warning indicators are chosen to assist in maintaining the desired condition by detecting impending deterioration before substantial impact has occurred. Diagnostic indicators are essential for determining the management required for fulfillment of objectives.

**12.4.3 Development of an Indicator Program**

To foster a comprehensive and organized approach to Great Lakes management, the Council of Great Lakes Research Managers proposes the development of an indicator program, based on three general types of indicators: compliance indicators, diagnostic indicators, and early warning indicators.

The overall indicator framework developed in this section is outlined in Figures 12.2 and 12.3. This strategy encompasses efforts both to restore conditions that have been impaired by
previous stressors and to prevent deterioration, resulting from stressors that have yet to be identified and/or contained.

12.4.4 Integrated Measures of Ecosystem Health

Indicators of ecosystem health can be identified for each level of biological organization. No single measure is superior. Because of the inevitable limitations on the use of any single indicator for monitoring ecosystem conditions, various attempts have been made to combine a suite of biological indicators into a robust index of ecosystem health or integrity. The use of an integrated measure of ecosystem condition is advantageous since deficiencies in the indicator ability of any one parameter should not invalidate the overall assessment. The development of an index that is sensitive to several stressors would be beneficial in light of the complexity of environmental impacts in the lakes region. Integrated indices that reduce information from several measures into a single value are advantageous for decision-making. In particular, measures are generally chosen that provide complementary information about environmental effects and are not redundant.

Indices of biotic integrity (IBI) to assess and monitor ecosystem health in the United States often use fish and macroinvertebrate communities (Karr et al. 1986; Davis and Lubin, 1989). Several parameters, referred to as metrics, are selected; they reflect individual, population, community and ecosystem attributes. Metrics have been used to assess ecosystem health, using fish communities. Species richness and composition is measured with indicator taxa, trophic composition and the overall abundance and condition (e.g., proportion diseased or with tumors). Indices of richness for macroinvertebrates of various orders, proportional abundance of various taxa, percentage of “tolerant” species in the community, and the dominance of different feeding groups (e.g., shredders vs filter-feeders) in the community may be useful measures of biotic integrity.

12.4.5 Reasonable Human Use

Major categories of human use that are likely objects of protection are listed in Table 12.1 with examples of potential indicators. Indicators include monetary estimates: actual market values, shadow prices and contingent valuation (willingness-to-pay or adequate compensation for loss estimates). Non-monetary estimates include stocks and flows in terms of biomass, counts of standard violations or instances of inadequate quality, and human preferences.

12.4.6 Conclusions

The continued evolution of monitoring programs in the Great Lakes should be anticipated for several reasons:

- the relative concern over various types of human impact will change as current restoration activities succeed in their goals and new forms of impact are identified and quantified

- results of continued basic research and surveillance programs will, undoubtedly, modify the suite of parameters most useful for evaluating ecosystem health

- ecosystem goals and objectives will continue to be developed and refined to meet the broad and changing demands and expectations of various shareholders. In order to preserve continuity in the face of inevitable change, a comprehensive framework for developing and implementing ecosystem indicators, such as that proposed here, should be adopted for the Great Lakes region.
Table 12.1  Potential indicators of the response of human use to environmental degradation

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>QUALITY</th>
<th>VALUATION COSTS</th>
<th>MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial Fisheries</strong></td>
<td>• stock, harvesting, recruitment estimates</td>
<td>• presence of preferred species</td>
<td>• stocking</td>
</tr>
<tr>
<td>Bird &amp; Rapport, 1986</td>
<td></td>
<td>• restriction on consumption</td>
<td>• lampey control</td>
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<td></td>
<td></td>
<td>• incidence of tainting, deformities</td>
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<tr>
<td></td>
<td></td>
<td>• shadow pricing, farm reared vs feral fish</td>
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<td></td>
<td></td>
<td>• employment and payroll</td>
<td></td>
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<tr>
<td><strong>Drinking Water</strong></td>
<td>• stock, withdrawal, replenishment estimates</td>
<td>• treatment costs</td>
<td>• treatment costs</td>
</tr>
<tr>
<td>Wentworth et al. 1986</td>
<td></td>
<td>• chemical and bacterial standards violations</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• restrictions on consumption</td>
<td></td>
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<td></td>
<td></td>
<td>• reported acute illness</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• user satisfaction*</td>
<td></td>
</tr>
<tr>
<td><strong>Recreation</strong></td>
<td>• visit counts: sport fishing, swimming, boating, bird watching</td>
<td>• incidence of fish consumption restrictions</td>
<td>• employment and payroll</td>
</tr>
<tr>
<td>Hunsaker &amp; Carpenter, 1990;</td>
<td>• boat registration</td>
<td>• incidence of contact sport restrictions</td>
<td>• stocking</td>
</tr>
<tr>
<td>Lichtkoppler &amp; Hushak, 1999</td>
<td>• marina and beach counts</td>
<td>• incidence of fish deformities or tainting</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• catch per unit effort</td>
<td></td>
</tr>
<tr>
<td>**Industrial, Energy and</td>
<td>• stock, withdrawal, replenishment rates</td>
<td>• productivity, crop, livestock losses attributable to water quality problems</td>
<td>• compensation for loss of use</td>
</tr>
<tr>
<td>Agricultural Water Use**</td>
<td></td>
<td>• costs of pre-use treatment: descaling, defouling</td>
<td>• increased product cost due to degradation</td>
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<tr>
<td></td>
<td></td>
<td>• shadow valuations: water view vs inferior real estate</td>
<td><strong>cost of post-use treatment</strong></td>
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<tr>
<td></td>
<td></td>
<td>• contingent valuation; willingness to pay and compensation for loss*</td>
<td></td>
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<tr>
<td><strong>Aesthetics</strong></td>
<td>• subjective satisfaction</td>
<td>• incidence of objectionable odor*</td>
<td>• landscape planning</td>
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<td></td>
<td>• miles of shoreline</td>
<td>• incidence of turbidity</td>
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<td>• incidence of algal blooms</td>
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<tr>
<td><strong>Transportation Water Use</strong></td>
<td>• water levels</td>
<td>• shadow valuations: water view vs inferior real estate</td>
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<td></td>
<td></td>
<td>• contingent valuation; willingness to pay and compensation for loss*</td>
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<tr>
<td><strong>Human Health</strong></td>
<td>• community level</td>
<td>• income lost due to restrictions on dredging</td>
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<td></td>
<td>• native people</td>
<td>• costs of disposal for contaminated dredge spoils</td>
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<td></td>
<td>• perception of a healthy environment</td>
<td>• costs of pollution controls</td>
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<td></td>
<td>• human welfare</td>
<td>• costs of control of nuisance growths: macrophytes, zebra mussels</td>
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<td></td>
<td>• social values</td>
<td>• medical costs</td>
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<td></td>
<td></td>
<td>• loss of human potential</td>
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</tbody>
</table>

**Support of General Economic Well-being of Region**
- traditional economic indicators (GNP, unemployment, income class distribution, etc.)

**Future Use**
- genetic poll for pharmaceuticals, genetic engineering, temperature buffer in global warming

* Subjective evaluations, dependent on survey of shareholders
12.4.7 Recommendations

The framework proposed here allows for the integration of reactive and predictive management strategies into an integrated monitoring program. Different types of indicators are needed to perform the various functions required of a comprehensive monitoring program.

- Development of an Indicator of Each Type for Each Lake:
  - compliance indicators, those measurements that can be used to judge whether a stated ecosystem objective has been achieved
  - diagnostic indicators, those measurements that can be used to determine the cause of impacts that prevent the achievement of the stated objectives
  - early warning indicators, measurements that are especially sensitive to ecosystem stress and, thus, are capable of detecting the onset of deleterious conditions before significant impact has occurred

- Development of a Suite of Indicator Species.

Several species are needed to integrate adequately the effects of all important stressors.

- Further Identification of Integrator Species

Integrator species, such as the lake trout and the walleye, are suitable for use as monitoring tools in the Great Lakes. Other species include the herring gull as an indicator species for monitoring the effects of persistent organic toxicants and an alga such as *Cladophora*, for monitoring changes in phosphorus availability.

- Research on Ecosystem Indicators

Basic research be conducted in translating concepts related to ecosystem integrity into concrete measures that can be used as indicators of integrity.

- Indicators of Human Health
  - Biomarkers that measure both human beings and sentinel species (e.g. herring gulls) should be developed and validated for future use as early warning systems.
  - Registries should be established to gather statistical data on mortality and morbidity in the basin in such a manner that data from different jurisdictions can be compared and pooled, that data are amenable to cross-linkage with other statistical data banks, and so that trends in population health can be tracked in future years. As a minimum, tumors, respiratory and heart disease and congenital abnormalities should be included.
  - Studies of the offspring of women who consume large amounts of Great Lakes fish need to continue in order to investigate further the relationships between maternal fish consumption and effects such as cognitive and motor deficits, birth weight and gestational age.

- Reasonable Human Use

Environmental goods and services be translated into monetary terms for compatibility with most economic policy-making instruments requires further research.
Perceptions of Environmental Quality and Quality of Life

A standardized instrument should be developed to monitor trends in perceived environmental quality and quality of life for shareholders in the Great Lakes basin.

Develop a Framework of Ecosystem Health

Research be conducted to determine the linkages between ecosystem and economic indicators related to human activities. The determination of these linkage relationships could monitor sustainable concepts.

12.5 Inventory of Great Lakes Research

One of the ongoing responsibilities of the Council of Great Lakes Research Managers is to compile and summarize current and planned research programs related to the implementation of the Great Lakes Water Quality Agreement. This inventory of Great Lakes research programs is an iterative process and requires annual updates from government agencies, research institutions, universities and funding agencies on both sides of the U.S./Canadian border. The focus of the inventory is primarily Great Lakes water quality and is currently limited to selected organizations represented by the Council and a limited number of others.

The coding and classification system for research projects was developed during the previous (1988/89) inventory and modified in the 1990/91 inventory review. The classification system consists of mutually exclusive categories relevant to research and monitoring pursuant to the GLWQA. The research effort within categories is being evaluated on the basis of the amount of funding and the number of person years allocated to each relevant project. Once completed, current research trends and effort in each category will be assessed in relation to earlier inventories and research-related recommendations of the GLWQA, the Science Advisory Board, the Water Quality Board and the Council of Great Lakes Research Managers. This process will allow the evaluation of recent trends in Great Lakes research, correspondence to directions set out by the IJC, and identification of research areas requiring further development.

Although the current inventory is incomplete at the present, it is possible to detect large-scale trends in Great Lakes research. The majority of projects classified to date investigate toxic chemical exposure in the field, using chemical analytical approaches, and the fate and effects of toxic chemicals both in the field and in the laboratory. An increasing number of ongoing studies are designed to quantify the concentrations of toxic chemicals in environmental media and in the tissues of fish and humans residing in the Great Lakes basin. The number of studies documenting inputs of agricultural chemicals, the ecology and deleterious effects of exotic species, and human health effects resulting from toxic chemical exposure are also on the increase. In contrast, remedial technology, the socio-economic impacts of pollution, and legal aspects appear to receive little attention. This situation may arise from a lack of such research projects or the incomplete nature of the current inventory, which represents institutions with expertise in the physical sciences. Finally, it should be emphasized that trends in Great Lakes research, as reflected by this inventory, may have changed by the time that the project is completed.

When completed, the inventory will be made available upon request to government agencies, research institutions, nongovernment organizations and the public, with the aims of facilitating the coordination of research activities and the communication among researchers, and disseminating research information to the general public. To aid in the efficient transfer of this information to potential users, the inventory will be available on an electronic bulletin board at the Great Lakes Regional Office of the IJC.
12.5.1 Recommendations

- A standardized framework be established to serve as a mechanism to facilitate identification of water quality research needs and coordination of research activities in the Great Lakes basin. Annual or biennial research inventories should become an integral part of this process, providing baseline information for the evaluation of the adequacy of the existing research programs of the Parties.

- Increased cooperation among research institutions and the inclusion of experts from disciplines other than the physical sciences (e.g. social sciences, economics, law, citizen groups) is recommended to arrive at well-balanced, interdisciplinary approaches to the design of water quality research programs, consistent with the ecosystem approach adopted by the Parties.

- Continued significant research in the natural sciences is required to elucidate ecological processes in the Great Lakes, as well as to maintain a focus on water quality problems caused by toxic chemicals and other significant environmental perturbations.
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Kingsley, M. 1991. Personal communication with the Maurice Lamontagne Institute, Mont-Joli, Quebec.


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Schlesinger, M. and Z. Zhao. 1988. Seasonal Climate Changes Induced by Doubled CO₂ or Simulated by the OSU Atmospheric GCM/Mixed-Layer Ocean Model. Oregon State University, Climate Research Institute, Corvallis, Oregon.


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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AOC</td>
<td>Area of Concern</td>
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<tr>
<td>BaP</td>
<td>Benzo(a)pyrene</td>
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<tr>
<td>BCD</td>
<td>Biological and Conservation Data System</td>
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<tr>
<td>BTX</td>
<td>Benzene, Toluene and Xylene</td>
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<tr>
<td>CERCLIS</td>
<td>Comprehensive Emergency Compensation and Liability Inventory System (Superfund Sites)</td>
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<td>CGLRM</td>
<td>Council of Great Lakes Research Managers</td>
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<tr>
<td>DBCP</td>
<td>dibromochlorophane</td>
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<td>DCPA</td>
<td>dimethyl tetrachloro-2,3,5,6-tetrachloro-1,4-benzenedicarboxylate (formerly dimethyl tetrachloroephthalate (clorthal or Dacthal))</td>
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<tr>
<td>DDE</td>
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<tr>
<td>DDT</td>
<td>dichlorodiphenyltrichloroethane</td>
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<tr>
<td>DNA</td>
<td>“Double helix” of DNA (Deoxyribonucleic acid) which contains the genetic code</td>
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<td>DRASTIC</td>
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<td>D</td>
<td>depth to water</td>
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<td>(net) recharge</td>
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<td>soil media</td>
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<td>T</td>
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<td>impact of the vadose zone</td>
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<tr>
<td>C</td>
<td>conductivity (hydraulic) of the aquifer</td>
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<td>EDB</td>
<td>ethylene dibromide</td>
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<td>Fishery Management Plan</td>
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<td>IUPAC</td>
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<tr>
<td>kg</td>
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<tr>
<td>LWMP</td>
<td>Lakewide Management Plan</td>
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<tr>
<td>m³</td>
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<td>NAWMP</td>
<td>North American Waterfowl Management Plan</td>
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<td>World Health Organization</td>
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<td>Watershed Management Plan</td>
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MEMBERSHIP AND ORGANIZATION

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  - STATE OF THE GREAT LAKES BASIN ECOSYSTEM TASK FORCE
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A/S Acting Secretary
C Chair/CoChair of referenced board/committee
L Liaison of referenced board/committee
S Secretary of referenced board/committee
1 Science Advisory Board
2 Science Advisory Board Executive Committee
3 Council of Great Lakes Research Managers
4 Ecological Committee
5 Ecological Committee’s Biological Effects Subcommittee
6 Health Committee
7 Societal Committee
8 Technological Committee
9 Joint State of the Great Lakes Basin Ecosystem
10 Virtual Elimination
11 Great Lakes 2000 Committee
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Dr. Jan Barica
National Water Research Institute

Dr. Donald A. Chant
Ontario Waste Management Corporation

Dr. Katharine S. Davies
Toronto, Ontario

Dr. Ursala M. Franklin
University of Toronto

Dr. Andrew Hamilton
former IJC Canadian Section liaison
now with Rawson Academy of Aquatic Science

Dr. Richard Liroff
The Conservation Foundation
SCIENCE ADVISORY BOARD MEETING RECORD
AND ACKNOWLEDGEMENTS

76TH THROUGH 83RD MEETINGS

1. 76TH, WEDNESDAY, OCTOBER 11, 1989 (in conjunction with 1989 Biennial)
SHERATON HOTEL, HAMILTON, ONTARIO
   - This half-day meeting prefaced the fourth biennial and discussions centered on SAB
     presentations to the Commission on the following day as well as addressed policy,
     future issues, priorities and proposed organizational changes. A report from the
     Council on their current Futures workshop was presented, including four new
     initiatives arising from it (the establishing of a Futures Committee, and proposals for
     an Ecosystem Model, an Ecosystem Integrity Indicators workshop and an International
     Centre for Global Ecosystem Research).
   - Presentation of the 1989 Science Advisory Board report.

2. 77TH, WEDNESDAY, DECEMBER 6, 1989 THROUGH FRIDAY, DECEMBER 8, 1989. HYATT
   REGENCY HOTEL, MILWAUKEE, WISCONSIN
   - Mayor of Milwaukee, John Norquist opened this meeting, providing encouragement,
     and inviting criticism and recommendations for improvement of Milwaukee’s RAP
     program.
   - Tour of Milwaukee Metro Sewerage District’s Deep Tunnel Project given by Messrs.
     W. White, Executive Director and G. Moder, Vice Chair RAP Citizen Action Group.
   - Presentations:
     Dr. K.W. Bauer/Mr. R. Biebal
     Mr. S. Skavroneck
     Mr. J. Bauman
     Ms. Glenda Daniels/Ms. K. Bero
     Dr. W. Page
     Southeastern Wisconsin Regional Planning Commission Estuary Study
     Wisconsin RAPs with a focus on Milwaukee Harbour
     Wisconsin DNR Priority Watershed Program
     Lake Michigan Federation
     Chairperson of Milwaukee RAP Public Advisory Committee
     Long-Range Strategic Plan for Milwaukee Harbour
   - Closing day remarks given by Mr. D. Schultz, Milwaukee County Executive

3. 78TH, WEDNESDAY, FEBRUARY 21 THROUGH FRIDAY, FEBRUARY 23, 1990
   IJC REGIONAL OFFICE, WINDSOR, ONTARIO
   - Overview presentations from Mr. John Schwarts and Mr. Ken Vrana on Michigan Sea
     Grant.
   - Dr. William Cooper of Michigan State University’s Center for Environmental Toxicology
     addressed the developments in risk analysis since the EPA report “Unfinished Business.”
     An overview on the organization of the Center was provided by Dr. Lawrence Fisher.

4. 79TH, WEDNESDAY, MAY 23 THROUGH FRIDAY, MAY 25, 1990
   RADISSON HOTEL, LANSING, MICHIGAN
   - Overview presentations from Mr. John Schwarts and Mr. Ken Vrana on Michigan Sea
     Grant.
   - Dr. William Cooper of Michigan State University’s Center for Environmental Toxicology
     addressed the developments in risk analysis since the EPA report “Unfinished Business.”
     An overview on the organization of the Center was provided by Dr. Lawrence Fisher.
- Mr. J.D. Snyder, Michigan Department of Natural Resources, spoke to the Board on three issues of importance to Michigan: the Great Lakes Protection Fund, Spill Preparedness and the Governor’s First Order.

- Dr. Vaughn Wagenar, Interagency Centre for Health and Environmental Quality presented a detailed summary of the Michigan Great Lakes Spills Program.

- Ms. Elizabeth Harrison, Chairperson, recounted the inception of the Michigan Council on Environmental Quality through to the recommendations contained in the April 1990 State of the Environment Report.

- Mr. David Dempsey, Director of the Council on Environmental Quality, described the role and function of his agency.

- Ms. Raj Weiner, Director, Department of Public Health emphasized the importance of collaborative efforts in looking at the environmental health effects in children.

5. 80TH, TUESDAY, AUGUST 21 THROUGH THURSDAY, AUGUST 22, 1990
THE DRAWBRIDGE INN, SARNIA, ONTARIO

- The first day, August 21, also marked the first joint meeting of the Council of Great Lakes Research Managers and the Science Advisory/Board.

- Wine and Cheese reception, hosted by the Environmental Steering Committee and the Board of Directors of the Centre for Entertainment and the Environment, was held the evening of the 21st at the Sarnia Yacht Club.

- A working luncheon, held August 22 hosted by George Werezak of Dow Chemical, followed by a briefing tour of the plant and facilities, attended by special representatives from Sarnia petro-chemical companies: Mr. Ron Denning, Lambton Industrial Society; Mr. Peter Forrestal, Imperial Oil; Mr. Jim Greenshields, Sunoco; Mr. Dennis Lauzon, Dow; Mr. Colin McLuckie, ICI; Mr. Jorma Salmikivi, Dow; and Mr. Bud West, Nova.

- A presentation on the development of the St. Clair Remedial Action Plan was made by Mr. Johnson and Mr. Thornley of OMOE, assisted by Ms. Looby, RAP Coordinator.

- Mr. John Jackson and Ms. Kristina Lee of the St. Clair River International Citizens Network spoke of local concerns and the need for citizen groups to work together binationally with government.

- Mr. Dave Zaber, National Wildlife Federation, summarized the work being done to address model water quality standards in the CIELAP/NWF Program for Zero Discharge.

- Dr. A. Gilman, Health and Welfare Canada, presented information pertinent to the Great Lakes Health Effects Program.

6. 81ST WEDNESDAY, FEBRUARY 20 THROUGH FRIDAY, FEBRUARY 22, 1991
POSTPONED FROM NOVEMBER 7 - 9, 1990
IJC CANADIAN SECTION OFFICES, OTTAWA, ONTARIO

- Luncheon hosted by the Assembly of First Nations, with presentations being made by: Ms. Carol Mills on the Great Lakes Indian Health Program and Mr. Lloyd Benedict, Chief, Akwesasne Nation, on their environmental problems and RAP development; Mr. Mike Williams on the Walpole Island Integrated Monitoring Proposal; Mr. Max Assineway, Chief, Sheguindah Band, United Chief and Council of Manitoulin Island; and special mention to Mr. Hugh Taylor for the buffalo stew and bannock.
7.  82ND, WEDNESDAY, MAY 15 THROUGH FRIDAY, MAY 17, 1991
HOLIDAY INN, MICHIGAN CITY, INDIANA

- Informal tour of Grand Calumet area, hosted by Mr. R. Tolpa, U.S. EPA, Water Division.
- Indiana Dunes State Park. Workshop with the 1991 International Great Lakes - St. Lawrence Mayors Conference.
- Great Lakes - St. Lawrence Mayor’s Reception, Radisson Star Plaza, Merrillville, Indiana.

8.  83RD, SATURDAY, SEPTEMBER 28 and SUNDAY, SEPTEMBER 29, 1991
(In conjunction with 1991 Biennial)
TRAYESCE CITY, MICHIGAN

- Presentation of 1991 Science Advisory Board report.