October 1993

International Joint Commission
United States and Canada

Commissioners:

The Great Lakes Science Advisory Board is pleased to submit its 1993 Report to the Commission and the Water Quality Board, as provided for under the Terms of Reference for the joint institutions by the Great Lakes Water Quality Agreement.

Over the 1991-1993 Biennial Cycle, the Board has directed its efforts to address the priorities of the Commission as expressed in your memorandum of November 25, 1991, especially those priorities related to human and ecosystem health and state-of-the-lakes reporting, for which the Board has had lead responsibilities. Along with these lead responsibilities, individual Board members also actively participated in and directly contributed to several other Commission priorities, most notably the work of the Virtual Elimination Task Force. The results of these individual efforts are reflected in other reports and comments submitted to the Commission under separate cover from their respective groups.

Several topics covered in Chapters 3 and 4 of the Board’s report, by the Workgroups on Parties Implementation, and Emerging Issues, respectively, address issues identified by the Board during the biennial cycle and approved by the Commission as supplemental activities to the original priorities. By allowing flexibility within the priority planning process, the Commission provided an opportunity for the Board to provide advice on several important issues whose salience was most relevant to current progress under the Agreement.

In conclusion, we would like to share with you our confidence that the current Commission approach to priorities, which integrates the efforts of Board and Council members while at the same time retaining the unique perspective that each advisory group provides under its collective mandate, is proving to be productive and beneficial in addressing the challenges associated with assessing progress under the Agreement.

On behalf of the members of the Board, we look forward to the energy and excitement of the 1993 Biennial Meeting in Windsor, Ontario, October 22 - 24, 1993, and the opportunity to share the findings from our 1993 Report with the Commission and basin citizens.

Respectfully submitted,

Ralph J. Daley, Ph.D.
Co-Chair, Canadian Section

Michael J. Donahue, Ph.D.
Co-Chair, United States Section
# Table of Contents

## Summary of Recommendations

1. Introduction

2. Workgroup on Parties Implementation
   - 2.1 Evaluation of Progress on Toxics Reduction
     - 2.1.1 Findings
     - 2.1.2 Recommendations
   - 2.2 Binational Consistency of the Great Lakes Water Quality Initiative and the Great Lakes Water Quality Agreement
     - 2.2.1 Science Advisory Board Review
     - 2.2.2 Conclusions
     - 2.2.3 Recommendation

3. Workgroup on Emerging Issues
   - 3.1 Toward a Chlorine Sunset
   - 3.2 Climate Change and the Great Lakes
     - 3.2.1 Development of the Climate Change Issue in the Great Lakes
     - 3.2.2 Workgroup on Emerging Issues Activity
     - 3.2.3 Events After the 1988 Symposia
     - 3.2.4 Recommendations
   - 3.3 Use of Predictive Tools in Remedial Action Plan Decisionmaking
     - 3.3.1 Results for Nine RAPs Containing Modelling
     - 3.3.2 Discussion
     - 3.3.3 Findings and Conclusions
     - 3.3.4 Recommendations

4. Workgroup on Ecosystem Health
   - 4.1 Activities of the Workgroup on Ecosystem Health
     - 4.1.1 Workshop on Our Community, Our Health: Dialogue Between Science and Community
     - 4.1.2 Workshop on Integrating Human Health Considerations in Remedial Actions
     - 4.1.3 Workshop on Bioindicators as a Measure of Success of Virtual Elimination of Persistent Toxic Substances
     - 4.1.4 Workshop on Risk Assessment, Communication and Management in the Great Lakes Basin
   - 4.2 Future Directions for Research on Ecosystem Health
     - 4.2.1 Measuring Ecosystem Health
     - 4.2.2 Weight-of-Evidence
     - 4.2.3 Human Health Assessment Parameter in Remedial Action Plans
5. **STATE-OF-THE-LAKES REPORTING:**  
**SOCIAL AND ECONOMIC STRESSORS**

5.1 The Commission and State-of-the-Environment Reporting
5.2 The Challenge to Science of State-of-the-Environment Reporting
5.3 General Conclusions from State-of-the-Environment Reporting
5.4 Conclusions from the Great Lakes Reporting Experience
5.5 Recommendations

6. **THE GREAT LAKES WATER QUALITY AGREEMENT TO THE YEAR 2000**

6.1 Goals
6.2 Policy and Management
6.3 Economics, Trade and Environment
6.4 Recommendation

7. REFERENCES

APPENDICES

I. Glossary of Acronyms and Abbreviations
II. Membership List for the Science Advisory Board and its expert workgroups
III. Science Advisory Board Meeting Record and Acknowledgements: 83rd through 91st meetings

LIST OF TABLES AND FIGURES

Tables
2.1 Chronology: 1912-1989
2.2 Data response to Workgroup on Parties Implementation requests
2.3 Comparison of proposed Great Lakes Initiative criteria/values and Great Lakes Water Quality Agreement ambient water quality objectives
3.1 Impaired uses and models developed for evaluating remediation options
4.1 Partial list of possible human health indicators of ecosystem health

Figures
1.1 International Joint Commission Priorities and Assignments 1991-1993
1.2 The joint institutions and other advisory entities reporting to the International Joint Commission with general and specific mandates related to the Great Lakes Water Quality Agreement, 1991-1993
2.1 A framework for the control of toxic substances in the Great Lakes basin to Great Lakes Water Quality Agreement water quality objectives
2.2 Ratio of proposed Great Lakes Water Quality Initiative criteria/values to Great Lakes Water Quality Agreement water quality objectives
3.1 Forty-three Areas of Concern identified in the Great Lakes basin

COVER

*Untitled*, artist Roy Thomas, 1978, Canadian Museum of Civilization, Negative #S82-833
Chapter 2: Workgroup on Parties Implementation

It is recommended that:

- the Commission urge the Parties to implement the 1980 Toxic Substances Committee recommendations (IJC 1981) (2.1.2)
- the Commission urge the Parties to confirm whether resources are being used effectively to reduce loadings of toxic substances (2.1.2)
- the Commission promote the establishment by the Parties of a compatible toxic substances loadings database, possibly using Geographic Information System technology (2.1.2)
- the Commission urge the Parties to establish a binational workgroup to develop a Great Lakes toxics reduction strategy that would include timetables, specific load reduction targets and phase-out plans (2.1.2)
- the Commission recommend that the Parties submit a biennial assessment of their progress toward achieving loading reduction targets for toxic chemicals (2.1.2)
- the Commission urge the Parties to strengthen and formalize their binational approach in water quality objective setting to ensure that the Great Lakes Water Quality Initiative and related future U.S. and Canadian initiatives are pursued in a binational forum consistent with Great Lakes Water Quality Agreement goals (2.2.3)

Chapter 3: Workgroup on Emerging Issues

It is recommended that:

- the Commission, together with the Parties, undertake a comprehensive, binational, scientific assessment of approaches to develop environmental management policy where socio-economic and biophysical data are incomplete or contradictory. The options for implementing the sunsetting of chlorine and chlorine-containing industrial feedstocks and the societal implications of those options, should form a case study of such policy development (3.1)
- the Commission urge the Parties to develop and implement a binational program to address global climate change through the integrated study of the Great Lakes basin as a regional pilot project (3.2.4)
- the Commission urge the Parties to make a long-term commitment to climate change research through identification of climate change in Annex 17 of the Great Lakes Water Quality Agreement, and to provide a report on progress at appropriate intervals of time, in a holistic and systematic reporting fashion, as recommended in Chapter 6 of this report (3.2.4)
- the Commission urge the Parties to utilize state-of-the-art predictive capabilities and apply them widely to assure cost effective and timely improvements of water quality at Areas of Concern, and in the Great Lakes generally (3.3.3)
- the Commission support proposals for a basinwide workshop to exchange experiences between local officials and scientists who are using models successfully in Remedial Action Plans and others in the region who are considering proposals for local and lakewide remedial action (3.3)
CHAPTER 4: WORKGROUP ON ECOSYSTEM HEALTH

It is recommended that:

- the Commission further promote the weight-of-evidence concept as a comprehensive explicit tool in support of environmental decisionmaking (4.1)

- the Commission promote the establishment of mechanisms by which "resource poor" organizations and the general public can obtain scientific information, referrals and assistance (4.1.1)

- the Commission promote studies examining the effects of the environment on ecosystem health that take into account the empowerment, participation and involvement of the community in all aspects of the study, including design, conduct and interpretation (4.1.1)

- the Commission encourage comparable state-of-the-art methodologies with appropriate Quality Assurance/Quality Control in basin studies to certify the sensitivity, accuracy and reproducibility of the methods in each laboratory (4.1.1)

- the Commission take new initiatives to communicate its recommendations to a wider audience. This might involve presentations at major conferences and working more actively with the network of individuals and organizations already aware of the policy recommendations (4.1.1)

- the Commission promote the assessment of human health in Remedial Action Plans by encouraging Remedial Action Plan groups to involve human health experts in their public advisory committees (4.1.2)

- the Commission, in conjunction with several Remedial Action Plan teams, develop guidelines for selection of human health indicators in Remedial Action Plans, taking into account the feasibility of the indicator to be studied and its importance, sensitivity and specificity (4.1.2)

- the Commission encourage research and development of indicators, including ecosystem-level indicators, which will demonstrate the links between ecosystem stress and human health (4.1.3)

- the Commission promote public education about the importance, meaning and implications of the interrelationship of ecosystem and human health (4.1.3)

CHAPTER 5: STATE-OF-THE-LAKES REPORTING: SOCIAL AND ECONOMIC STRESSORS

It is recommended that:

- the Commission evaluate the reporting responsibilities under the Agreement and develop a systematic approach to data organization and the reporting strategies of the Parties in order to assess progress under the Agreement (5.5)

- the Commission continue to provide advice on an ecosystem approach that will encourage the synthesis by the Parties of U.S./Canada data and information requirements under the Agreement (5.5)
the Commission encourage the Parties to continue to support educational/research programs directed towards Great Lakes communities on the implications of sustainability within the limits of the “carrying capacity” of the basin ecosystem (5.5)

CHAPTER 6: THE GREAT LAKES WATER QUALITY AGREEMENT TO THE YEAR 2000

It is recommended that:

• the Commission, together with the Parties, undertake a binational review of the implications of economic policy and trade commitments relative to the goals and purpose of the Great Lakes Water Quality Agreement, to identify opportunities for implementing the Agreement through improved environment and economy linkages (6.4)
1. INTRODUCTION

The 1991-93 Biennium has been a period of reassessment and reorientation for the Great Lakes Science Advisory Board (Board or SAB). In a constructive effort to optimize its contribution to the International Joint Commission (Commission or IJC) during the current decade, the Board reviewed its role and organization in relation to the responsibilities assigned to it under the Agreement and by the Commission (Figure 1.1). The impetus for this review was two-fold — the revised role recommended for the SAB by the “Task Force on Commission Roles and Responsibilities under the Great Lakes Water Quality Agreement” in March 1991, and the decision by the Commission to adopt an explicit priority planning process following public input at the 1991 Biennial Meeting. As part of its review, the Board articulated a set of operating principles, identified key functions, and reorganized its substructure to implement the revised mandate.

In overview, the SAB provides scientific advice to the Commission and to the Great Lakes Water Quality Board on current and anticipated issues of significance within the Great Lakes Basin Ecosystem. To contribute effectively in this broad advisory role, the Board concluded it should strive in all of its activities to be:

- supportive of the Commission in providing constructive comment on the Parties’ progress towards commitments under the Great Lakes Water Quality Agreement (Agreement or GLWQA)
- broad in perspective, encompassing key issues and disciplines potentially impinging upon the Great Lakes science/policy domain
- integrative across scientific disciplines, including the natural, physical and social sciences, as reflected in the membership of the Board
- evaluative of data, programs and policies, based on peer-reviewed science and recommendations, both to the Commission and to the public
- anticipatory and outspoken, not merely reactive, in identifying key issues for IJC attention
- catalytic in identifying and promoting important and feasible change
- educative of the public on important science/policy issues relating to the Great Lakes Basin Ecosystem
- independent and neutral, in keeping with the mandate of the Commission

From the assessment of its mandate and responsibilities, the Board identified three principle functions which it serves, although not exclusively, in support of the Commission’s activities:

- assessment and advice on Great Lakes Basin Ecosystem health, including the scientific underpinning of public policy
- review and evaluation of science policy and programs related to the Parties’ implementation of the Agreement
- identification and evaluation of emerging issues and future priorities

To meet these responsibilities, the Board reorganized its substructure, creating three operational workgroups on: Ecosystem Health; Parties Implementation; and Emerging Issues,
FIGURE 1.1  International Joint Commission Priorities and Assignments, 1991-1993

<table>
<thead>
<tr>
<th>STRATEGY FOR VIRTUAL ELIMINATION OF PERSISTENT TOXIC SUBSTANCES</th>
<th>WQB</th>
<th>VETF</th>
<th>RAP</th>
<th>SAB</th>
<th>CGLRM</th>
<th>IAQAB</th>
<th>STAFF</th>
<th>EAC</th>
<th>DIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Criteria for Chemical Selection</td>
<td>Supp</td>
<td>Lead</td>
<td>Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Source Investigation</td>
<td></td>
<td>Lead</td>
<td></td>
<td>Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Contaminant Removal or Remediation</td>
<td></td>
<td>Lead</td>
<td>Su pp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Indicators</td>
<td></td>
<td>Lead</td>
<td>Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Consultation and Outreach</td>
<td></td>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| HUMAN AND ECOSYSTEM HEALTH                                    |     |     |     |     |       |       |       |     |     |
| 1. Applicability of Investigative/Integrative Approaches to Human Health |     |     | Lead |       |       |       |       |     |     |
| 2. Liaise with Health Bodies                                   |     | Lead |       |       |       |       |       |     |     |
| 3. Health Effects in Eastern Europe                           |     | Supp| Lead | Support |       |       |       |     |     |
| 5. Transmission of Health Effects to Progeny                   |     | Lead |       |       |       |       |       |     |     |
| 6. Risk Assessment                                            |     | Lead | Support |       |       |       |       |     |     |
| 7. Biological Markers                                          |     | Lead |       |       |       |       |       |     |     |

| REMEDIAL ACTION PLANS                                         |     |     |     |     |       |       |       |     |     |
| 1. Evaluation of Connecting Channels                          |     |     | Lead | Support |       |       |       |     |     |

| GREAT LAKES ENVIRONMENTAL EDUCATION AND COMMUNITY AWARENESS   |       |     |     |     |       |       |       |     |     |
| 1. Data and Information Needs                                 |     |     |     | Supp| Lead |       |       |     |     |

| STATE-OF-THE-LAKES REPORTING                                  |     |     |     |     |       |       |       |     |     |
| 1. Groundwater Contamination                                  |     |     |     |     |       |       |       |     |     |
| Testing of the Council of Great Lakes Research Managers       |     |     |     |     |       |       |       |     |     |
| Tracking Parties Work on Airborne Toxic Substances to Lake Superior |     |     |     |     |       |       |       |     |     |
| Emerging Issues                                               | Support | Lead | Support |       |       |       |       |     |     |
| Research Inventory                                            |     | Lead |       |       |       |       |       |     |     |
| Boards and Council Operations                                 | Lead | Lead | Lead | Lead |       |       |       |     |     |

LEGEND
- WQB  Water Quality Board
- VETF  Virtual Elimination Task Force
- RAP  Remedial Action Plan Steering Committee
- SAB  Science Advisory Board
- IAQAB  International Air Quality Advisory Board
- CGLRM  Council of Great Lakes Research Managers
- EAC  Educators Advisory Council
- DIN  Data and Information Needs Workgroup
- STAFF: RO  Regional Office
- EAC  Educators Advisory Council
- WA  Washington Section Office
- OT  Ottawa Section Office
respectively (Figure 1.2). Each workgroup consists of SAB members, augmented in some cases by non-SAB experts in critical specialties. The effect of this reorganization is to implement the 1991 decision by the Commission that the Water Quality Board (WQB) should shift from program evaluation to policy advice, while the SAB should play "... a somewhat more practically-oriented role and assume certain responsibilities previously undertaken by the WQB, such as consideration of the state of the lakes, and the review of certain programs" (Task Force on Commission Role and Responsibilities 1991).

In developing the Board’s biennial program, each workgroup selected three or four key activities for approval by the full Board and Commission, taking into account the Commission’s priorities and advice as well as members’ views on topical and important issues. At the outset of the Biennium, the Board was assigned lead responsibility for projects concerned with ecosystem health (including human health) and state-of-the-lakes reporting (Figure 1.1).

The results of the Board’s deliberations, as described in the remainder of this report, are diverse and vary in level of treatment, depending on the scope and complexity of the issues. There is, however, a common thread running through many of the sections, namely an overarching concern with the state of “information management” in the Great Lakes Basin Ecosystem.

Repeatedly in our examination of issues, questions have arisen about the quality of information needed to support decisionmaking and to verify progress in meeting the goals of the Agreement. Thus, for example, the Workgroup on Parties Implementation discusses deficiencies in source data and the management of environmental information for evaluating progress on toxic chemical reduction (Section 2.1). They also raise concerns about binational approaches to contaminant loadings and water quality objectives in relation to the U.S. Great Lakes Water Quality Initiative (GLI; Section 2.2). The Workgroup on Ecosystem Health identifies a variety of data and information challenges concerning the weight-of-evidence approach, risk assessment, data harmonization, and the use of biomarkers in relation to the evaluation of ecosystem health (Chapter 2).

Similarly, deficiencies in knowledge and in the management of information pervade the discussions of the Workgroup on Emerging Issues in Chapter 3. The organization of information as a “user-friendly” decisionmaking tool is examined in relation to Remedial Action Plans; requirements for long-term binational research on climate change are assessed; and the need to resolve conflicting scientific views on environmental impacts of chlorinated organics and to evaluate the socio-economic implications of chlorine sunsetting are discussed.

In Chapter 5, the challenge of assessing the state of the lakes is examined from the perspective of state-of-environment reporting, noting information deficiencies and the need to develop indicators of ecosystem integrity that can be used to evaluate Agreement progress within a holistic framework, based on the Great Lakes Basin Ecosystem.

Finally, the concluding chapter of the report addresses issues related to the binational commitment of the United States and Canada under the Agreement and the broader implications of sustainable development and environment/economy linkages, especially multi-lateral trade agreements.

The Board is concerned that deficiencies in knowledge and information are critical issues that will increasingly impinge on progress in achieving the goals of the Great Lakes Water Quality Agreement. The Board is prepared to provide additional advice and assistance to the Commission to ensure that the recommendations contained in this report can be acted upon, which will form a basis for further progress under the Agreement.
FIGURE 1.2 The joint institutions and other advisory entities reporting to the International Joint Commission with general and specific mandates related to the Great Lakes Water Quality Agreement
2. WORKGROUP ON PARTIES IMPLEMENTATION

The Workgroup on Parties Implementation was formed as part of the reorganization of the Science Advisory Board (Board or SAB) in late 1991. The following Terms of Reference were adopted by the workgroup at its first meeting on May 14, 1992:

The workgroup will review and analyze the 1972 Great Lakes Water Quality Agreement, revised in 1978 and amended by Protocol in 1987, relevant data and scientific reports in order to evaluate and report on the extent and pace of implementation. The workgroup will identify obstacles to implementation in order to recommend steps to improve the rate of progress.

At that meeting, workgroup members identified two central issues of importance to the Commission: continuing slow rate of progress by the Parties on the control of toxic substances and the degree to which the U.S. Environmental Protection Agency's Great Lakes Water Quality Initiative (GLI; 1993) is or can be consistent with the Great Lakes Water Quality Agreement (Agreement or GLWQA). These issues are treated separately in the following sections.

2.1 Evaluation of Progress on Toxics Reduction

Toxics is not a new issue. For the past 80 years, the United States and Canada have attempted to control pollution, including toxic chemicals. The successful strategy created in the 1970s to control point sources of phosphorus may be a useful model for a strategy to reduce discharges of toxic substances. However, such a toxics control strategy has not yet emerged. The jurisdictions were requested to provide toxic loading data, but little information has been forthcoming. If reductions in loadings of toxic substances have been attained, there is very little data to document it, except for the Niagara River. Strategic planning, effective implementation and careful evaluation are clearly required by the GLWQA to reduce or eliminate discharges of toxic substances. For the purposes of this report, the term toxic substances is used to include toxic substances, persistent toxic substances and hazardous polluting substances, as used in the GLWQA.

The chronology in Table 2.1 describes efforts by the Parties and the International Joint Commission (Commission or IJC) to address toxics. The 1912-1964 chronology was excerpted from "The Great Lakes, 1955-1985: An Overview," a paper by Professor Leonard Dworsky of Cornell University. The 1969-1989 data comes from an internal report by Walter A. Lyon, member of the Science Advisory Board.

Binational efforts to date include problem statements, references to the IJC by the Parties, agreements between the Parties, and admonitions by the IJC concerning the need for action in this area. The SAB believes that a renewed commitment is needed by the Parties to formulate and implement strategies to reduce loadings of toxic substances.

The IJC's Toxic Substances Committee specifically recommended implementation programs to limit loadings of toxics to the Great Lakes (see Figure 2.1), beginning in 1980.

There are three broad categories of environmental data that are needed to determine progress in toxics loadings reductions:

- **Source data**, which provide loadings and permit compliance levels. This type of data records changes in inputs to the system and is used to determine sources of toxics and to measure progress in reducing loadings to the lakes.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912</td>
<td>The two governments refer the matter of pollution of the Great Lakes to the International Joint Commission (IJC).</td>
</tr>
<tr>
<td>1918</td>
<td>The IJC reports to governments that &quot;... situation along the frontier is generally chaotic, everywhere perilous and in some cases, disgraceful.&quot;</td>
</tr>
<tr>
<td>1920</td>
<td>Canada proposes a pollution control treaty to the United States; agreement was not reached.</td>
</tr>
<tr>
<td>1946</td>
<td>Another reference similar to that sent in 1912, but pertaining to the St. Clair River, Lake St. Clair and the Detroit River, was sent to the IJC.</td>
</tr>
<tr>
<td>1946</td>
<td>Reference extended to include St. Marys River.</td>
</tr>
<tr>
<td>1948</td>
<td>Reference extended to include Niagara River.</td>
</tr>
<tr>
<td>1954</td>
<td>In report on Reference, IJC found injury being caused to health and property from municipal and industrial wastes and shipping sources; recommended that governments adopt specific water quality objectives and extend authority of IJC to maintain surveillance of water quality to ensure achievement of quality objectives. Governments approved both recommendations and further authorized establishment of advisory boards on each of the connecting channels to report semi-annually to the IJC.</td>
</tr>
<tr>
<td>1964</td>
<td>A new reference resulting from deteriorating conditions in Lakes Erie and Ontario was given to IJC by the two governments.</td>
</tr>
<tr>
<td>1969</td>
<td>Lower Lakes Board recommends fate studies and lake chemical budgets of pesticides and toxics.</td>
</tr>
<tr>
<td>1970</td>
<td>IJC expresses concerns about toxics, especially concerning complacency about the subject and recommends identification and quantification.</td>
</tr>
<tr>
<td>1972</td>
<td>The Great Lakes Water Quality Agreement: toxics identified as a major concern.</td>
</tr>
<tr>
<td>1977</td>
<td>IJC Special Report to governments on heavy metals and persistent toxic substances. Too little is known and it's a matter of the highest priority.</td>
</tr>
<tr>
<td>1977</td>
<td>Research Advisory Board (previous to the Science Advisory Board), annual report on the need for toxic substance mass balance for each lake.</td>
</tr>
<tr>
<td>1978</td>
<td>The Great Lakes Water Quality Agreement. More emphasis needed on toxics, hazardous polluting substances and persistent toxic substances.</td>
</tr>
<tr>
<td>1978</td>
<td>Appendix E lists 405 chemicals.</td>
</tr>
<tr>
<td>1981</td>
<td>Toxic Substances Committee recommends loading reductions and goal to be achieved by the year 2000.</td>
</tr>
<tr>
<td>1983</td>
<td>Inventory of 1,000 chemicals; 360 applicable to the Great Lakes.</td>
</tr>
<tr>
<td>1984</td>
<td>Toxics Substances Committee dissolved. Recommendations not implemented.</td>
</tr>
<tr>
<td>1986</td>
<td>IJC advises Parties to implement better methods of assessing point sources.</td>
</tr>
<tr>
<td>1987</td>
<td>The Protocol to the Great Lakes Water Quality Agreement requires more emphasis on toxics from nonpoint, sediment, groundwater and airborne sources.</td>
</tr>
<tr>
<td>1989</td>
<td>IJC notes the need for data on 11 priority substances and emphasizes the need for coordinated strategy and immediate action.</td>
</tr>
</tbody>
</table>
- **Ambient data**, which indicate conditions in sediments and waters of the lakes, can also be used to determine whether or not water quality objectives are being met.

- **Effects data** indicate the impact of toxic substances on the human body and on other organisms in the ecosystem. They include data that quantify adverse impacts on fish-eating birds, aquatic organisms and human subpopulations at particular risk.

While some toxic loading reductions have been attained, there are little source data to measure program effectiveness. During 1992, the Commission’s Regional Office assisted the SAB in its
attempt to obtain information on source reductions by requesting data from senior personnel in federal, state and provincial agencies on loadings, compliance levels and resources available to reduce toxic loadings to the Great Lakes. As indicated in Table 2.2 on the following page, only five of eleven jurisdictions provided data. The inadequate response either reflects a lack of data or the inability of the jurisdictions to provide it in a timely manner and in a usable format.

Identification and quantification of toxic substances loadings and trends are particularly important activities in the implementation of Great Lakes toxic initiatives. The U.S. EPA's Great Lakes National Program Office undertook a major Great Lakes Basin Risk Characterization Study (U.S. EPA 1992, unpublished) to comprehensively assess and rank the relative environmental risks from chemical contamination in the U.S. portion of the Great Lakes. Lack of data, particularly toxic substance data, was cited as a severe limiting factor in the study.

A draft of the Lake Michigan Lakewide Management Plan (U.S. EPA 1992) was made available by U.S. EPA for review and comment. The plan is described as a synopsis of the current knowledge regarding specific pollutants, their effects on the waters of Lake Michigan and their current release or loading rates into the system. The draft report states that the current data on sources and loading rates into the Lake Michigan system are extremely limited. This finding is echoed in the assessment of toxic pollution in a report of the Citizens Fund and the Industrial States Policy Center (1992).

The lack of adequate data impinges on the ability to make decisions on load reductions and to measure the beneficial results of these reductions. The Upper Great Lakes Connecting Channels report (UGLCCS 1988) indicates that there are insufficient data to compute, with any degree of certainty, the loadings of toxic substances from air, surface water, groundwater and sediments.

The phosphorus experience can be a guide for the level of data that is required for effective action. Scientific diagnosis of the cultural eutrophication problem of Lakes Erie and Ontario led the IJC and the Parties to successfully implement a strategy which included a timetable, funding for programs, and projects designed to reduce loadings of phosphorus to meet specific targets. The target loadings were generally attained on schedule.

This extraordinary success has not been extended to the toxics issue. Today, the data necessary to fully evaluate the work of the Parties over a period of more than 75 years do not exist or are not available. The success or failure of efforts to control toxics is uncertain because source data to measure the toxic loadings to the lakes are unavailable and the level of compliance with permits is generally unknown.

It is clear that program planning on toxic substances needs more attention. Several jurisdictions that responded to the workgroup's inquiry indicated problems due to inadequate staff and budget that limit data collection and analysis activities. Yet the workgroup considers this to be a fundamental underpinning of efforts to shape a more successful strategy for reducing toxics loadings.

The question of adequacy of programs is important and needs to be addressed as part of the IJC's responsibility under the Agreement. Articles VI, 1c and Article VII, 1c of the Great Lakes Water Quality Agreement calls on the Commission to work with the Parties in shaping programs and pollution abatement requirements to develop a strategy that moves toxics reduction efforts toward attainable goals.

In Canada, jurisdiction over the control of pollution by toxic substances is a shared responsibility, therefore, the implementation of programs to control toxic substances under the Agreement can only be effective through federal-provincial cooperation. One of the primary mechanisms for this cooperative effort is the Canada-Ontario Agreement (COA). This agreement ended in 1991 but was extended to March 31, 1993. It has now expired. The future of successful program implementation will depend, to a significant extent, on the successful renegotiation of a new COA.
The Niagara River is a major toxic pollution "hot spot" of the Great Lakes system. Work to reduce toxic loadings to the Niagara River began in the 1960s and was intensified during the 1980s and '90s. According to New York State estimates, there has been an 80 percent reduction in priority pollutants discharged from all New York point sources. Nevertheless, point sources alone discharge 248 kg (546 lb) a day of U.S. EPA priority pollutants to the Niagara River. This does not include toxic substances discharged from nonpoint sources, notably from at least 38 hazardous waste disposal sites known to contribute contaminants to the river via groundwater flow. It is estimated that 341 kg (750 lb) of contaminants enter the river by groundwater discharge every day. Mirex levels escalated significantly in downstream Lake Ontario sediment and fish over the last decade as a result of inputs from Niagara and Erie County landfill sites (Whittle and Keir, 1991). The loadings of 26 of 74 substances have increased at Niagara-on-the-Lake, including eight chlorobenzene compounds, six pesticides, seven polynuclear aromatic hydrocarbon (PAH) compounds, three phthalate compounds and two chlorophenolic compounds, most of which are persistent toxic substances (NYS DEC 1992).

Thus, even after more than two decades of effort, many water quality guidelines adopted under the Great Lakes Water Quality Agreement are still frequently exceeded in the Niagara River. The effects of these continued toxics loadings are that indigenous organisms such as lake trout and bald eagle are unable to reestablish self-sustaining populations, and beluga whales in the Gulf of St. Lawrence continue to experience increased mortality and reproductive impairment (IJC 1992c; U.S. EPA 1993a; Martineau et al. 1988).

### 2.1.1 Findings

Initiatives are not enough. After seven decades of initiatives to clean up toxic pollution in the Great Lakes, there are insufficient data to measure past success and establish the benchmarks needed to direct future efforts. Data that is available does not substantiate success of these initiatives.

It is clear that the Parties need to shift emphasis from "initiatives" to strategies supported by timetables, schedules and project funding designed to meet attainable goals. The pace of this effort must be assessed by source data designed to measure and report on progress. The IJC and the Parties have been successful in this regard with phosphorus. It is even more important, however, to use strategic approaches to achieve progress in the reduction of toxic discharges.

<table>
<thead>
<tr>
<th>Information Request</th>
<th>Env. Can.</th>
<th>U.S. EPA</th>
<th>ON</th>
<th>IL</th>
<th>IN</th>
<th>MI</th>
<th>MN</th>
<th>NY</th>
<th>OH</th>
<th>PA</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistent and other toxic loads to waters from all sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biochemical oxygen demand loads to waters from all sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effluent permit compliance trends, especially for municipal discharges for last decade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deferred infrastructure maintenance costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radionuclide discharges from municipal and industrial sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shaded areas indicate jurisdiction response.
2.1.2 Recommendations

It is recommended that:

- the Commission urge the Parties to implement the 1980 Toxic Substances Committee recommendations (IJC 1981)
- the Commission urge the Parties to confirm whether resources are being used effectively to reduce loadings of toxic substances
- the Commission promote the establishment by the Parties of a compatible toxic substances loadings database, possibly using Geographic Information System technology
- the Commission urge the Parties to establish a binational workgroup to develop a Great Lakes toxics reduction strategy that would include timetables, specific load reduction targets and phase-out plans
- the Commission recommend that the Parties submit a biennial assessment of their progress toward achieving loading reduction targets for toxic chemicals.

2.2 Binational Consistency of the Great Lakes Water Quality Initiative and the Great Lakes Water Quality Agreement

In the Great Lakes Critical Programs Act of 1990, Congress directed the U.S. Environmental Protection Agency (U.S. EPA) to propose and publish water quality guidance for the Great Lakes. Titled the Great Lakes Water Quality Initiative (GLI), the proposed guidance establishes minimum water quality criteria, anti-degradation policies and implementation procedures for waters within the jurisdiction of the eight Great Lakes states as well as Indian tribes. The procedures are to be used to establish consistent water quality goals and in so doing, better control discharges from industries and municipalities within these waters.

The GLI seeks to address two recognized weaknesses of existing U.S. programs through the development of a regional program. First, existing programs do not adequately take into account the adverse effects of persistent toxic chemicals. Second, the GLI addresses the consistency problem around Great Lakes jurisdictions with respect to the development and implementation of water quality programs. Six related procedures are associated with the GLI:

- deriving criteria to protect aquatic life
- deriving criteria to protect human health
- deriving criteria to protect wildlife
- using bioaccumulation factors in calculating criteria
- protecting current water quality (antidegradation)
- expressing standards as regulatory commitments to facilitate implementation

The genesis of the GLI occurred in the late 1980s, when Great Lakes states requested U.S. EPA to ensure consistency in procedures for permitting discharges under their National Pollutant Discharge Elimination System (NPDES) programs. Over the last several years a steering committee, a technical workgroup and a public participation group have provided the structure for GLI development, collectively involving U.S. federal and state agencies, tribal authorities, municipalities, environmental groups and academia, and an observer role for Canadian government representatives.
Once the GLI guidance is incorporated into law, states and Indian tribes will be required to implement its provisions within two years or responsibility will revert to the U.S. EPA. The GLI guidance, under the terms of its development, is to conform with the Great Lakes Water Quality Agreement of 1987 and be no less restrictive than current national policy and guidance established by U.S. EPA.

2.2.1 Science Advisory Board Review

The Commission's Science Advisory Board (Board or SAB), through its Workgroup on Parties Implementation, recognized that implementation of the GLI would substantively affect U.S. water quality programs and have implications for U.S. and Canadian commitments under the terms of the GLWQA. It was therefore suggested that the GLI be examined with respect to its consistency with the GLWQA. Such an endeavour was intended to highlight and address relevant questions and issues and, in so doing, move forward the cooperative, binational approach to the Great Lakes water quality protection. The express intent of the inquiry was to examine issues of consistency and GLWQA implications; no effort was made to evaluate the GLI or generate findings on its adequacy. This approach was accepted by the Commission in early 1993 and an assessment was subsequently undertaken on behalf of the Science Advisory Board by the workgroup.

Several key items from this investigation warrant presentation. The Science Advisory Board found that:

- If fully implemented, the GLI will lead to a reduction in persistent toxic chemicals entering the Great Lakes.

- If fully implemented, the GLI will move the U.S. Federal Government and Great Lakes states closer to a goal of virtual elimination as outlined in the GLWQA. In and of itself, however, the GLI will not fully achieve that goal and will need to be augmented by subsequent related initiatives.

- The GLI is not intended to address nonpoint sources of pollution, pollution prevention, or elimination of point source discharges of persistent toxic substances. Sunsetting chemicals also is not explicitly addressed. The SAB recognizes the Great Lakes Toxics Reduction Initiative (GLTxRI) as a potentially effective vehicle in this regard, as it may address nonpoint sources (e.g. airborne pollutants, urban runoff, groundwater discharge) as well as sunsetting certain toxic chemicals. The GLTxRI is presently in its formative stages as an adjunct to the GLI.

- A comparison of GLI criteria/values with GLWQA ambient water quality objectives reveals some variances (Table 2.3)

Specific water quality objectives proposed in the GLI are called either "criteria," if they are determined via the "Tier 1" methodology (data considered sufficient); or "values," if they are determined using "Tier 2" methodology (data considered insufficient). The GLI proposal includes criteria or values for 35 different chemicals. For 19, there are also GLWQA numeric water quality objectives for ambient water.

The GLI proposal includes procedures that will allow calculation of Tier 2 values for any chemical for which the minimum database exists (as little as one acute toxicity test with a daphnid species). The U.S. EPA completed Tier 2 calculations for a few chemicals (see notations on Table 2.3 and Figure 2.2) but it is possible to calculate Tier 2 values for literally hundreds more. Thus, the criteria/values published for the 35 chemicals in the GLI proposal should be viewed as an initial effort with many more to follow.
Table 2.3 and Figure 2.2 present a comparison of the proposed GLI numeric criteria and values as proposed in the Federal Register of April 16, 1993, and the numeric water quality objectives as presented in Annex I of the Great Lakes Water Quality Agreement of 1978, as amended by Protocol on November 18, 1987. All figures shown are for concentrations in ambient waters. Only the most stringent (i.e. lowest) criteria from the GLI are shown in the table. For example, the chronic aquatic criterion for Lindane is 0.7 µg/L and the human cancer value (Tier 2) is 0.02 µg/L. GLI criteria/values for metals are based on ambient water hardness of 50 ppm.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>GLI</th>
<th>GLWQA</th>
<th>Ratio of GLI to GLWQA</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin</td>
<td>0.018</td>
<td>0.001</td>
<td>18.0</td>
<td>1, 5, 8</td>
</tr>
<tr>
<td>Arsenic III</td>
<td>150.0</td>
<td>50.0</td>
<td>3.0</td>
<td>2, 5</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.78</td>
<td>0.20</td>
<td>3.9</td>
<td>5</td>
</tr>
<tr>
<td>Chlordane</td>
<td>0.0002</td>
<td>0.060</td>
<td>0.0033</td>
<td>7, 8</td>
</tr>
<tr>
<td>Chromium III</td>
<td>49.0</td>
<td>50.0</td>
<td>0.98</td>
<td>2, 5</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>11.0</td>
<td>50.0</td>
<td>0.22</td>
<td>2, 5</td>
</tr>
<tr>
<td>Copper</td>
<td>5.2</td>
<td>5.0</td>
<td>1.04</td>
<td>5</td>
</tr>
<tr>
<td>DDT</td>
<td>0.00000087</td>
<td>0.003</td>
<td>0.00029</td>
<td>3, 6</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.0001</td>
<td>0.001</td>
<td>0.10</td>
<td>1, 7</td>
</tr>
<tr>
<td>Endrin</td>
<td>0.037</td>
<td>0.002</td>
<td>18.5</td>
<td>5</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>0.0005</td>
<td>0.001</td>
<td>0.5</td>
<td>4, 7</td>
</tr>
<tr>
<td>Lead</td>
<td>8.3</td>
<td>10.0</td>
<td>0.83</td>
<td>5, 8</td>
</tr>
<tr>
<td>Lindane</td>
<td>0.02</td>
<td>0.01</td>
<td>2.0</td>
<td>7, 8</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.00018</td>
<td>0.2</td>
<td>0.0009</td>
<td>6</td>
</tr>
<tr>
<td>Nickel</td>
<td>29.0</td>
<td>25.0</td>
<td>1.16</td>
<td>5</td>
</tr>
<tr>
<td>Parathion</td>
<td>0.013</td>
<td>0.008</td>
<td>1.63</td>
<td>5</td>
</tr>
<tr>
<td>Selenium</td>
<td>5.0</td>
<td>10.0</td>
<td>0.50</td>
<td>5</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>0.00002</td>
<td>0.008</td>
<td>0.0025</td>
<td>7</td>
</tr>
<tr>
<td>Zinc</td>
<td>60.0</td>
<td>30.0</td>
<td>2.0</td>
<td>5</td>
</tr>
</tbody>
</table>

NOTES:
1. The GLWQA specifies dieldrin plus aldrin
2. The GLWQA specifies only total of species
3. The GLWQA includes DDT metabolites
4. The GLWQA includes heptachlor epoxide
5. GLI criterion based on chronic aquatic effects
6. GLI criterion based on wildlife effects
7. GLI criterion based on human health effects (cancer)
8. GLI number computed using Tier 2 methodology
FIGURE 2.2  Ratio of proposed Great Lakes Water Quality Initiative criteria/values to Great Lakes Water Quality Agreement water quality objectives

While such a comparison between the GLI and the GLWQA must be qualified given differences in approaches to calculations (see Table 2.3 notes), it is useful in understanding the level of consistency between the two initiatives.

Nine of the GLWQA objectives are more stringent than the proposed GLI criteria/values: two, by just over an order-of-magnitude. Ten of the proposed GLI criteria/values are more stringent than the GLWQA objectives: one, by an order-of-magnitude; two, by two orders-of-magnitude; and two, by three orders-of-magnitude.

None of the chemicals have identical numbers, though nine are within 100 percent of each other. Among the ten others, differences of up to three orders-of-magnitude are found (see Figure 2.2). There is a tendency for the differences to be largest when the GLI is more stringent than the GLWQA.

Water quality criteria have been developed under the GLI for two substances for which no comparable water quality objectives have been included in the GLWQA. These substances are PCB and 2,3,7,8-tetrachlorodibenzo-p-dioxin. Water quality objectives for these two substances were, however, developed and proposed to the International Joint Commission but were not incorporated into the Agreement. PCB and dioxin have been inferred to be the two substances that have caused damage to fish and wildlife populations in the Great Lakes basin (Gilbertson et al. 1991; U.S. EPA 1993). A comparison of the numbers derived for PCB and dioxin through the two different processes is therefore warranted.
The value for PCB published in Appendix A to the 1974 Water Quality Board report was 1 ng/L. This value was designed to protect aquatic biota as well as consumers of aquatic life by recommending tissue levels in fish below 0.1 µg/g and utilizing a bioconcentration factor of $10^5$. The value for 2,3,7,8-TCDD recommended by the IJC was 0.01 ng/L which was based on the limit of analytical detection at that time (IJC 1974; 1980).

The comparable values for PCB and dioxin under the GLI are 0.0017 ng/L and 0.0000096 ng/L, respectively, for protection of wildlife. Thus, the ratio of the criteria derived for the Initiative versus those developed through the IJC are 0.017 for PCB and 0.00096 for dioxin.

### 2.2.2 Conclusions

The Science Advisory Board recognizes the GLI as a positive step in encouraging greater consistency among water quality programs of Great Lakes states. The Board also believes that the Great Lakes Basin Ecosystem is best served by a consistent, coordinated approach at the binational level as well as an approach that recognizes the GLWQA as the primary vehicle by which the two Parties formulate and pursue shared objectives, relying upon their own regulatory approaches such as the GLI. Within this context, the Science Advisory Board’s analysis of binational implications yields two conclusions:

- First, the GLI has strong binational implications in regard to the implementation and future renegotiation of the GLWQA. The introductory sections of the GLI, for example, indicate the intention of the U.S. Government to submit the GLI as a basis to revise the GLWQA objectives. However, GLI development proceeded largely outside the binational arena. This matter should be addressed, as several questions from the SAB review remain unresolved. For example, some GLI criteria are more stringent than the GLWQA objectives, others are less. What are the implications for the latter? How will the GLI affect the negotiation of water quality objectives under the GLWQA? In instances where these criteria conflict with the GLWQA goals, or where the scientific basis of the objectives differ, how will binational commitments to the GLWQA be affected? If the GLI moves forward, the SAB believes that such issues should be explicitly addressed in a binational forum under IJC auspices to ensure shared efforts in addressing GLWQA goals.

- Second, the SAB believes that the institutional capacity under the Agreement to facilitate binational processes in water quality protection must be enhanced. Prior to 1991, the Water Quality Board (WQB) was mandated to evaluate the Parties’ progress by assessing the adequacy of policies and programs enacted to implement the Great Lakes Water Quality Agreement. Its mandate has since been revised to that of a policy advisor. However, the interests of the Parties (and the larger Great Lakes community) with regard to the GLI may well have been better served by the pre-1991 WQB mandate. Under that scenario, a formal mechanism for examining and addressing the binational implications of the GLI would have been operational within the IJC, and current uncertainties about the GLI relative to the GLWQA would have been addressed. The SAB believes that a return to the pre-1991 WQB mandate to binationally assess the Parties’ toxics reduction initiatives will enhance the binational support for both U.S. and Canadian initiatives (such as the GLI) to contribute to overall ecosystem health.

### 2.2.3 Recommendation

It is recommended that:

- the Commission urge the Parties to strengthen and formalize their binational approach in water quality objective-setting to ensure that the Great Lakes Water Quality Initiative and related future U.S. and Canadian initiatives are pursued in a binational forum consistent with Great Lakes Water Quality Agreement goals.
3. WORKGROUP ON EMERGING ISSUES

The task is not so much to see what no one has yet seen, but to think what no one has yet thought about what everybody sees.

Arthur Schopenhauer

An important attribute of the Science Advisory Board, in discharging its responsibilities under the Agreement, is to be proactive and farsighted in identifying emerging issues. These issues may be completely new, but often they provide new insights and solutions to current problems.

The Terms of Reference adopted by the workgroup and approved by the Science Advisory Board are as follows:

### Definition of Emerging Issues

- Changes in environmental and social dynamics that may, over the near or long term, impinge upon the Great Lakes Basin Ecosystem and influence the responsibilities of the International Joint Commission (IJC) under the Great Lakes Water Quality Agreement

### Mandate and Responsibilities

- To identify, evaluate and provide scientifically-based recommendations on emerging issues for IJC consideration
- To conduct an assessment process in an open and consultative manner

During an initial meeting of the workgroup, a preliminary list of 38 candidates for emerging issues was generated. From these, ten were ranked for more detailed consideration. These were then discussed at length and a subset of three was chosen for assessment. An emerging issue was considered by the workgroup during the single biennium, and recommendations generated to indicate how each issue might be carried forward into the next biennium.

Emerging issues of highest priority, as identified by workgroup consensus, were: Toward a Chlorine Sunset; Climate Change and the Great Lakes; and Use of Predictive Tools in Remedial Action Plan Decisionmaking. The workgroup’s findings and recommendations on these emerging issues are presented in this chapter.

#### 3.1 Toward a Chlorine Sunset

The virtual elimination of persistent toxic substances is a long-standing concern for the International Joint Commission (Commission or IJC) and its Boards. This is based on the fact that, despite progress to date, persistent toxic and bioaccumulating substances continue to be released into the Great Lakes Basin Ecosystem cause effects in fish, wildlife and humans. One group of contaminants, halogenated organic substances, has been a particular focus of concern. Specific members of this complex group, particularly polychlorinated aromatics such as like PCBs, DDT
and dioxins, have been shown to be toxic, persistent, widely distributed and capable of bioaccumulation in food chains.

Governments worldwide are taking action on persistent toxic chlorinated compounds. At a recent ministerial meeting in Paris (Paris Convention, September 1992) of the Contracting Parties of the Oslo and Paris conventions, 13 European nations adopted the Paris Convention, which targets specific chlorinated substances for sunset. Annex 1 of the Convention calls for "... plans for the reduction and phasing out of substances that are toxic, persistent, and liable to bioaccumulate arising from land-based sources." In addition, an appendix containing criteria and a list of specific substances targeted for action includes "organohalogen compounds (and substances which may form such compounds in the marine environment)."

Science Advisory Board (Board or SAB) conclusions on the issue were first reached in 1989 when a careful examination of available research suggested that "chemicals on the Water Quality Board's lists of primary and secondary track chemicals, particularly halogenated organics, should be gradually phased out of production." In its 1991 report, the SAB recommended that "the International Joint Commission declare that persistent toxic substances that biomagnify, particularly organochlorines, are a hazard to human health in the Great Lakes basin" and that the goal of the Parties be "to achieve virtual elimination of persistent toxic substances, especially organochlorines from human beings ...." These conclusions and recommendations were used by the Commission in its Sixth Biennial Report (1992), when it extended previous SAB recommendations by calling on the Parties to develop timetables "to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks ...." This recommendation to avoid the use of chlorine was based on a Commission judgment that the only way to prevent pollution from synthetic chlorinated organic substances was to treat them as a class, rather than manage them individually. The rationale provided by the Commission for preventing pollution through a chlorine sunset was based on their advancement of four assumptions:

- Many synthetic chlorinated organic substances are persistent and are thus eligible for the policy of virtual elimination under the Great Lakes Water Quality Agreement
- There is a body of evidence to suggest many of these substances are toxic and harmful to health
- The mix and exact nature of the various substances cannot be precisely predicted or controlled in production processes
- In many cases, alternatives exist

The Commission's assumptions and recommendation have generated significant discussion and debate within the scientific and policy communities. On the basis of the magnitude of the scientific and policy implications of the Commission recommendation and, in light of the pulp mill research noted in the case study on the following page, the Science Advisory Board's Workgroup on Emerging Issues targeted the proposed chlorine sunset for priority attention in 1992. Specifically, the workgroup called for a thorough examination of the socio-economic implications of implementing the Commission's recommendation. In acknowledging this "emerging issue," the Board recognized that it could play an important role in reviewing relevant scientific questions that should be addressed to implement the Commission recommendation. For example:

- What is the scientific rationale, and what alternatives exist, for regulatory assessment of all chlorinated organic substances as a class? Are subclasses more harmful or uses and exposures more trivial that, if identified, could provide a basis for the establishment of priorities for sunsetting?
- What are the science and engineering opportunities or challenges for chlorine technology to be precisely managed through a life-cycle approach as a control alternative to a sunset?
The Pulp and Paper Industry as a Case Study

Of the many sources of chlorinated organic contaminants, the pulp and paper industry has been of particular public concern. Historically, pulp mills have been one of the principal anthropogenic sources of chlorinated material (usually measured in bulk as AOX, adsorbable organic halogen). In the late 1980s, bleached kraft mill effluent was shown to contain low levels of chlorinated dioxins and furans, both persistent toxic substances. During that period Swedish scientists also detected sublethal effects in fish in pulp mill receiving waters, and they associated these effects with AOX.

In Canada, considerable federal research has been undertaken to support the regulation of pulp mill effluent under the Canadian Environmental Protection Act (CEPA). At issue was whether AOX could be used as a regulatory parameter. As a mixture of diverse compounds, AOX does not directly measure toxicity, persistence or bioaccumulation and therefore, it was decided that the regulatory initiative under CEPA would not set limits for chlorinated organic substances, other than for dioxins and furans. Nonetheless, the Province of Ontario decided to implement a reduction in pulp mill discharge of chlorinated organic substances, based on the measurement of AOX, with a requirement that all releases be planned for phase-out by 2002.

From the research, it is evident that only a small and declining fraction of the chlorinated organics in effluent from modern bleached kraft mills is persistent and of potential significance in terms of biological effects. Furthermore, physiological and reproductive effects are seen in fish exposed to effluent from all mill types, even from mills using chlorine-free bleaching processes. The results of this research indicate that some effects, including those relating to EROD response, may be transient and reversible.\(^1\)

For some, these results raise serious questions as to the extent or even existence of a cause-effect relationship between chlorinated organics from pulp mills and impairments to fisheries. For others, the previous research linking effects with chlorinated organic substances continues to be relevant while the new findings are pertinent to non-chlorinated effluent from pulp and paper mills, and indicative that all discharges from pulp mills can produce harm to ecosystems.

\(^1\) EROD (ethoxyresorufin O-deethylase) is an enzyme from a larger group of enzymes referred to as mixed function oxidases (MFO), which is induced as a response to exposure to certain foreign substances.

- In terms of alternative scenarios and assumptions concerning technological breakthroughs and barriers, what are the social and economic implications of implementing the Commission recommendation on the sunsetting of the use of chlorine as an industrial feedstock in the immediate term, 5-10 years; near term, 10-20 years; and long term, 20-50 years?

- What would be the legal and constitutional basis for sunsetting the use of chlorine as an industrial feedstock?

- If implemented, how would government know that the sunsetting of chlorine use as industrial feedstock had been successful and effective in restoring the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem?

Recommendation #7 from the Sixth Biennial Report states: "the Parties, in consultation with industry and other affected interests, develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks and that the means of reducing or eliminating other uses be examined." To achieve progress in this area, the SAB recommends that:
the Commission, together with the Parties, undertake a comprehensive, binational, scientific assessment of approaches to develop environmental management policy where socio-economic and biophysical data are incomplete or contradictory. The options for implementing the sunsetting of chlorine and chlorine-containing industrial feedstocks and the societal implications of those options, should form a case study of such policy development

3.2 Climate Change and the Great Lakes

Predicting effects of changes in climatic factors and then proactively adapting to or planning for such changes are important issues for the International Joint Commission (Commission or IJC) to address under the Great Lakes Water Quality Agreement (Agreement or GLWQA). Long-term climate change and short-term, year-to-year variation are primarily caused by changing temperatures, precipitation, ice cover, cloudiness, solar radiation and winds. In turn, these climatic causes influence short-term (year-to-year) variability and long-term (decade or longer) changes in lake levels and hydrologic flow; drought and potential extraction for irrigation; runoff and nutrient inputs; biological productivity and deep water anoxia; fish reproduction, growth, and harvests; water temperature and potential inversions; storm events, lake mixing, and wave generation. Each of these has relevance to the Agreement. Variability and the uncertainty that variability provides are perhaps the most difficult environmental properties for managers, planners and policy-makers to deal with effectively.

As the Commission considers policies for restoring and maintaining the integrity of the waters of the Great Lakes Basin Ecosystem, increases in greenhouse gases may produce global warming. The scenarios to predict the extent of warming contain several assumptions and thus uncertainties. The measured increase in atmospheric CO₂ and the consistencies among the predictions from several global atmospheric circulation models (Smith and Tirpak, 1989; Houghton et al. 1990) give credibility to the phenomenon of global warming and its potential to cause environmental change in the decades ahead. The predictions are far from certain, and some critics challenge the credibility of global warming and its potential negative consequences (Michaels 1992). Given the uncertainties, unexpected events may still occur despite the predictions.

The SAB has concluded that the issue of long-term climate change is a real issue in an uncertain world and is relevant to implementation of the GLWQA. It should be addressed by the IJC. The following recommendations are intended to be constructive notwithstanding of the climate change or variation that future generations will experience. The recommendations also represent a "no regrets" policy, in terms of usefulness in their short-term utility and long-term adaptability.

3.2.1 Development of the Climate Change Issue in the Great Lakes

The Science Advisory Board has recommended the consideration of climate change issues in each of its last three biennial reports to the Commission. To date, the uncertainties of an unknown future combined with pressing short-term issues have limited positive action regarding climate change recommendations. Climate change was not widely perceived as an issue when the revised Great Lakes Water Quality Agreement was drafted and signed in 1978 and the Great Lakes scientific community's awareness developed perhaps as late as 1985 when R.E. Munn convened a workshop on the effects of climate on fishes (Timmerman and Grima, 1986).

The U.S. Environmental Protection Agency's Office of Policy, Planning and Evaluation chose the Laurentian Great Lakes as one of four regions of the United States for an initial consideration of the uncertainties and potential impacts of climate change (Smith and Tirpak, 1989; Smith 1991). Other significant papers and workshops were also developed around the issue (Meisner et al. 18
1987; Regier et al. 1990; U.S. National Climate Program Office et al. 1989). In general circulation models (Manabe and Wetherald, 1987; Hanson et al. 1988; Schlesinger and Zhao, 1988) available in the mid-1980s, ecosystems of the Great Lakes were strongly influenced by changes in climatic factors simulated by a doubling of greenhouse gases. Many properties and processes of concern to the IJC were sensitive to these simulated climate changes, including water levels (Croley 1990), ice cover (Assel 1991), water temperature and dynamics (McCormick 1990), deep water anoxia (Blumberg and Di Toro, 1990), fish distributions and production (Hill and Magnuson, 1990; Magnuson et al. 1990; Shuter and Post, 1990), invasion of exotics (Mandrak 1989; Johnson and Evans, 1990) and the spread of sea lamprey (Holmes 1990). While negative and positive apparent effects were noted from a human perspective, potential negative effects were the most prevalent (Smith 1991; U.S. National Climate Program Office et al. 1989). These analyses were essentially complete by 1988, at five years least ago.

Summary recommendations from the American Fisheries Society symposium in 1988, taken from Regier et al. (1990), included the following:

We, the conveners of the 1988 symposium, feel strongly that it is now time for researchers, educators, entrepreneurs, and managers to take the issue of climate change seriously.

Now is the time to get involved, seriously.

The major issues and plan of action from the 1988 Illinois State Water Survey symposium, cosponsored by the Canadian Climate Centre and the National Climate Program Office of the United States (quoted from U.S. National Climate Program Office et al. 1989) were identified as follows:

**Major Issues:**

1. Considerable uncertainty exists about the potential future physical and socio-economic impacts, responses and adjustments to sizable climatic change
2. Better climate modelling information is needed
3. Existing planning bodies, and policy and regulatory entities are inadequate to address the problems of basinwide climate change
4. Several conflicts could develop during rapid and sizable climatic change

**Plan of Action:**

The broad and challenging extent of the above recommendations for studies, assessments, research and changes in various public and private activities led attendees to recommend development of a plan of action that recognized: (1) the needs of the Great Lakes basin communities, and (2) the evolving international concerns over climatic change. The United States and Canada share joint management of the Great Lakes. Attendees agreed that although future climate is uncertain, now is the time to translate past experience into future programs aimed at ensuring availability of the widest possible knowledge. To the end, the conferees strongly recommended two actions:

- Develop a U.S.-Canada integrated study of the Great Lakes basin as a regional pilot project for an international response to global climatic change
- Establish a joint planning group to organize and develop the pilot project. The recommended activity should be integrated with and built upon two major ongoing basin efforts, the Remedial Action Plan (RAP) program for the Areas of Concern (AOC) in water quality and the ongoing International Joint Commission (IJC) Lake Levels Reference Study. Both of these programs contain activities and elements that should be considered in the planning and development of the recommended global change pilot project
3.2.2 Workgroup on Emerging Issues Activity

As part of the IJC Science Advisory Board’s Workgroup on Emerging Issues, investigations into climate change, the activities regarding climate change in the Great Lakes that followed the two 1988 symposia were reviewed, as well as the U.S. Environmental Protection Agency’s evaluation of the potential changes in the Great Lakes from further increases in greenhouse gases. To assist in the review, a briefing was conducted at a workgroup meeting in Toronto on December 15, 1992. Participants included: Stanley Changnon, Illinois State Water Survey, Champaign, Illinois; John J. Magnuson, University of Wisconsin-Madison, Madison, Wisconsin; Linda Mortsch, Atmospheric Environment Service, Downsview, Ontario; Frank H. Quinn, National Atmospheric and Environmental Service, Ann Arbor, Michigan; and Joel B. Smith, R.C.G. Hagler Bailey, Arlington, Virginia. The SAB concurs with the conclusions provided by this expert group.

The recommendations from the 1988 Illinois Symposium have only recently begun to be acted on by the two governments in any substantive manner. The U.S. EPA effort (Smith and Tirpac, 1989), while a most useful one-time analysis, did not fill the need for an integrated long-term program that would follow changes in the science and status of the issues. For example, present estimates for a doubling of CO₂ to occur are at about the year 2100, whereas in the EPA study it was envisaged to be 2020.

There are compelling reasons to study the Great Lakes region climate. The basin is the appropriate scale, the scientific community is active and interdisciplinary, the database is large, the region is sensitive to climate factors, and the public constituency is supportive. In written comments to the workgroup, Stanley Changnon recommended that “the International Joint Commission assess the emerging issue of climate change on the Great Lakes basin and establish a policy of encouraging both nations to plan, organize and conduct a major joint research effort to understand the potential effects of climate change in the basin and to identify the responses that may be needed to address the change.”

A recent review article by Carpenter et al. (1992) on global change and freshwater ecosystems argued that “freshwaters have been neglected in research planning for global change” even though freshwaters are critical for sustainability of ecosystems and society, and are tightly coupled to climate and land use.” The Great Lakes provide a good example of such neglect. The Canadian program relative to the Great Lakes is small, and in the United States, only a few individual research projects on climate change were funded by National Oceanic and Atmospheric Administration (NOAA) in 1991. One project concerns invasions of exotics into Green Bay, funded by Wisconsin Sea Grant, and another retrospectively analyzes water temperature, ice cover and fish catches in the Great Lakes, funded by NOAA’s Global Change Program.

Ecological models of ecosystem response to climate are more complex and difficult than physical models. They need to be developed with climate models which have not yet integrated land with atmospheric aspects, making impact analyses related to the hydrologic cycle uncertain. Climate models are also not yet linked to models on lake physics, chemistry or ecology. The IJC Reference on fluctuating Great Lakes water levels has been most concerned with high water, but more problems could occur with low water in terms of pollution and economic impacts. Analyses suggest that lake levels may become lower rather than higher in a warming climate (Croley 1990). Scientific advances in these areas will help Great Lakes researchers, managers and planners better understand the important effects of short-term dynamics on the Great Lakes Basin Ecosystem. Uncertainty in the science of climate change is clearly an issue that decisionmakers will have to address in the near and long-term future (Joint Climate Project 1992).

While warming from a doubling of greenhouse gases has been predicted to be in the range of 3-6°C (37-43°F), such a change cannot yet be judged as positive or negative in economic terms or with respect to issues under the Agreement. For example, warming brings the advantage of longer shipping seasons as well as the disadvantages of increased dredging of contaminated...
Sediments in Areas of Concern. Warming increases habitat for Great Lakes fish, which could increase fish yields, but also increases the potential for invasions of exotic species, which have a history of altering Great Lakes ecosystems, often irreversibly.

Several policy options were considered by the workgroup. The importance of policy criteria for assessments was emphasized, which would facilitate adaptation to climate change within the context of economical factors such as discount rates and opportunity costs. Flexibility and an understanding of both the benefit and costs of decisions in the long term also were viewed as important. Highest priorities might be assigned to actions associated with irreversible or catastrophic impacts and to decisions made now for infrastructure and other projects with a long-term planned obsolescence. The role of government should be to facilitate adaptability in goals or targets that consider climate change as a long-term issue.

3.2.3 Events After the 1988 Symposia

A Canada-U.S. bilateral commitment (memorandum of understanding) was made between the National Oceanic and Atmospheric Administration in the U.S. and the Atmospheric Environment Service in Canada in 1990. This memorandum ensures mutual assistance in planning climate-related programs and their operations to the extent practicable and mutually desirable, and communication and sharing of climate-related information. Annual planning and review processes are prescribed.

In February 1992, participants in a symposium at the Annual Meeting of the Association for the Advancement of Science in Chicago restated the significance of climate change in the Great Lakes basin (Climate Change on the Great Lakes Basin 1992). Primary areas of discussion included water levels, policy, needed research, socio-economic and other impacts, and social and institutional responses.

Canada established a Great Lakes climate-change program entitled “Reducing The Threat of Global Warming” under the Green Plan initiative in 1992. The program’s goal “to take interdisciplinary, integrated studies on the physical, biological, social and economic impacts of, and policy responses to, climate change in the Great Lakes-St. Lawrence basin, in order to improve our understanding of the complex interactions between climate and society, so that informed regional adaptation responses can be developed for the basin.” While no parallel program exists in the U.S., the Canadian project has the objective to develop “partnerships which involve Canadian and American interests, government agencies, academia, interests groups, and industry,” further stating “that a collaborative research agenda with the U.S. is critical for a binational effort.”

As part of this Canadian program, a workshop entitled “Adapting to the Impacts of Climate Change and Variability” was convened in Quebec City in February 1992. Agreement was reached among NOAA and other state/federal representatives in attendance that a parallel effort should be developed.

A NOAA initiative has been underway since January 1993 to develop a U.S. component to a binational program on climate change in the Great Lakes. An integrative program with research, monitoring, assessment and policy components is proposed, with emphasis on the effects of climate change on physical, ecological, economic and social systems. Anticipated outputs include practical policy alternatives related to potential for adaptation and mitigation. To date, only modest funds have been allocated to this effort. A planning workshop is scheduled for October 1993.

On the occasion of the 89th meeting of the Science Advisory Board, climate change was unanimously adopted as a future priority candidate, for consideration by the Commission in the development of their 1993-1995 workplans.
3.2.4 Recommendations

Great Lakes ecosystems are considered by the SAB to be sensitive to climate warming. These sensitivities influence a number of properties and processes that relate to Commission responsibilities, including toxic chemicals, nutrients, other substances and materials, lake levels and heat that result from human activity and interfere with beneficial uses.

The Board recommends that:

- the Commission urge the Parties to develop and implement a binational program to address global climate change through the integrated study of the Great Lakes basin as a regional pilot project
- the Commission urge the Parties to make a long-term commitment to climate change research through identification of climate change in Annex 17 of the Great Lakes Water Quality Agreement, and to provide a report on progress at appropriate intervals of time, in a holistic and systematic reporting fashion, as recommended in Chapter 6 of this report

3.3 Use of Predictive Models in Remedial Action Plan Decisionmaking

Remedial actions to restore impaired uses are being planned or are underway at the 43 Areas of Concern (AOCs) in the Great Lakes basin (Figure 3.1). Implicit in the planning and budgeting process is the prediction of beneficial outcomes expected to follow from proposed actions. Public confidence in the prediction of benefits from correcting water quality problems is a significant issue for future policy and funding of remediation programs throughout the Great Lakes basin. The Science Advisory Board (SAB) has examined whether these expectations are sound and whether the available models developed in recent years have been used advantageously in building local consensus and reaching decisions.

Several research programs have been designed to improve modelling approaches for application to Great Lakes remediation, but there is not yet consensus for their routine use in assessing pollution abatement or preventative (as opposed to reactive) management (IJC 1986; 1990; 1991a). An earlier section on the Workgroup on Parties Implementation (see Table 3.2) shows the extent to which analysis of options for toxic substance control and cost-benefit analysis has been sought for the past decade. For the International Joint Commission (IJC), the promotion of further progress in reaching the goals of the Great Lakes Water Quality Agreement may require indepth use of predictive capabilities and quantitative means to assure confidence in the decisions made. Making hundreds of regulatory or preventive management decisions requires more sophisticated and more general uses of scientific understanding of the lakes.

To examine this issue, the SAB asked a series of questions: Are advanced models actually needed for the decisions being made? Does the decision process need less data-intensive models? Is there a need for more user-friendly interactions at several levels of government? Do the models currently available provide an adequate balance between the scientific assessment of risk and the socio-economic assessment of costs? Is there a need for feedback from the user community, which, if responded to by the modelling community, would improve confidence in the process of remedial planning? While we cannot yet answer all of these questions, they must be considered as part of the scientific underpinnings of the Remedial Action Plan (RAP) decision process. In asking these questions, the SAB recognizes that most Stage 1 reports at the Areas of Concern (AOCs) were not intended to evaluate the magnitude of the problem of remediation quantitatively (IJC 1989; IJC 1991b) and, therefore, few of the RAPs to date have sought to apply modelling. The
FIGURE 3.1 Forty-three Areas of Concern identified in the Great Lakes Basin
Board has concluded, however, that local use and understanding of the various approaches for choosing among remediation alternatives may be an important limitation in the next phases of remedial action planning. Uncertainty as to benefits and costs of remediation is widespread and new models, both for the analysis of decisions in the presence of uncertainty and for the communication of the benefits of decisions, are coming into general use.

To place the use of predictive models in context, the status of all 43 Stage 1 Remedial Action Plans was reviewed. Nine RAP reports contained information on the use of models (Table 3.1). Only a few used models to instill confidence in the numerical basis of goals in remediation planning and decisionmaking. Most of the other 34 Stage 1 RAPs did not (and were not intended to) discuss the use of predictive models in remedial analysis, but did generally address similar impaired uses to those of the other nine areas. Information on each of the 43 RAPs was considered independently, and a one-page tabular summary was compiled using four descriptors: the impaired uses; the sources of pollution; the transport subsystem involved; and the extent of modelling of remediation options where this applied. The 34 RAPs where no modelling was done were reviewed for the first two descriptors only.

### 3.3.1 Results for Nine RAPs Containing Modelling

The nine sites with modelling can be summarized in four sets: one very large bay; a set of three connecting channels (binational sites); two harbour sites in Canada; and three river and harbour sites in the U.S.

**The Fox River/Green Bay**

This Wisconsin site is the "modelling exemplar" among all AOCs, perhaps because of the seriousness of the impaired uses and the priority attached by the general public in Wisconsin for recovery of impaired uses. Eleven out of the 14 possible uses are impaired (Table 3.1), including fish tumours, deformities in birds, beach closings, degradation of aesthetics and restrictions on fish and wildlife consumption (Wisconsin DNR 1991; IJC 1991b). These impairments result from exposures to some 100 toxic substances, including 39 priority pollutants (IJC 1987a) discharged over many years from 14 pulp and paper mills and five major municipal wastewater treatment plants along the Fox River. These pollutants have accumulated mainly in the river's bottom sediments and therefore can be resuspended and remobilized during high-flow conditions in the river and through bioturbation.

Over the course of several years, and as a result of a significant investment in database development, a coordinated set of models was created specifically to analyze remediation options for the Fox River and Green Bay system (Beltran 1992). The program, known as the Green Bay Mass Balance Modelling Project, includes a suite of models, including those used to estimate pollutant loadings, transport, eutrophication, mobility of solids, fate of toxic substances, food chain accumulation and uncertainty. Combined, these models have provided a valuable predictive capability to estimate mobility and year-to-year spatial mass balance of PCBs in the river, bay and fishery. The models also address management questions about the effectiveness of remedial options for controlling loadings, resuspension rates and subsequent transport to Green Bay from point and nonpoint sources, including the in-situ contaminated sediments in the Fox River.

Following development of the models, eight scenarios were selected for intensive evaluation through simulation studies. Priority was placed on sediment resuspension during high-velocity river flow events, including consideration of the Fox River's 100-year peak flow event, PCB source reductions by sediment removal, and Fox River flow "clipping" to reduce peak flow rates through construction of flood storage (U.S. EPA/Wisconsin DNR, 1992). Five scenarios have improved understanding of the potential for success through remedial measures on the Fox River as well as the consequences of natural flooding events on the proposed measures. Some criteria developed
TABLE 3.1. Impaired uses and models developed for evaluating remediation options

<table>
<thead>
<tr>
<th>SITE</th>
<th>IMPAIRED USES</th>
<th>MODEL DEVELOPMENT AND APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fox River/Green Bay</td>
<td>• Restrictions on fish and wildlife consumption</td>
<td>Modelling Approach and Comprehensive Remediation Options Analyzed</td>
</tr>
<tr>
<td></td>
<td>• Degradation of fish and wildlife population</td>
<td>- Mass Balance of PCBs. The suite of Fox River/Green Bay models were applied to predict long-term</td>
</tr>
<tr>
<td></td>
<td>• Fish tumours and other deformities</td>
<td>trends in PCB concentrations for six remediation scenarios. Utilizes several component models,</td>
</tr>
<tr>
<td></td>
<td>• Degradation of benthos</td>
<td>including hydrodynamics, load transport, eutrophication, toxics fate, food chain and uncertainty.</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities</td>
<td><em>(Beltran 1992; US EPA &amp; Wisconsin DNR, 1992)</em></td>
</tr>
<tr>
<td></td>
<td>• Eutrophication or undesirable algae</td>
<td>Management Questions</td>
</tr>
<tr>
<td></td>
<td>• Beach closings</td>
<td>- What are the loading rates of chemicals from point and nonpoint sources, including in place</td>
</tr>
<tr>
<td></td>
<td>• Degradation of aesthetics</td>
<td>contaminated sediment?</td>
</tr>
<tr>
<td></td>
<td>• Degradation of phytoplankton and zooplankton populations</td>
<td>- Is the bay a source or sink of contamination to Lake Michigan?</td>
</tr>
<tr>
<td></td>
<td>• Loss of fish and wildlife habitats</td>
<td>- What is the response in the bay water, sediment and biota to alternative loading reductions,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>including &quot;no action.&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Beltran 1992; US EPA &amp; Wisconsin DNR, 1992)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Five Scenarios Selected for Simulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Outcome of Fox River, hundred-year peak flow event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Outcome of selected remediation above and below DePere, Wisconsin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Outcome of PCB load reduction above, DePere, Wisconsin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Outcome of Fox River peak-flow clipping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Fox River phosphorus load-step reductions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remedial Action Goals being Considered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Year 15 Walleye PCB concentrations meet health standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Year 25 PCB concentrations in walleye meet health standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamilton Harbour</td>
<td>• Restrictions on fish and wildlife consumption</td>
<td>Modelling Approach and Remediation Options Analyzed</td>
</tr>
<tr>
<td></td>
<td>• Degradation of fish and wildlife population</td>
<td>- Klapwik and Snodgrass (1985) suggested that Hamilton Harbour’s flushing rates to the lake could</td>
</tr>
<tr>
<td></td>
<td>• Fish tumours and other deformities</td>
<td>be estimated using a mass balance for conservative dissolved substances as measured by conductivity.</td>
</tr>
<tr>
<td></td>
<td>• Bird or animal deformities or reproductive problems</td>
<td>The purpose involves predicting the fate of the lake water once it enters the harbour. Under what</td>
</tr>
<tr>
<td></td>
<td>• Degradation of benthos</td>
<td>conditions is lake water retained within the harbour for a time long enough to have a beneficial</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities</td>
<td>effect on water quality?</td>
</tr>
<tr>
<td></td>
<td>• Eutrophication or undesirable algae</td>
<td><em>(OMOE et al. 1988)</em></td>
</tr>
<tr>
<td></td>
<td>• Beach closings</td>
<td>- The Janus-Vollenweider model (1981) for annual average concentrations was used to predict</td>
</tr>
<tr>
<td></td>
<td>• Degradation of aesthetics</td>
<td>phosphorus loading to the harbour from a variety of sources such as wastewater treatment plants,</td>
</tr>
<tr>
<td></td>
<td>• Degradation of phytoplankton and zooplankton populations</td>
<td>combined sewer overflows (CSOs), creeks and storm sewer discharges. In order to reduce algal growth,</td>
</tr>
<tr>
<td></td>
<td>• Loss of fish and wildlife habitats</td>
<td>it is necessary to reduce phosphorus inputs to the harbour. The model was modified to take into</td>
</tr>
<tr>
<td></td>
<td></td>
<td>consider the effect that iron has upon the settling of phosphorus. Used to initiate loading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reductions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Dick and Marsalek model (1973) used to examine the effects of landfilling shallow littoral areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(inflows) on Hamilton Harbour retention and flushing times as well as oxygen depletion. No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>remedial actions taken.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remedial Actions Taken</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- One regional municipality has constructed retention basins, and a dredging project was initiated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in 1988 to contain contaminated sediment. Industries have modified discharges.</td>
</tr>
<tr>
<td>Port Hope</td>
<td>• Degradation of benthos</td>
<td>Modelling Approach and Remediation Options Analyzed</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities due to presence of low-level radio-</td>
<td>- Hydraulic Mass Balance. Long-term averages (1984-87) for CAMECO cooling water discharges have</td>
</tr>
<tr>
<td></td>
<td>nuclides</td>
<td>been estimated in two flows used to determine average loadings from CAMECO discharges. No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>remedial actions taken.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Sediment-benthological studies in 1984 were used to determine the stochastic dose an individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>would receive upon consuming a brown bull head catfish. In 1985, a study was done to investigate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the uptake of contaminants by resident and non-resident fish species in the turning basin. It has</td>
</tr>
<tr>
<td></td>
<td></td>
<td>been determined that the radionuclide levels detected in the tissue of sport fish would not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>produce a significant adverse impact on the fish or human use of the fish.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remedial Actions Proposed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- The sediments have been designated as historic low-level radioactive waste. If the harbour is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to remain operative as a small craft mooring facility, the contaminated sediments must be</td>
</tr>
<tr>
<td></td>
<td></td>
<td>removed from the turning basin and west slip.</td>
</tr>
</tbody>
</table>

Continued
<table>
<thead>
<tr>
<th>SITE</th>
<th>IMPAIRED USES</th>
<th>MODEL DEVELOPMENT AND APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuyahoga River</td>
<td>Modelled Approach and Remediation Options Analyzed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Restrictions on fish and wildlife consumption</td>
<td>Hydrodynamic Model Development. Efforts are being directed towards building a model to frame and quantify the linkages between contributing sources and their effect on beneficial uses.</td>
</tr>
<tr>
<td></td>
<td>- Degradation of fish and wildlife population</td>
<td>- The goal of the Cuyahoga modelling is to produce a WASP4 water quality model to assess the impact of point and nonpoint source dischargers on water quality in the lower section of the river. Ohio Environmental Protection Agency (OEPA) will use the model to monitor National Pollutant Discharge Elimination System (NPDES) discharges, to evaluate use designation and water quality standard criteria, and to evaluate the Stage 2 RAP alternative.</td>
</tr>
<tr>
<td></td>
<td>- Fish tumours and other deformities</td>
<td>- Wet Weather Modelling. The purpose of the model being developed by the OEPA is to analyze conditions during low-river flow and to use the model to investigate issues of transport and fate for specific pollutants of concern. (CCC 1992)</td>
</tr>
<tr>
<td></td>
<td>- Degradation of benthos</td>
<td>- Restrictions on dredging activities</td>
</tr>
<tr>
<td></td>
<td>- Restrictions on dredging activities</td>
<td>- Eutrophication or undesirable algae</td>
</tr>
<tr>
<td></td>
<td>- Restrictions on drinking water consumption or taste and odour problems</td>
<td>- Beach closings</td>
</tr>
<tr>
<td></td>
<td>- Beach closings</td>
<td>- Degradation of aesthetics</td>
</tr>
<tr>
<td></td>
<td>- Degradation of aesthetics</td>
<td>- Loss of fish and wildlife habitats (under assessment)</td>
</tr>
<tr>
<td>Detroit River</td>
<td>Modelled Approach and Remediation Options Analyzed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Restrictions on fish and wildlife consumption</td>
<td>Hydrodynamic Model Development. Efforts are being directed towards building a model to frame and quantify the linkages between contributing sources and their effect on beneficial uses.</td>
</tr>
<tr>
<td></td>
<td>- Fish tumours and other deformities</td>
<td>- The goal of the Cuyahoga modelling is to produce a WASP4 water quality model to assess the impact of point and nonpoint source dischargers on water quality in the lower section of the river. Ohio Environmental Protection Agency (OEPA) will use the model to monitor National Pollutant Discharge Elimination System (NPDES) discharges, to evaluate use designation and water quality standard criteria, and to evaluate the Stage 2 RAP alternative.</td>
</tr>
<tr>
<td></td>
<td>- Degradation of benthos</td>
<td>- Wet Weather Modelling. The purpose of the model being developed by the OEPA is to analyze conditions during low-river flow and to use the model to investigate issues of transport and fate for specific pollutants of concern. (CCC 1992)</td>
</tr>
<tr>
<td></td>
<td>- Restrictions on dredging activities</td>
<td>- Restrictions on fish and wildlife consumption</td>
</tr>
<tr>
<td></td>
<td>- Restrictions on drinking water consumption or taste and odour problems</td>
<td>- Eutrophication or undesirable algae</td>
</tr>
<tr>
<td></td>
<td>- Beach closings</td>
<td>- Beach closings</td>
</tr>
<tr>
<td></td>
<td>- Degradation of aesthetics</td>
<td>- Degradation of phytoplankton and zooplankton populations</td>
</tr>
<tr>
<td></td>
<td>- Loss of fish and wildlife habitats (under assessment)</td>
<td>- Loss of fish and wildlife habitats (under assessment)</td>
</tr>
<tr>
<td>River Raisin</td>
<td>Modelled Approach and Remediation Options Analyzed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Restrictions on fish and wildlife consumption</td>
<td>Hydrodynamic Model Development. Efforts are being directed towards building a model to frame and quantify the linkages between contributing sources and their effect on beneficial uses.</td>
</tr>
<tr>
<td></td>
<td>- Degradation of benthos</td>
<td>- The goal of the Cuyahoga modelling is to produce a WASP4 water quality model to assess the impact of point and nonpoint source dischargers on water quality in the lower section of the river. Ohio Environmental Protection Agency (OEPA) will use the model to monitor National Pollutant Discharge Elimination System (NPDES) discharges, to evaluate use designation and water quality standard criteria, and to evaluate the Stage 2 RAP alternative.</td>
</tr>
<tr>
<td></td>
<td>- Restrictions on dredging activities</td>
<td>- Wet Weather Modelling. The purpose of the model being developed by the OEPA is to analyze conditions during low-river flow and to use the model to investigate issues of transport and fate for specific pollutants of concern. (CCC 1992)</td>
</tr>
<tr>
<td></td>
<td>- Degradation of benthos</td>
<td>- Restrictions on dredging activities</td>
</tr>
</tbody>
</table>

Remedial Actions Taken

- Wastewater pretreatment implemented on LTV Steel and the City of Cuyahoga Falls has lined a section of sewers with a plastic sleeve.

- Modelling PCB Mass Balance. An analysis of PCB mass loadings in the River Raisin was undertaken to identify significant pollutant sources and sinks. The models were created to assess the following questions: What is the status of PCBs in the water? Are local point sources contributing significant contaminant loads to Monroe Harbour? Does the River Raisin/Monroe Harbour act as a sink or a source for PCBs? If the point sources are important, what is their rank according to loading? Are nonpoint source loads a concern? (Michigan DNR 1987)

- Fate and Transport of Cu, Cr and Zn. The prediction of metals exposures in the River Raisin was determined using a mass balance approach. No remedial options were considered.

- A model has been created for the lower 2.6 miles of the River Raisin to estimate pollutant fate and transport. No remedial options considered.

Remedial Actions Taken

- NPDES permit for City of Detroit requires development and implementation of a Combined sewer overflow (CSO) control program.

- Local landfills and industrial sites have developed cleanup plans. (IJC 1991b)
### TABLE 3.1. (Cont’d) Impaired uses and models developed for evaluating remediation options

<table>
<thead>
<tr>
<th>SITE</th>
<th>IMPAIRED USES</th>
<th>MODEL DEVELOPMENT AND APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saginaw Bay</td>
<td>• Restrictions on fish and wildlife consumption</td>
<td><strong>Modelling Approaches and Remedia-tion Option Analyzed (Michigan DNR 1988)</strong></td>
</tr>
<tr>
<td></td>
<td>• Degradation of fish and wildlife populations</td>
<td>• A deterministic phytoplankton simulation model was developed to describe</td>
</tr>
<tr>
<td></td>
<td>• Fish tumours and other deformities (under assessment)</td>
<td>the cause-effect connection between external nutrient loading and phytoplankton growth in Saginaw Bay.</td>
</tr>
<tr>
<td></td>
<td>• Degradation of benthos</td>
<td>• The principal issue addressed in the development of the model was cultural</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities</td>
<td>eutrophication. The model was developed for two reasons:</td>
</tr>
<tr>
<td></td>
<td>• Eutrophication or undesirable algae</td>
<td>• to gain insight into the relevant physical, chemical and biological processes</td>
</tr>
<tr>
<td></td>
<td>• Beach closings</td>
<td>• to use the model as a tool to compare future effects of various wastewater</td>
</tr>
<tr>
<td></td>
<td>• Degradation of aesthetics</td>
<td>management strategies. No remediation options considered.</td>
</tr>
<tr>
<td></td>
<td>• Degradation of phytoplankton and zooplankton populations</td>
<td><strong>Remedial Actions Taken</strong></td>
</tr>
<tr>
<td></td>
<td>• Loss of fish and wildlife habitats (under assessment)</td>
<td>• The City of Saginaw’s new discharge permit, issued October 1989, mandates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a construction schedule for six retention basins.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Funds have been appropriated to address various nonpoint source issues in the Saginaw Bay.</td>
</tr>
<tr>
<td>St. Clair River</td>
<td>• Restrictions on fish and wildlife consumption</td>
<td><strong>Modelling Approach and Remediation Options Analyzed</strong></td>
</tr>
<tr>
<td></td>
<td>• Degradation of fish and wildlife populations</td>
<td><strong>Dispersion models (GLCCS 1988)</strong></td>
</tr>
<tr>
<td></td>
<td>• Fish tumours and other deformities (under assessment)</td>
<td>• Hambdy and Kinkead (1979) predicted in stream concentration of chloride</td>
</tr>
<tr>
<td></td>
<td>• Bird or animal deformities or reproductive problems</td>
<td>from shore-based discharge outfalls. No remedial options considered.</td>
</tr>
<tr>
<td></td>
<td>• Degradation of benthos (mainly due to oil and grease tars)</td>
<td><strong>Hydrodynamic and Chemical Transport Models</strong></td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities</td>
<td>• McCorquodale and Bewtra (1982) provided a user’s manual for a model</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on drinking water consumption or taste and odour problems</td>
<td>• also designed to assess the convection-dispersion and decay of vertically mixed pollutants from multiple outfalls.</td>
</tr>
<tr>
<td></td>
<td>• Beach closings</td>
<td>• Also considered the dispersion and transport of phenols in the St. Clair River. No remedial options considered.</td>
</tr>
<tr>
<td></td>
<td>• Degradation of aesthetics</td>
<td>• Chan et al. (1986) modelled the fluxes and the concentration distributed</td>
</tr>
<tr>
<td></td>
<td>• Loss of fish and wildlife habitats (under assessment)</td>
<td>• No remedial options considered.</td>
</tr>
<tr>
<td>St. Marys River</td>
<td>• Restrictions on fish and wildlife consumption</td>
<td>• Funds have been appropriated to address various nonpoint source issues in the Saginaw Bay.</td>
</tr>
<tr>
<td></td>
<td>• Degradation of fish and wildlife populations</td>
<td><strong>Modelling Approach and Remediation Option Analyzed (UGLCCS 1988)</strong></td>
</tr>
<tr>
<td></td>
<td>• Fish tumours and other deformities (under assessment)</td>
<td>• For the purpose of modelling, the St. Marys River has been divided into an</td>
</tr>
<tr>
<td></td>
<td>• Degradation of benthos</td>
<td>• an upper reach (above the regulatory works) and a lower reach (below the regulatory works).</td>
</tr>
<tr>
<td></td>
<td>• Restrictions on dredging activities</td>
<td><strong>Fate and Transport Modelling</strong> accomplished using the contaminant dispersion submodel of KETOX and used to predict</td>
</tr>
<tr>
<td></td>
<td>• Eutrophication or undesirable algae</td>
<td>phenol concentrations along the Canadian shoreline.</td>
</tr>
<tr>
<td></td>
<td>• Beach closings</td>
<td><strong>Hydrodynamics Modelling</strong> accomplished using the mixing model (k-E). Allows the mixing zone to be defined so that</td>
</tr>
<tr>
<td></td>
<td>• Degradation of aesthetics</td>
<td>various loading scenarios can be compared and evaluated. These models have been used to derive the maximum</td>
</tr>
<tr>
<td></td>
<td>• Degradation of phytoplankton and zooplankton populations</td>
<td>effluent loads for given outfalls along the river.</td>
</tr>
<tr>
<td></td>
<td>• Loss of fish and wildlife habitats (under assessment)</td>
<td><strong>Remedial Actions Taken</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wastewater filtration plant opened in 1990 (Algoma Steel), combined sewer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>overflow control program is required by the NPDES permit for the City of Sault St. Marie, Michigan.</td>
</tr>
</tbody>
</table>
during this process have provided guidance on the choice of goals for remedial actions. These include: 25-year projections of mass balance and transport of PCB; 15-year projections of PCB concentrations in walleye and birds; and 25-year projections of PCB in walleye. All are a function largely of sediment concentrations and mobility upstream in the Fox River and of the pattern of storm-event flows and subsequent biomagnification in the bay (U.S. EPA/Wisconsin DNR, 1992).

Some years ago, sediments contaminated with PCBs from the Fox River were considered for remediation. The cost could well have exceeded $500 million, plus additional risks of PCB contamination of downstream sediments during dredging, as well as at burial sites on the land. The simulation studies of resuspension during flood events and the transport and biomagnification in the food chain of Green Bay indicate that even with no treatment, average concentrations of PCB in walleye are projected to meet current health tolerances within 15 years, thereby probably alleviating the deformities in fish-eating birds. The models project that the river and bay systems would be free of even episodic PCB resuspension events during floods within 25-30 years.

A summary of the models and their results was presented at a two-day workshop in Chicago, December 3-4, 1992, entitled: "Balancing the Bay: Implications of the Green Bay/Fox River Mass Balance Study." Workshop participants were confident that the approaches to remediation would lead to desired and cost-effective results. A public and political consensus on which goals to choose was still needed, but with benefits and costs now more certain, further progress seems imminent.

Thus, the Fox River and Green Bay modelling studies have focused the analysis of remedial options on those with the potential to accelerate permanent burial of toxic substances and prevent their further resuspension, particularly within 10 to 25 years. The river-bed resuspension simulations identified a small number of highly contaminated sediment beds at high risk of resuspension during the next 15 years. These sources would contribute most to the long-term risk of recontamination, and should be the focus of specific dredging decisions and determinations of costs and benefits from remediation. Clearly, the cost of these measures, if any are undertaken, will be a small fraction of the cost once considered necessary.

These and related results tell us several things about the potential uses of modelling at AOCs. First, the systematic analysis of remediation options using site-specific simulations of projected outcomes has, despite a substantial expense for data, provided assurance that low cost remedial measures have the potential to perform as well or better than very high cost alternatives. Even the "cost" (from delayed benefits) of a no-action alternative can be evaluated and compared with other options. Greater consensus can also be obtained because the budget needed for a specific course of action can be shown quantitatively to be commensurate with projected benefits. When this is the case, the proposed remediation appears to command broad-based public support.

Although the cost of the Green Bay mass balance modelling was high ($10,000,000), the study was undertaken in part as a generic research and demonstration project, with many redundancies in data collection to assure accuracy. When the research and development costs are removed and the approach is applied to small harbours or short river-reach sites, the costs will be much smaller and the investment becomes reasonable in comparison to the likely benefits in terms of community consensus on a course of action and long-term use of the resource. An information base for the design of a model is essential and cost-effective for analysis and decisionmaking, especially when scarce resources are allocated to measures that could otherwise be based on the exaggeration or underestimation of the problems.

Does the decision process need less data-intensive models? Probably yes, although the Green Bay applications of modelling involved an unusually large and complex site, and it represents only a single case study to date. At other sites with little upstream input, existing data and simple models adapted from those at Green Bay may suffice. The real question is whether the stakeholder communities and governments are reaching reasonable consensus on the scope, ap-
proach and costs of recovering impaired uses of resources. Taking short-cuts in data collection and modelling could contribute to further postponement of consensus and action.

**Detroit, St. Marys and St. Clair Rivers**

These three Areas of Concern (AOCs) were investigated as part of the Connecting Channels Study (UGLCCS 1988), and the results have some similarities (on a smaller scale) to the Fox River/Green Bay modelling study. Generally similar impairments of uses are present, creating similar problems for remediation. Beach closings, restrictions on fish and wildlife consumption, fish tumours, deformities and degradation of aesthetics are all present (IJC 1991b). At the Detroit River AOC, major pollutants include PCBs and heavy metals transported to the AOC directly from small tributaries and through biological and natural resuspension (IJC 1987a). The Detroit River RAP also has used mass balance modelling, and the results indicate that the river is a significant source of several heavy metals and phosphorus, as well as PCBs. Other models have been used or created for the Detroit River, including the Trenton Channel Mass Balance, the Trenton Channel Transport Model and related process models (UGLCCS 1988). They have not been used to identify remediation options, however, nor has the data collection and modelling been adapted for simulation or for comparison of outcomes over time. However, eight effluent management scenarios were chosen by the Detroit Wastewater Treatment Plant (WWTP) for evaluation of the environmental fate of substances, using models for that part of the system (UGLCCS 1988).

The St. Clair River, another AOC included in the Connecting Channels Study, has impairments in 11 of the 14 use categories, including beach closings, restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, fish tumours and degradation of aesthetics (IJC 1991b). The impairments in this AOC are largely due to 12 municipal treatment plants and 44 industrial dischargers (IJC 1987a). Nonpoint sources such as agriculture, urban and rural runoff and spills also contribute (Michigan DNR/OMOE 1991b). Contaminants are transported within the AOC via groundwater movement, biological and natural resuspension and small tributaries. The modelling activities conducted on the St. Clair River do not appear in the Stage 1 RAP, but are found in the Upper Great Lakes Connecting Channels Study (UGLCCS 1988). Various models have been developed, including chemical transport models, hydrodynamic models and dispersion models (Table 3.1). However, none appear to be in use currently to explore and compare long-term outcomes of remediation options.

The St. Marys River is the third of the Connecting Channels Study sites, impaired in similar ways to the two above. These impairments are due largely to contaminant loading from three municipal wastewater treatment plants, two industries and a variety of other nonpoint sources such as urban runoff, combined sewer overflows and spills (Michigan DNR/OMOE, 1992). The contaminants are brought to this AOC via small streams and tributaries, overland runoff and biological and physical resuspension. Modelling in the St. Marys River has been accomplished through the Connecting Channels Study (UGLCCS 1988), but was not used to support analysis of remediation options. However, several different types of models have been developed and are available for the river, including fate and transport, hydrodynamics and process models.

**Hamilton Harbour and Port Hope Harbour**

The Hamilton Harbour AOC's impaired uses include restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, fish tumours, beach closings and the degradation of aesthetics (IJC 1991b). These impairments are due largely to the historical discharge of contaminants from point sources, including two steel mills and four wastewater treatment plants. Some nonpoint sources include agricultural runoff, road salt and shipping spills (OMOE et al. 1988). Most contamination is transported to and within the AOC via small streams and rivers, overland runoff, direct discharge and shoreline resuspension processes. Models have been developed...
for preliminary comparison of remediation measures, and in the case of the Janus-Vollenweider model, have been used to suggest reduction targets for phosphorus loading to the harbour (OMOE et al. 1988). The Canada Centre for Inland Waters, located near Hamilton, has played an important role in supporting these data collections and modelling activities, in cooperation with a range of local stakeholders.

The Port Hope AOC has only two use impairments, degradation of benthos and restrictions on dredging activities, both due to the presence of radionuclides in the sediment (IJC 1991b). This AOC is unique in that the contamination is due to historical discharges from a single uranium conversion facility, and thus primary contaminants are derivatives of radium, uranium and thorium (Environment Canada/OMOE 1989). These materials are transported within the system through physical and biological resuspension processes. Modelling in the form of a hydraulic mass balance was undertaken at one time, but no specific remedial measures appear to have been influenced as a result of this work.

Saginaw Bay, Cuyahoga and Raisin Rivers

These three AOCs display many of the same impairments as the AOCs discussed above. At the time the Saginaw Bay Stage 1 RAP was prepared, eutrophication was thought to be the most serious problem due largely to the direct discharges of 127 wastewater treatment facilities and 87 industrial facilities (Michigan DNR 1988). Nonpoint source pollution is present from agriculture, urban runoff, in-situ pollutants and atmospheric deposition. Contaminants are transported in many ways, including small streams and tributaries, overland runoff, and sediment and biological resuspension (Michigan DNR 1988). The Stage 1 RAP did not contain any modelling, but a deterministic phytoplankton simulation model was developed to describe the cause-effect relationships between external nutrient loading and phytoplankton growth in the bay (Bierman and Dolan, 1981). However, the model has not been used yet in evaluating options for remediation of the enrichment. The serious problems caused by organochlorine compounds are being addressed in the Stage 2 RAP.

The Cuyahoga River RAP discusses ten impaired uses, including restrictions on fish and wildlife consumption, fish tumours, beach closings and degradation of aesthetics (IJC 1991b). These impairments are due largely to a variety of historical and present dischargers, including steel mills, chemical manufacturers, wastewater treatment plants and metal refining facilities (IJC 1987a). Nonpoint sources include hazardous waste sites, landfills, quarries, mines, industrial stock piles, tank storage areas, underground storage tanks, oil and gas wells, waste injection wells, chemical spills, and rural and urban runoff (CCC 1992). The contaminants are transported to and within the AOC by sediment resuspension, overland runoff and biological resuspension. Some modelling for the AOC is underway, but little is reported in the RAP. The immediate goal has been to produce a hydrodynamic model to quantify the linkages between sources and in-stream conditions and their effect on use. In particular, a Water Analysis Simulation Program (WASP) water quality model is being used to assess point and nonpoint impacts (CCC 1992). Efforts are also underway to produce a wet weather model that would aid in predicting conditions during high and low flows. To date, none of these models appear to have been used to advise among remedial options or facilitate remediation decisions.

The River Raisin AOC has impaired uses for fish and wildlife consumption, degradation of benthos and restrictions on dredging (IJC 1991b). The contamination problems within the river are due in part to local automobile component production, power plants and wastewater treatment facilities (Michigan DNR 1987). Most wastes are transported to the AOC via land runoff, groundwater, sediment resuspension and biological resuspension. Several preliminary models have been developed, including PCB mass balance, fate and transport models and sediment resuspension, but the PCB mass balance is the only one that has been used to address management questions such as the significance of nonpoint sources to this AOC (Michigan DNR 1987).
3.3.2 Discussion

The uses of models at these nine sites range from intensive to superficial. However, the extent of public confidence concerning benefits from remedial measures seems generally to be proportional to the degree that future risks, prospective outcomes from remediation programs, and local community activism are quantitatively examined. The status of decisionmaking is fluid at all of the sites, however, and the specific situation at some sites may be different now than the information available at the time of this assessment. In addition, community enthusiasm for recovery of beneficial uses may suffice in some cases to build consensus on remediation options, at least in those locations where there is little divergence in the costs and benefits of the available alternatives. Nevertheless, a general pattern remains: where specific data have been obtained to define the problem and the goals for its remediation, and where the mechanisms and time-course for reaching those goals are understood and generally agreed on by all stakeholders, consensus on a course of action over a specific timeframe is likely.

The diversity of problems among the nine sites is interesting. Certain impairments are present in a recurring pattern, including a 78% beach closing rate, 78% occurrence for fish tumours and other deformities, 78% degradation of aesthetics, 88% restriction on fish and wildlife consumption, and 100% restrictions on dredging and degradation of benthos. Many of these impairments have the ability to severely restrict a wide range of public uses. In comparison with data on impairments at the 34 sites without modelling, there is some evidence of a relationship between the seriousness of the impairments and the apparent priority attached to evaluating remedial options quantitatively. For example, the presence of fish tumours and deformities is less frequent among the 34 than in the initial set of nine (IJC 1991b). The nine AOCs with modelling are mostly high profile sites located near major population centers, valued not only for their ability to assimilate waste, but for their value as a source of recreation and other public uses. However, other high profile sites with major impairments of use have not yet developed programs for analysis of remediation options.

There may be a need for greater interaction between scientists analyzing remedial options and the stakeholders and user community (the “public”) who must pay for implementation. Certainly, the Fox River/Green Bay AOC appears to have benefited from recurring workshops that brought the modelling community, governments and local stakeholders together to consider specific measures and schedules for decisions and implementation. This has not been the case for many other modelling activities, and the absence of feedback mechanisms should be recognized as a potential limitation in the RAP process rather that a limitation of modelling per se.

Two other broad questions should be considered: How universal is the need for improved database development and quantitative comparison of remediation options across the entire array of 43 AOCs? Similarly, how constant will be the benefits from systematic comparison of an array of remediation options using simulation modelling or other predictive models? The two categories of RAPs examined showed general similarities in the impaired uses, in the types and sources of contamination and in the general class of transport subsystems that create a local or areawide problem. These similarities suggest that the modelling approaches used in the first set of nine sites need to be considered at the other 34 sites in the future.

Differing levels of priority given to modelling seem to be related more to the number of people affected by the impaired uses, rather than by the nature of the site. The absence of modelling at the 34 sites, therefore, seems not to be due to the absence of a need for predictive models. Rather, the local community does not appear to have yet urged remedial action in as strong terms as has been the case in the first set where modelling is being used. Governments and community leaders apparently have not felt pressed to support development of the necessary database, predictive models or precise comparison of options. The absence of good databases and the fear of high cost remediation programs (possibly unfounded) may be discouraging both governments and local communities from even evaluating their options.
3.3.3 Findings and Conclusions

• Several RAPs do not contain models, but some modelling activities are associated with particular AOCs. Modelling undertaken for the Detroit, St. Clair and St. Marys Rivers has not yet been incorporated into Stage 2 RAPs. Other modelling reports specific to a given AOC, but external to the RAP, also exist. These "collateral studies" (with their separate funding mechanisms) offer great potential to support the RAP process and provide documentation of prospective benefits through use of comprehensive, quantitative models.

• The pattern among sites where modelling has been used with some intensity (i.e. Green Bay and Hamilton Harbour) indicates generally more confidence and more consensus in a proposed course of action than where modelling has been limited to current descriptions of the processes operating at a site. Analysis of the differences suggests that where prospective benefits have been explored over time through simulation studies, multi-stakeholder consensus improves.

• Past experience at sites outside the Great Lakes basin (reviewed at the Green Bay Mass Balance Workshop, December 1992) shows that use of predictive models leads to more cost-effective data collection and goal definition, and builds consensus on a course of remedial action. These advantages should be made explicit to improve the timetable for broad implementation of the Great Lakes Water Quality Agreement in the Areas of Concern.

3.3.4 Recommendations

Thus, the Board concludes that strong leadership from the International Joint Commission family, and demonstration of the utility of modelling through successful case studies, is needed to assure systematic analysis of remediation options and costs at AOCs. The analysis is needed also to build confidence in the decisionmaking process, and to support strategies for the most cost effective data collection, monitoring and remediation. It is recommended that:

• the Commission urge the Parties to utilize state-of-the-art predictive capabilities and apply them widely to assure cost effective and timely improvements of water quality at Areas of Concern, and in the Great Lakes generally

• the Commission support proposals for a basinwide workshop to exchange experiences between local officials and scientists who are using models successfully in Remedial Action Plans and others in the region who are considering proposals for local and lakewide remedial action
The Terms of Reference adopted by the Workgroup on Ecosystem Health and approved by the Science Advisory Board at their 87th meeting, September 17, 1992 meeting are as follows:

**Fundamental Principles**

- People are part of, and not separate from, the rest of the ecosystem
- Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO)
- The "weight-of-evidence" approach is a sufficient basis for policy development

**Mandate and Responsibilities**

1. Interpret and advise on public policy and perspectives underpinning that policy affecting and affected by the Great Lakes Basin Ecosystem health through an ecosystem approach

2. Investigate and devise systematic and comprehensive means of assessing the health of the Great Lakes Basin Ecosystem, including the essential community structure and life-sustaining processes

3. Identify and anticipate injury to biodiversity and the integrity of the Great Lakes Basin Ecosystem revealed through multiple perspectives on the environment

4. Advise the International Joint Commission, through the Science Advisory Board, on:
   - the current state of knowledge and data gaps on exposure through all media of humans and other biota to hazardous substances
   - evaluation of the relationships between exposure to hazardous substances or agents and ecosystem health status (e.g. risk assessment)
   - assessment of the value of the usefulness of different biological markers in an ecosystem approach
   - development of a comprehensive approach for monitoring ecosystem health
   - development of strategies for ecosystem disease/injury prevention and restoration

The workgroup was formed to further develop, explore and identify the concept of ecosystem health as it pertains to the Great Lakes basin. The concept of ecosystem health is developed by analogy through understanding human health, animal and plant life health, the health of communities, and the complex interactive development of all biota and abiotica found in one place at one time. The workgroup is exploring the conceptual framework that follows from this analogy encourages a focus on ecosystem health in the broadest of terms. This includes evaluation of changes, orderly flow, harmonic and disharmonic interrelationships, flexibility, resilience, sustainability, productivity and reproduction. The workgroup has widened the discourse in an attempt to move more freely between more traditional notions of human health and rich ecosystem function, and in so doing explore complex and new (or at least unrealized) relationships in the ecosystem.

An example of the complexity of the ecosystem health approach is the area of ecosystem stress, for which there is no identity or simple prescription. Consider oxygen in the atmosphere. In very real ways it is a pollutant, the end product of photosynthesis. For human and other
eucaryotic organisms, oxygen is a part of a healthy ecosystem. However, for anaerobic bacteria, oxygen is a toxic environmental pollutant of the entire ecosystem. This raises the issue of the nature of pathology. In human health, pathology is easier to identify than in ecosystem health. The problems of definition of wellness and pathology not only for humans, but other species and the entire complex ecosystem, is very difficult.

If defining ecosystem health is difficult and complex, developing sensitive tools and methods to measure ecosystem health is even more challenging. There are, however, several indicators of ecosystem health that have been employed over the years as measures of ecosystem health such as species diversity and/or loss of habitat. Similarly, the health of birds or fish that are high in the food chain has for a long time been suggested as a bioindicator of ecosystem health.

Nevertheless, new methods to study ecosystem health that are more sensitive and address the complexity of the ecosystem must be developed. This new methodology must not only bridge the scientific disciplines but also transcend the traditional boundaries of the biological, physical and social sciences. There is a growing recognition of the need for a “transdisciplinary approach” to ecosystem science employing a systems analytical framework to integrate the “knowledge base” developed in specialized scientific domains such as plant, animal and human physiology, toxicology, molecular biology, chemistry, ecology, community health, economics, political sciences and ethics. The implementation and design of such ecosystem health research must also incorporate the stakeholders across the basin who have valuable knowledge and perspectives to contribute, not necessarily by virtue of any formal training but because they live and work in the basin.

4.1 Activities of the Workgroup on Ecosystem Health

The workgroup in its first year has participated in five activities to explore the complexities of ecosystem health and to develop methods and tools to monitor the ecosystem. The first and possibly the most important was the inception of the workgroup itself, and the start of the members' dialogue on ecosystem health as outlined above. In addition, the workgroup sponsored one major workshop “Our Community, Our Health: Dialogue Between Science and Community,” and members participated in three other workshops on integrating human health considerations in Remedial Action Plans, bioindicators as a measure of success of virtual elimination of persistent toxic substances, and risk assessment, communication and management in the Great Lakes basin. Reports on these three sessions will be presented in greater detail in other submissions to the Commission.

4.1.1 Workshop on Our Community, Our Health: Dialogue Between Science and Community

This workshop, held September 14 and 15, 1992 in Ann Arbor, Michigan, was called to examine ecosystem health issues from the scientific and community points of view. Its goal was to explore how the scientific and the general public communities perceive each other, and to identify opportunities for both communities to work together to improve the overall health of the ecosystem.

Workshop participants included Commissioners, representatives of environmental and community organizations, scientists actively working in a range of health areas, public health officers, representatives of industry and governments. A full report of this workshop is available as a separate publication of the International Joint Commission (Commission or IJC).

The workshop was divided into several sections. First, leaders from several community groups discussed their environmental concerns: how they have tried to deal with their environ-
mental issues; how they involved public health officers and specific scientists; how their concerns were addressed by the scientific and public health communities and how they attempted to scientifically study their community’s health. Community groups present were the East Toronto 2000 Participatory Health Study and the Akwesasne Mother’s Milk Project, representing native communities’ traditional ecosystem approach.

In the second section of the workshop, ecosystem health investigators discussed the complexity of current scientific models and the limitations of the models, methods and results. A significant limitation of many studies is the inability to extrapolate the results of one study on one species to other species or locations.

The workshop participants then discussed four areas of community/science concern:

- scientific uncertainty and the weight-of-evidence approach for making decisions
- extrapolating data from the very small (biochemical indicators or individual communities) to the very large (ecosystem as a whole)
- the role of science and professional scientists in environmental health concerns of the community
- communications between the concerned general public and the scientific community

The following thoughts were generated in the discussions of the four major topics. These thoughts and suggestions in some cases did not constitute the general consensus of the workshop, but are listed because they demonstrate a distinct point of view:

**The Weight-of-Evidence Approach**

- The weight-of-evidence concept must be developed into a comprehensive, explicit process for environmental decisionmaking
- The IJC’s determination, in 1990 and 1992, using the weight-of-evidence approach that persistent toxic substances should be virtually eliminated from the Great Lakes basin, is strongly supported

**Inference Across Levels of Biological Organization**

- Our ability to draw inference from the very small (e.g. molecular effects in individuals, or effects in single populations or communities) to the very large (clinical effects in individuals, and effects at the ecosystem level) needs further development
- Of greatest importance are biological indicators of stress from hazardous substances that provide early warning of adverse effects. Research and development of these indicators must be supported, and governments must officially recognize their value
- The general public needs to be educated about the importance, meaning and implications of biological indicators
- Ecosystem-level indicators must also be developed to enable inference in the opposite direction, from the very large to the very small

**The Role of Scientists**

- Scientists are encouraged to become involved in community-based health studies, in policy advisory committees, and in environmental advocacy
- The IJC should promote the establishment of mechanisms by which “resource poor” organizations and interests can obtain scientific information, referrals and direct assistance, particularly in dispute situations
- Scientists should be trained in advocacy methods, cross-disciplinary and cross-sectoral teamwork, and a more holistic approach to data collection and analysis
- Environmental health studies should not be undertaken in a community without the community’s explicit permission
Environmental health studies should encourage community participation and involve community members wherever possible.

Environmental health studies should provide direct benefits to the community, including environmental health education, training, employment, quick feedback of study results, and assistance in developing strategies for community action to reduce or eliminate the effects of environmental problems.

The IJC should encourage harmonization in data collection so that data can be shared across the basin.

A binational inventory of data on the use, release and storage of hazardous substances should be developed.

Pharmaceutical drug use patterns, such as antihistamines, asthma inhalers, and/or thyroid supplements should be investigated as potential bioindicators of community health status.

Communication

- The recommendations of the IJC's Sixth Biennial Report (1992) are the substance of what needs to be communicated at this time. This includes the weight-of-evidence concept and its implication: virtual elimination of persistent toxic substances. To be effective, the recommendations need target dates.
- The IJC should encourage and facilitate communities, organizations and governments at all levels to review the Biennial Report, to excerpt, summarize, endorse and adopt the recommendations, as appropriate; and to communicate their endorsement to the two federal governments.
- While changes are needed at the individual lifestyle level for society to change course, these recommendations need to be communicated to and acted upon by legislators.
- The IJC should take new initiatives to communicate its recommendations to a wider audience. This might involve presentations at major conferences and working more actively with the network of individuals and organizations already aware of the IJC's policy recommendations.

Working Together

- Value positions must be in the open, acknowledged and respected for any multi-party process to work.
- Environmental decisionmaking processes should respect the concerns and experience of affected communities as valid.
- The use of partnership processes for identifying problems, finding and implementing solutions, and evaluating effectiveness should be promoted.

After the workshop, the workgroup and then the Science Advisory Board examined the discussions, comments and recommendations. Based on their conclusions, the Science Advisory Board recommends that:

- the Commission further promote the weight-of-evidence concept as a comprehensive explicit tool in support of environmental decisionmaking.
- the Commission promote the establishment of mechanisms by which "resource poor" organizations and the general public can obtain scientific information, referrals and assistance.
- the Commission promote studies examining the effects of the environment on ecosystem health that take into account the empowerment, participation and involvement of the community in all aspects of the study, including design, conduct and interpretation.
- the Commission encourage comparable state-of-the-art methodologies with appropriate Quality Assurance/Quality Control in basin studies to certify the sensitivity, accuracy and reproducibility of the methods in each laboratory.
the Commission take new initiatives to communicate its recommendations to a wider audience. This might involve presentations at major conferences and working more actively with the network of individuals and organizations already aware of the policy recommendations.

4.1.2 Workshop on Integrating Human Health Considerations in Remedial Actions Plans Workshop

The Workgroup on Ecosystem Health assisted the International Joint Commission’s Remedial Action Plan Steering Committee in planning a Roundtable on Integrating Human Health Issues into Remedial Action Plans (RAPs). Members of the workgroup participated in the session held at Toronto in January 1993. About 25 RAP practitioners and health professionals, Commission Co-Chairs Lanthier and Durnil, and Commissioner Walker also attended.

A high degree of support was expressed for the need to incorporate information about human health considerations in RAPs and to involve health professionals in the process at the community level. In order for this to happen, however, a number of initiatives are required:

- RAP coordinators should encourage persons with human health expertise and local experience to become involved in RAPs and their public advisory committees.
- Opportunities should be provided for health professionals to become more aware of environmental issues as they relate to human health and humans as part of broader ecosystem health.
- Relevant data and scientific information and guidelines in particular are needed to identify what indicators of human health should be incorporated into RAPs.

In considering these issues, the workgroup noted that some progress is being made by RAP coordinators to encourage the involvement of local human health experts in the development of RAPs. The Commission itself has been encouraging the development of education programs for health professionals.

The workgroup proposed that the Science Advisory Board develop a list of potential human health indicators and recommend guidelines on how RAPs should discuss, assess, study and monitor human health in Areas of Concern. This could initially be accomplished with one or two RAP teams to ensure the practicability of the tool. Baseline information is needed for potentially important parameters of human health as suggested in Table 4.1. Once these RAP parameters have been studied, they can be monitored to demonstrate the benefit to human health from the implementation of RAPs. The discussion and study of these parameters can also be used to educate the public about the ecosystem, the health risks in Areas of Concern, the feasibility of health studies, and the links between human health and overall ecosystem health.

It is recommended that:

- the Commission promote the assessment of human health in Remedial Action Plans by encouraging Remedial Action Plan groups to involve human health experts in RAPs in their public advisory committees.
- the Commission, in conjunction with several Remedial Action Plans teams, develop guidelines for selection of human health indicators in Remedial Action Plans, taking into account the feasibility of the indicator to be studied and its importance, sensitivity and specificity.
### TABLE 4.1 Partial list of possible human health indicators of ecosystem health

**HUMAN REPRODUCTION: Control for mother's residence during pregnancy**

1. Proportion low birth weight newborns and/or microcephalic newborns
2. Proportion of premature newborns
3. Sex ratio of liveborn
4. Contaminants in breast milk
5. Birth defects (anatomical/functional)
6. Toxicological studies of chord blood and/or placental tissue
7. Infertility

**CHILDREN: Pre-first grade physical examination**

1. Asthma/respiratory infection
2. Serious allergies
3. Height, weight and nutritional status
4. Standardized neurological testing
5. Blood lead testing (venous)
6. Skin problems
7. Eye irritation, redness or puffiness
8. Lymphadenopathy
9. Learning disabilities
10. Sexual maturation

**ADULT: Hospital discharges and other indicators**

1. Ischemic heart disease/cardiovascular diseases
2. Respiratory diseases
3. Cancer incidence
4. Neurological dysfunction

---

4.1.3 Workshop on Bioindicators as a Measure of Success of Virtual Elimination of Persistent Toxic Substances

Members of the workgroup also participated in the planning and sessions of this workshop held in Ann Arbor, Michigan during April 1992. A section of this workshop was focused on biomarkers, which are currently being developed by the workgroup as indicators of ecosystem health in the Great Lakes basin. The proceedings of the Workshop on Bioindicators is available as a report to the IJC Virtual Elimination Task Force.

The Workgroup on Ecosystem Health will continue to develop holistic approaches to, and biomarkers for the health of the Great Lakes Basin Ecosystem. The intent is to shift the focus from catastrophic endpoints to very early indicators of harm, with the view that early remediation and prevention can reverse the trend. The workgroup will also participate in a joint event with the First International Symposium on Ecosystem Health and Medicine, to be held June 18-22, 1994, in Ottawa, Ontario.

It is recommended that:

- the Commission encourage research and development of indicators, including ecosystem-level indicators, which will demonstrate the links between ecosystem stress and human health
- the Commission promote public education about the importance, meaning and implications of the interrelationship of ecosystem and human health
4.1.4 Workshop on Risk Assessment, Communication and Management in the Great Lakes Basin

Risk assessment is a concern of several groups within the IJC community. The Commission, as a priority for the 1991-1993 biennial, directed the Water Quality Board in concert with the Science Advisory Board, Workgroup on Ecosystem Health and others, to review the various ways the Parties and jurisdictions assess and manage risks, how consistent they are -- both between and within agencies and countries -- and how the Parties communicate risk assessments to the communities. Papers given at the workshop will be published separately and a synopsis of the workshop may be found in the Water Quality Board report to the IJC.

4.2 Future Directions for Research on Ecosystem Health

4.2.1 Measuring Ecosystem Health

The concept of ecosystem health must continue to be developed by identifying ways in which ecosystem health can be measured, educating the general public on ecosystem health and its importance to the human, and exploring how the scientific community and the local community can work together to study, understand and improve ecosystem health.

4.2.2 Weight-of-Evidence

The Commissioners, in their Sixth Biennial Report, recommended that the Parties adopt and apply a weight-of-evidence approach to the identification and virtual elimination of persistent toxic substances. There is a need to develop a working framework for the term “weight-of-evidence.”

4.2.3 Human Health Assessment Parameters in Remedial Action Plans

The workgroup is dedicated to the concept of ecosystem health. In that context, and since RAPs have frequently not included human health analysis or assessment, there is a need for RAP developers to examine the relevant human health bioindicators in Areas of Concern and adopt those parameters that are the most sensitive, practical and feasible to implement in the RAPs.
5. **STATE-OF-THE-LAKES REPORTING: SOCIAL AND ECONOMIC STRESSORS**

The 1991 Science Advisory Board (Board or SAB) Report to the International Joint Commission (Commission or IJC) discussed the need for a comprehensive reporting strategy for the Great Lakes Basin Ecosystem (IJC 1991a). The SAB's comments focused on the integrity of natural ecosystems in context of human stress factors, an approach consistent with the Great Lakes Water Quality Agreement (Agreement or GLWQA) definition of the Great Lakes Basin Ecosystem:

... the interacting components of air, land, water, and living organisms, including humans, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States.

*Article I (g) of the GLWQA, 1978*

In response to the IJC priority to determine data needs to assess the state of the lakes, particularly the IJC role under Article VI1 of the Agreement, the Science Advisory Board established an *ad hoc* workgroup to examine the options available to the IJC with respect to the surveillance and monitoring programs described in Annex 11 and other reporting requirements specified by the GLWQA. This led to an inquiry into the nature and scope of integrated state-of-environment (SOE) reporting, with a particular focus on the frameworks used to link human activities with biophysical changes. A review of the current state of international, national and regional SOE reports was commissioned in order to assess the state of the art in this rapidly evolving field (Karasek 1992, unpublished). This study was further analyzed and summarized in a report entitled "Past Lessons, Future Directions: An Assessment of Great Lakes Basin Ecosystem Reporting" (Hodge 1993, unpublished). These studies provided much of the background material for the following analysis and conclusions.

5.1 **The Commission and State-of-Environment Reporting**

The IJC involvement in state-of-environment reporting may be traced to public concern over rising pollution levels in the connecting channels in the late 1940s. While the first pollution study was a 1912 reference on pollution of boundary waters, serious concerns emerged three decades later regarding the pollution of the St. Clair, Detroit and St. Marys Rivers, Lake St. Clair and the Niagara River. The first reference to the whole lake was that of the pollution of the lower Great Lakes, followed by the upper Great Lakes. About the same time a large-scale land use study was undertaken, referred to as the Pollution from Land-Use Reference Group (PLUARG). The analysis of surveillance and monitoring data on Great Lakes pollution has subsequently been identified as a "reporting responsibility" of the Commission. Thus, the IJC defined a functional role of essentially assessing the change in the environmental state of large-scale systems. Paradoxically, the mandate for this now dominant activity of the IJC evolved from a secondary clause in the 1909 Boundary Waters Treaty (Article IV):

*It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.*

The primary purpose of the Treaty, however, is clearly noted in the order of precedence with respect to conflicting water uses; that is:

- Uses for domestic and sanitary purposes
- Uses for navigation, including the service of canals for the purposes of navigation
- Uses for power and for irrigation purposes
No mention is made of the uses of waters to support healthy and flourishing biological habitats, (i.e. integrity of aquatic ecosystems). The concern for polluted waters was, in the main, directed at public health issues (cholera and typhoid) and property damage.

While a North American conservation movement was emerging at the time, little of this ideology was reflected in the articles of the Treaty. Nonetheless, a quotation from Theodore Roosevelt's message to Congress in December 1908 demonstrates that the concept of long-term sustainability of resources was a critical factor in the environmental conservation debate, to wit:

*Any real civilized nation will so use [its] national assets that the nation will have their benefit in the future. Just as the farmer, after all his life making a living from his farm, will, if he is an expert farmer, leave it as an asset of increased value to his son, so we should leave our national domain to our children, increased in value and not worn out.*

*National Geographic* 1909

Seventy years later, the concept of the Great Lakes Ecosystem Basin defined in terms of a “national asset” was incorporated into the Great Lakes Water Quality Agreement of 1978.

The desirability of a more holistic approach to state-of-the-lakes reporting gained currency from the scientific community with the widespread public alarm of the “dying lakes” in the 1960s. The establishment of advisory groups under the 1972 GLWQA provided the framework for a comprehensive approach, taking into account whole lake systems in studies, research and survey activities (the Science Advisory Board and its predecessor, the Research Advisory Board has produced approximately 76 reports between 1972 and 1992; IJC 1992a).

A major step in the development of comprehensive assessments occurred with the IJC study on pollution of the Great Lakes by land use activity, referred to as PLUARG (Pollution from Land Use Activity Reference Group; IJC 1978, 1980). The key concern was to identify the origin and level of pollution from nonpoint sources and to determine the implications of such loadings from the perspective of environmental management of the Great Lakes basin. The reports from this wide-ranging reference directed attention to the importance of an integrated air-land-water approach to the environmental restoration of the Great Lakes system. The new problems identified by this study included the serious impact of agricultural and urban runoff on Great Lakes water quality, the unexpectedly high loads of contaminants from air pollution, generated from both within and beyond the basin, and the potential for delayed impacts from accumulated toxic substances in sediments and waste dumps. While these activities greatly improved understanding of the dynamics of the interactive forces of ecosystems and human activities in the Great Lakes system, they did not provide a coherent picture of the state of a system as complex as the Great Lakes Basin Ecosystem.

5.2 The Challenge to Science of State-of-the-Environment Reporting

One main purpose of SOE reporting is to provide a framework for synthesizing data. These reports are public documents that not only describe and assess environmental trends but also imply some degree of “accountability” in the field of public decisionmaking. They also challenge the scientific community to transcend disciplinary boundaries to connect the parts to the whole. This latter objective has proven to be difficult in practice. For the most part, SOE reports to date have not fully reflected integrative concepts like ecosystems and sustainable resource use. A major challenge of SOE reporting is in development of:
• diagnostic indicators of ecosystem health
• relevant measures to assess the level of environmental stress
• an integrated reporting framework, or model, monitoring the dynamic spatial and
temporal dimensions of environmental stress and response
• a framework for interpreting data in the context of differing community values concerning
environmental quality2

There is a growing awareness among scientists, and to some extent the public, that no com-
pletely objective means exists to measure the level of ecosystem health, and/or integrity. Science is
increasingly being challenged to explore the boundaries of the traditional scientific methods in order to
explain complex behaviour. These approaches can serve not only to advance knowledge but also as
"decisionmaking tools" for the management of whole systems in the future. While the specific nature
of these new approaches is still unclear, its general characteristics can be described as:

• Transdisciplinary, the need to transcend the traditional boundaries of the sciences, both
physical and social, to communicate specialist experience and knowledge more effectively
and to re-draw boundaries for scientific research

• Integrative, employing general systems theory and methodologies to link the social and
physical sciences

• Predictive, applying advanced computer technology to develop dynamic spatial/temporal
models (supported by the growing volume of real-time monitoring from both ground and
remote sensing platforms), to anticipate future states and to provide user friendly
decisionmaking and education tools.

• Community Oriented, placing primary emphasis on social and cultural values of communities and regions as opposed to the traditional object of social observation like the household or individual. Thus the object of inquiry becomes the community in context to its institutions and cultural values.

Despite the uncertainty in the science of assessing the state of the environment, national
reports are now undertaken routinely in most of the industrial world and increasingly by developing
countries. Governments everywhere are beginning to recognize that environmental protection,
conservation and restoration activities are as integral a part of governance as managing the
economy or implementing programs to improve education, health and security. To date, SOE
reporting has been viewed largely as a function of national governments and international envi-
ronmental agencies, such as the United Nations Environment Program. There has been a growing
demand for regional and local reports produced by state, provincial and municipal governments,
however, as well as nongovernment organizations and industry.

5.3 General Conclusions from Current State-of-the-Environment Reports

Formal government efforts in environmental reporting originate from the early 1970s. The annual
report to the President of the United States produced by the Council for Environmental Quality
(CEQ) must be considered a pioneer. However, it was not until the Organization for Economic

2 These values may change over time or may differ with respect to cultural background and economic status. While values can,
to some extent, be measured by surveys, the most realistic reflection is through the political process. What is important to note,
however, is that SOE reporting should be sensitive to the distinct values of different communities and employ a pluralistic
approach to the evaluation of environmental change. Native peoples for example might place higher values on access to
plentiful fish and wildlife than on economic compensation to enable these people to find alternative means of livelihood.
Cooperation and Development (OECD) established an Expert Group on the State-of-Environment in 1976 that the questions of the nature and scope of these reports were examined with respect to their use in decisionmaking and their role in public accountability of human actions.

As might be expected, the experience of "economic reporting" within the OECD and national governments influenced SOE reporting, placing emphasis on statistical indicators of environmental change and the presumed causal factors. While ecosystem integrity was recognized as an important objective function, the actual reporting protocols largely reflected the existing institutional framework for environment and resource management responsibilities in order to link public policy responses with environmental degradation. The OECD Expert Group on SOE reporting emphasized the need for reliable reporting statistics, including the specifications for a commonly agreed set of environmental indicators. This approach, based on a "stress-response framework," was adapted in many OECD countries for their national SOE reports.

While there is much in common between environmental and economic reporting, there are also distinct differences. First, there are no broadly accepted protocols for assessing ecosystem health. This is in contrast with an assessment of "healthy economies" based, for the most part, on accepted "diagnostic" indicators such as rate of inflation, level of employment and balance of payments, which are identifiable with daily experience such as cost of living, availability of work, or foreign exchange rates. Thus, economic conditions are, for the most part, a function of a well defined decisionmaking framework. Environmental conditions, on the other hand, are more in the nature of "unintended" results of human actions, referred to in the economic literature as the "externalities" of production and consumption. In addition, it is sometimes difficult to choose the appropriate indicators to reflect the spatial and temporal scales when monitoring environmental conditions.

Additional conclusions drawn from recent experiences in SOE reporting are:

1. **Need for a commonly agreed upon SOE reporting framework:** While economic reporting has established a set of reporting protocols subscribed to by all agencies concerned with the analysis of economic performance or the effectiveness of policy initiatives, these kinds of protocols have yet to be achieved for SOE reporting.

2. **Weak links to decisionmaking:** Human intervention is generally recognized as the agent of both environmental degradation and improvement, however the underlying decisionmaking processes that affect this are rarely addressed. To achieve this would require deeper analysis of the actions of governments, businesses and households and the effect of their interlocking behaviour on environmental decisions. For example, farmers may believe that agricultural chemicals are environmentally harmful, yet still feel they must use them to compete successfully in the market. Such choices must be examined as an outcome of national economic policies and international trade, as well as local economic conditions. A critical element is often the incompatibility between economic and environmental "time horizons" in social decisions.

3. **Inadequate understanding of the human-ecosystem interface:** It is generally acknowledged that we are only beginning to understand the global interconnectedness between human well-being and ecosystem health. Scientific predictions and assessments of actual injury are difficult to validate and thus may be ignored by decisionmakers as simulations, not hard facts. SOE reports are generally introduced with holistic concepts about links between humans and ecosystems, but their underlying premise is rarely pursued in actual analysis. Instead, what is presented is a report of a fragmented environment divided into the familiar categories of air, water and land. At best, a trend analysis is presented of the human environment in its institutional context, i.e. agriculture, forestry, fisheries and human settlement. The ecosystem approach advocated by the GLWQA, the IJC and others clearly suggests that the focal point of SOE reporting must be human activities linked to ecosystem function and goals.
4. **Reports are rarely anticipatory:** The public, and in particular decisionmakers, are more responsive to future expectations rather than historical trends. A major criticism of SOE reports is that they provide impressive compilations of data on environmental conditions but often do not provide conclusions of “what will happen if things go on as they are.”

5. **Inadequate environment-economy linkages:** The key parameters of environment and economy integration are those that measure rates of resource extraction with respect to available stock and pollution loading to represent assimilative capacity. SOE reporting in its current form is largely concerned with the latter, and thus limits economic linkages to pollution loading and costs of environmental cleanup. Improvements are needed so that SOE reports address the full cycle of resource extraction, economic production and the reabsorption of waste matter and energy in the environment. With the growing focus on sustainable development and the escalating costs of environmental degradation, a strong argument could be made for strengthening the environment-economy linkages in SOE reporting.

6. **Limited treatment of social equity and participatory decisionmaking:** While the case for environment-economy linkages is well articulated, the same cannot be said for environment-social equity linkages (i.e. who wins and who loses in the distribution of environmental degradation). Apart from human exposure to environmental contamination, the opinion prevails that cultural and aesthetic values are either already embedded in economic values (e.g. ecotourism) or could be obtained indirectly by survey methods to ascertain non-market environmental values (e.g. willingness to pay). Most SOE reports have avoided the difficult question of the social distribution of environmental goods and services, in part because of the subjective nature of environmental values and in part because of the very real difficulties in developing statistical surveys linking the state of the environment with human conditions. Despite these difficulties, there is an increasing concern with the application of methods and techniques for integrating ecosystem health with human well-being. Furthermore, environmental and public health policies are increasingly acknowledging social and cultural values in the management of the environment, such as native peoples claims to ancestral lands, urban values in protecting old growth forests, and community values in decisionmaking.

7. **Restrictive analytical boundaries of SOE reporting:** Once one is drawn into the world where “everything is connected with everything else,” category boundaries lose all meaning. Nonetheless, a reporting process that ignores traditional categories like air, water and land can become confusing unless they are transcended by descriptions of the behavioural characteristics of the system itself. In addition, one or several, “objective functions” must be identified in order to develop selection criteria to observe factors assumed to be important influences on the state of the system. For example, the maintenance of the integrity of the Great Lakes Basin Ecosystem defined in the GLWQA is such an “objective function.” This approach to SOE reporting would steer away from the familiar categories of air, water and land, and identify systems categories like the generation of waste residuals, harvesting and permanent environmental restructuring. Other influences, albeit more abstract, are cultural values, legal frameworks, proprietary rights and the distribution of wealth. These human expressions have a profound influence on the state of the environment but are nevertheless difficult to define with respect to observed behaviour, except when activities are reflected in markets and prices, such as land values.

8. **Authorship:** SOE reporting is largely undertaken by official agencies, usually by environmental departments. In some countries the national statistical office has taken a lead role. Government-produced SOE reports stem largely from a legislated mandate to provide public information. The sheer amount of work required in data collection and analysis, it has been argued, makes it difficult for anyone other than a government agency to produce these reports. Government agencies tend to prefer delivering good news stories to their constituencies. Thus, it has been suggested that an independent reporting agency would better satisfy the audit function and would be less inhibited in interpreting data and projecting trends.
Conclusions from the Great Lakes Reporting Experience

1. **Data collection, analysis and dissemination:** In the past 25 years, monitoring, surveillance and research have produced a large amount of scientific data on the changing state of the Great Lakes Basin Ecosystem. This experience is probably unique in the world, with respect to scale and degree of international cooperation. Of particular significance is the institutional framework that made this possible and the high level of influence this publicly accessible information has had on policies of environmental cleanup and resource conservation. The Great Lakes experience has valuable potential for transfer elsewhere in the world, where people are addressing large-scale ecosystem degradation and competition for shared resources.

2. **Data synthesis and the IJC:** Despite the availability of environmental information, little effort is devoted to data integration and synthesis under the GLWQA. The major direct sources of SOE data are those obtained from: (a) the "regulator," whose concern is level of compliance and target performance with respect to specific contaminants; (b) the resource manager, whose concern is the availability and access to stock; (c) statisticians concerned with surveys; and (d) researchers concerned with critical variables of environmental changes. Only the (c) and (d) sources are of sufficient generality to be useful for SOE reporting, whereas the selectivity and partiality of the (a) and (b) sources makes these data suspect as unbiased samples of general trends. As a result the state of the Great Lakes is reported in a fragmented manner. The IJC, given its mandate, could play an important leadership role in encouraging the development of an information base consistent with "ecosystem concepts" in which human activities are a subcomponent of the basin ecosystem. It is only by developing and capturing the "collective memory" of the Great Lakes community that the long-term perspectives required to maintain ecosystem health and human well-being in the Great Lakes basin can be achieved.

3. **Need to assess human well-being:** As the concern for resource sustainably and the need to restructure the processes of production and consumption increases, there will be a need for Great Lakes Basin Ecosystem assessments to include human well-being. The IJC has taken the initiative in reporting on human and ecosystem health concerns. It seems likely that this will expand the question of well-being to whole communities, particularly in reference to native people, the urban poor, and communities vulnerable to resource degradation and depletion.

4. **Human activity and the GLWQA:** The reporting specifications of the Agreement generally focus on the physical, chemical and biological properties of impaired uses (Annex 11). Remedial Action Plans and Lakewide Management Plans, however, do include several socio-economic parameters in identifying impaired uses and assessing progress in restoration (Annex 2). The Science Advisory Board has recommended on several occasions that the "ecosystem approach" includes assessments of human activities that cause stress to ecosystems and human health, and result in socio-economic costs and benefits for the whole basin. For these reasons, and expected future demands, it may be worthwhile to reconsider the nature and scope of reporting on human activities in the basin, in relation to Annex 11.

5. **Assessing ecosystem integrity:** This remains the central reporting issue for the Great Lakes Basin Ecosystem. The IJC has played an important -- and to some extent pioneering -- role in advocating concepts of ecosystem integrity, calling for objectives and indicators of ecosystem health. Nonetheless, this is an ongoing and critical task that is still in the early learning stages. The IJC could, through its continued leadership, encourage the development of the research, education and policy initiatives required to establish this process on a solid foundation.
5.5 **Recommendations**

1. Given the IJC leadership role in reporting on the State of the Great Lakes Basin Ecosystem and its responsibility for assessing progress in implementing the GLWQA, the SAB considers that the data specification in Annex 11 and other reporting requirements in the GLWQA are insufficient to measure progress with respect to an ecosystem approach to the management and restoration of the Great Lakes. It is recommended that:

   - the Commission evaluate the various reporting responsibilities under the Agreement and develop a systematic approach to data organization and the reporting strategies of the Parties in order to assess progress under the Agreement

2. Given that the IJC has a reporting function with respect to the Great Lakes Basin Ecosystem, and that comprehensive SOE reports are underway and planned by various governments and NGOs recommended that:

   - the Commission continue to provide advice on an ecosystem approach that will encourage the synthesis by the Parties of U.S./Canada data and information requirements under the Agreement

3. Given the new insights stemming from holistic science with respect to the interrelationship of human well-being and ecosystem integrity and the shift towards policies that are consistent with sustainable resource use, recommended that:

   - the Commission encourage the Parties to continue to support educational/research programs directed towards Great Lakes communities on the implications of sustainability within the limits of the “carrying capacity” of the basin ecosystem
Success in achieving the purposes of the Great Lakes Water Quality Agreement (Agreement or GLWQA) is increasingly related to questions that are broader than the Agreement itself. While some of these questions do not appear to be directly relevant to the Agreement, they are nonetheless appropriate due to socio-economic changes that have occurred since the Agreement was signed.

The expansion of North American -- and indeed global -- trade and related policy discussions have linked economic and environmental policy. With the increasing adoption of policies directed toward sustainable development, the environmental carrying capacity of the North American continent is likely to have a significant effect on the economic future, as well as the course, scope and success of environmental policies and programs. These and other questions do not fall into traditional fields of science but profoundly affect environmental management in the Great Lakes Basin Ecosystem and hence, the future science needs that underpin our stewardship of the basin. In this concluding chapter, the Science Advisory Board (Board or SAB) poses a number of open questions which it considers important for the International Joint Commission (Commission or IJC) and the Parties to consider and to factor into future plans and programs for the Great Lakes.

6.1 Goals

Since 1972 when the Great Lakes Water Quality Agreement was signed, new needs, laws and programs have increased the scope and complexity, and in some cases, fragmentation of Great Lakes environmental and natural resource programs.

Question:

- Will the scope and substance of the goals of the GLWQA and future multi-lateral agreements be clear and consistent? Do they need further definition or clarification in order to work in harmony? Are there gaps or overlaps? How do these fit with binational, national, provincial and state environmental goals and programs?

6.2 Policy and Management

Since the 1972 GLWQA, two management schemes have dominated the work of the Parties and the IJC:

- Strategic implementation of plans to reduce point source loadings
- Extensive studies of other problems such as Areas of Concern, nonpoint sources, persistent toxics and other sources with recommendations for strategies with limited implementation

Questions:

- What management strategies are most amenable to achieving the purpose of the Agreement, as expressed in Article II?
Should land-use management play a key role in the future management of the Great Lakes? Besides land use, what other resources, including air, need new management strategies in order to meet the requirements of the Agreement?

What is the best institutional framework to harmonize and implement future trade agreements with provincial and state environmental programs? To what extent would national sovereignty have to be shared in binational institutions in order to successfully attain the goals of the Agreement and to effectively manage the Great Lakes?

How can program implementation be more cost effective, attuned to modern management techniques and more responsive to the ecosystem approach?

6.3 Economics, Trade and Environment

The emergence of international trade agreements and negotiations is increasingly relevant to environmental policies and create a new policy setting agenda for the GLWQA.

Questions:

- In setting North American environmental standards, should there be different policy zones, for example: (a) to address the special problems of international boundary waters and land; (b) interior zones; and (c) zones affected by transboundary transport of pollutants?

- What are the social impacts of the rising costs associated with matters such as more stringent environmental standards, chemical bans, environmental infrastructure, Areas of Concern, pollution from combined sewers, continuing point and nonpoint pollution, air deposition of toxics, groundwater pollution, and poor management of environmental programs?

- Considering the above, what are the costs of fully implementing the Great Lakes Water Quality Agreement? How can these costs be met? What are the best examples of creative links between government and industry in minimizing these costs?

- What can be learned from the experience of others in the international community in connection with "polluter pays," "beneficiary pays," and "user pays" principles?

- To what extent can and should social equity and income redistribution be shaped to mitigate the impacts of rising infrastructure costs (e.g. municipal wastewater management)?

- Should there be policies that differentiate between program and facility age? Should there be differentiation between new and old industrial plants? Should consideration be given to economic marginality of industries and communities in terms of financial assistance and standards?

- What are the links between transportation policy and the environment? What are the transportation needs within the Great Lakes region, and what are the options for meeting those needs relevant to environmental goals?

- How can subsidies, taxes, marketable permits, financial assistance and pricing be shaped to serve as stimulants to pollution cleanup and environmental management?

- How can economic sanctions from trade agreements, voluntary procurement policies by manufacturers and laws restricting purchases by governments from polluters be used to advance compliance with the Agreement?
- How can economic development programs, binational, regional and global duties, tariffs and trade barriers, sanctions and industrial policies be shaped and redesigned to enhance the process of environmental management? Should there be subsidies and tariff exemption for environmental pollution control products and services?

- What will be the relationship of the GLWQA to future trade agreements?

### 6.4 Recommendation

In reviewing the range of issues, the SAB believes it is necessary to move beyond the present scope of the Agreement and to consider emerging trends in the areas of trade, economy, social impact and infrastructure. It is recommended that:

- the Commission, together with the Parties, undertake a binational review of the implications of economic policy and trade commitments relative to the goals and purpose of the Great Lakes Water Quality Agreement to identify opportunities for implementing the Agreement through improved environment and economy linkages.
7. REFERENCES


Schlesinger, M. and Z. Zhao, 1988. Seasonal climate changes induced by doubled CO$_2$ or simulated by the OSU atmospheric GCM/mixed-layer ocean model. Oregon State University, Climate Research Institute, Corvallis, Oregon.


### I. Glossary of Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOC</td>
<td>Area(s) of Concern</td>
</tr>
<tr>
<td>AOX</td>
<td>Adsorbable Organo Halogens</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>CAMECO</td>
<td>Name of a company in Port Hope (formerly Eldorado Resources)</td>
</tr>
<tr>
<td>CCC</td>
<td>Cuyahoga River RAP Coordinating Committee</td>
</tr>
<tr>
<td>CCIW</td>
<td>Canada Centre for Inland Waters</td>
</tr>
<tr>
<td>CEQ</td>
<td>Council on Environmental Quality</td>
</tr>
<tr>
<td>CGLRM</td>
<td>Council of Great Lakes Research Managers</td>
</tr>
<tr>
<td>COA</td>
<td>Canada-Ontario Agreement</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CPA</td>
<td>Critical Programs Act</td>
</tr>
<tr>
<td>Cr</td>
<td>Chromium</td>
</tr>
<tr>
<td>CSO</td>
<td>Combined Sewer Overflows</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DIN</td>
<td>Data and Information Needs Workgroup</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichlorodiphenyltrichloroethane</td>
</tr>
<tr>
<td>EAC</td>
<td>Educators Advisory Council</td>
</tr>
<tr>
<td>ENGO</td>
<td>Environmental Nongovernment Organization(s)</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GLI</td>
<td>Great Lakes Initiative</td>
</tr>
<tr>
<td>GLTxRI</td>
<td>Great Lakes Toxics Reduction Initiative</td>
</tr>
<tr>
<td>GLWQA</td>
<td>Great Lakes Water Quality Agreement</td>
</tr>
<tr>
<td>GLI</td>
<td>Great Lakes Water Quality Initiative</td>
</tr>
<tr>
<td>GLTxRI</td>
<td>Great Lakes Toxics Reduction Initiative</td>
</tr>
<tr>
<td>HCB</td>
<td>Hexachlorobenzene</td>
</tr>
<tr>
<td>HCB</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>IAQAB</td>
<td>International Air Quality Advisory Board</td>
</tr>
<tr>
<td>IJC</td>
<td>International Joint Commission</td>
</tr>
<tr>
<td>KETOX</td>
<td>k-ε Toxics (Model)</td>
</tr>
<tr>
<td>Lind</td>
<td>Lindane</td>
</tr>
<tr>
<td>LwMP</td>
<td>Lakewide Management Plans</td>
</tr>
<tr>
<td>µg/L</td>
<td>micrograms per litre</td>
</tr>
<tr>
<td>NAFTA</td>
<td>North American Free Trade Agreement</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
</tr>
<tr>
<td>ng/L</td>
<td>nanograms per litre</td>
</tr>
<tr>
<td>NGO</td>
<td>Nongovernment Organization</td>
</tr>
<tr>
<td>Ni</td>
<td>Nickel</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>OCS</td>
<td>Octachlorostyrene</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OEPA</td>
<td>Ohio Environmental Protection Agency</td>
</tr>
<tr>
<td>OMNR</td>
<td>Ontario Ministry of Natural Resources</td>
</tr>
<tr>
<td>OMOE</td>
<td>Ontario Ministry of the Environment</td>
</tr>
<tr>
<td>PAH</td>
<td>Polynuclear Aromatic Hydrocarbon</td>
</tr>
<tr>
<td>PCB</td>
<td>Polychlorinated biphenyl</td>
</tr>
<tr>
<td>PLUARG</td>
<td>Pollution from Land Use Reference Group</td>
</tr>
<tr>
<td>ppb</td>
<td>parts per billion</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>QCB</td>
<td>Quintachlorobiphenyl</td>
</tr>
<tr>
<td>RAP</td>
<td>Remedial Action Plan(s)</td>
</tr>
<tr>
<td>SAB</td>
<td>Science Advisory Board</td>
</tr>
<tr>
<td>Se</td>
<td>Selenium</td>
</tr>
<tr>
<td>SOE</td>
<td>State-of-the-Environment</td>
</tr>
<tr>
<td>TOXIWASP</td>
<td>Toxics in Water Analysis Simulation Program</td>
</tr>
<tr>
<td>UGLCCS</td>
<td>Upper Great Lakes Connecting Channels Study</td>
</tr>
<tr>
<td>U.S. EPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Program</td>
</tr>
<tr>
<td>VETF</td>
<td>Virtual Elimination Task Force</td>
</tr>
<tr>
<td>WASP4</td>
<td>Water Analysis Simulation Program 4</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WQB</td>
<td>Water Quality Board</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater Treatment Plant</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
</tr>
</tbody>
</table>

Dr. Ed Addison
Ontario Ministry of Natural Resources
P.O. Box 5000 (10401 Dufferin)
Maple, Ontario L6A 1S9

Dr. Timothy F.H. Allen
Department of Botany
University of Wisconsin-Madison
Room 132, Birge Hall
Madison, Wisconsin 53706

Mr. Douglas Alley
(Secretary, Workgroup on Parties Implementation)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Anders W. Andren
Water Chemistry Program
University of Wisconsin
660 N. Park Street
Madison, Wisconsin 53706

Mr. Bruce L. Bandurski (Liaison)
International Joint Commission
1250-23rd Street, N.W., Suite 100
Washington, D.C. 20440

Dr. Kurt W. Bauer
Southeastern Wisconsin Regional Planning Commission
916 N.E. Avenue, Box 1607
Waukesha, Wisconsin 53187-1607

Dr. Alfred M. Beeton
(SAB U.S. CoChair to December 1991)
Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
2205 Commonwealth Boulevard
Ann Arbor, Michigan 48105

Dr. Rosalie Bertell
(Canadian CoChair, Workgroup on Ecosystem Health)
International Institute of Concern for Public Health
830 Bathurst Street
Toronto, Ontario M5R 3G1

Mr. Dave Best
U.S. Fish and Wildlife Service
301 Manly Miles Building
1405 South Harrison Blvd.
East Lansing, Michigan 48823

Mr. Peter C. Boyer
(Secretary, Science Advisory Board and Workgroup on Emerging Issues)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Lynton K. Caldwell
(to October 1991)
Department of Political Science
Indiana University
406 Woodburn Hall
Bloomington, Indiana 47405

Dr. John L. Clark
(Secretary, Workgroup on Ecosystem Health)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Theodora Colborn
The Conservation Foundation
1250-24th St., N.W., (#400)
Washington, D.C. 20037

Ms. Katsi Cook
Indigenous Permaculture Networking Center
First Environment Project Officer
226 Blackman Hill Road
Berkshire, New York 13736

Dr. Ralph J. Daley
(SAB Canadian CoChair)
National Water Research Institute
P.O. Box 5050, 867 Lakeshore Rd.
Burlington, Ontario L7R 4A6

Dr. Michael J. Donahue
(SAB U.S. CoChair)
Great Lakes Commission
The Argus II Building
400 Fourth Street
Ann Arbor, Michigan 48103-4816
Dr. June Fessenden-MacDonald
(U.S. CoChair, Workgroup on Ecosystem Health, to April 1, 1993)
Cornell University
Institute for Comparative and Environmental Toxicology
159 Biotechnology Building
Ithaca, New York 14853

Mr. Glen Fox
National Wildlife Research Centre
Environment Canada
100 Gamelin Boulevard
Ottawa, Ontario K1A 0E7

Dr. John W. Frank
Ontario Workers Compensation Institute
250 Bloor St. East, Suite 705
Toronto, Ontario M45W 1E6

Mr. Anthony M. Friend
103 Gilmour Street
Ottawa, Ontario K2P 0N5

Mr. Michael Gilbertson
(Resource Person, Workgroup on Ecosystem Health)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Ross H. Hall
P.O. Box 239, Mount Tabor Road
Danby, Vermont 05739

Dr. Isobel Heathcote
(Canadian CoChair
Workgroup on Parties Implementation)
School of Engineering
University of Guelph
Thornborough Building, Room 202
Guelph, Ontario N1G 2W1

Mr. Roy Hickman
(Canadian CoChair, Council of Great Lakes Research Managers)
Environmental Health Centre
National Health and Welfare
Tunney's Pasture, Room 103
Ottawa, Ontario K1A 0L2

Mr. David Hunter
Aird and Berlis Law Firm
BCE Place, Suite 1800
Box 754, 181 Bay Street
Toronto, Ontario M5J 2T9

Dr. George H. Lambert
(U.S. CoChair, Workgroup on Ecosystem Health)
Section on Neonatology
Loyola University Medical Center
2160 South First Avenue
Maywood, Illinois 60153

Dr. Orie L. Loucks
Department of Zoology
Biological Sciences Building
Miami University
Oxford, Ohio 45056

Mr. Walter A. Lyon
(U.S. CoChair
Workgroup on Parties Implementation)
University of Pennsylvania
20 Clifton Road
Camp Hill, Pennsylvania 17011

Dr. Donald Mackay
(to September 1992)
Department of Chemical Engineering and Applied Chemistry
University of Toronto
Toronto, Ontario M5S 1A4

Dr. John J. Magnuson
(U.S. CoChair
Workgroup on Emerging Issues)
Center for Limnology
University of Wisconsin
680 North Park Street
Madison, Wisconsin 53706

Dr. J. Alex McCorquodale
Department of Civil and Environmental Engineering
University of Windsor
Windsor, Ontario N9B 3P4

Ms. Laurie Montour
(to March 1993)
3635 Main Street
Wendover, Ontario K0A 3K0

1 Science Advisory Board
2 Workgroup on Ecosystem Health
3 Workgroup on Parties Implementation
4 Workgroup on Emerging Issues
5 Joint Council of Great Lakes Research Managers and Science Advisory Board Coordination Committee
Mr. Paul R. Muldoon
Pollution Probe
12 Madison Avenue
Toronto, Ontario M5R 2S1

Ms. Judi Orendorff
Ontario Ministry of Natural Resources
P.O. Box 5000 (10401 Dufferin)
Maple, Ontario L6A 1S9

Mr. Peter Seidl
(Secretary, Council of Great Lakes Research Managers)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Milagros S. Simmons
Department of Environmental and Industrial Health
The University of Michigan
2534 School of Public Health
109 Observatory Street
Ann Arbor, Michigan 48109-2029

Mr. Michel Slivitzky
(Canadian CoChair Workgroup on Emerging Issues)
1440 Notre-Dame, C.P. 698
Saint-Raymond, Quebec G0A 4G0

Dr. Jon Stanley
(U.S. CoChair, Council of Great Lakes Research Managers)
U.S. Department of the Interior
National Fisheries Center-Great Lakes
1451 Green Road
Ann Arbor, Michigan 48106

Mr. Geoffrey Thornburn (Liaison)
International Joint Commission
100 Metcalfe Street, 18th Floor
Ottawa, Ontario K1P 5M1

Mr. Jay P. Unwin
National Council of the Paper Industry for Air & Stream Improvement, Inc.
Central-Lake States Regional Center
Western Michigan University
Kalamazoo, Michigan 49008-3844

Dr. Jack R. Vallentyne
(SAB Canadian CoChair to December 1991)
National Water Research Institute
Canada Centre for Inland Waters
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario L7R 4A6

Dr. Robert G. Werner
Great Lakes Research Consortium
State University of New York
Environmental Sciences - Forestry
242 Ilick
Syracuse, New York 13210

Dr. George Werezak
Dow Chemical Canada Inc.
P.O. Box 1012, 1086 Modeland Road
Sarnia, Ontario N7T 7K7

1 Science Advisory Board
2 Workgroup on Ecosystem Health
3 Workgroup on Parties Implementation
4 Workgroup on Emerging Issues
5 Joint Council of Great Lakes Research Managers and Science Advisory Board Coordination Committee
III. Science Advisory Board Meeting Record and Acknowledgements: 83rd to 91st meetings

1. 83rd MEETING (Concurrent with 1991 Biennial Meeting)
   September 28 - October 2, 1991, Traverse City, Michigan
   - Meeting of the Board, September 29, and discussion of the SAB role relative to the Commission priorities over the Biennial Cycle 1991-1993.

2. 84th MEETING
   November 19 to 21, 1991, Canada Centre for Inland Waters, Burlington, Ontario
   - This meeting was attended by Commissioners Cleveland, Durnil, Fulton and Welch, who participated in a mini workshop on the future role of the Science Advisory Board. The workshop was facilitated by Dr. Isobel Heathcote and provided the basis for the reorganization of the Board.
   - Presentations were received from Ken Hall, Anne Redick and Gil Simmons representing the Bay Area Restoration Council and Implementation Team, Keith Rodgers from Hamilton Harbour RAP Committee and David McLeary of the Halton Region RAP Committee outlining their organizational structure and progress to date in the Hamilton Harbour Area of Concern.

3. 85th MEETING
   February 25 and 26, 1992, Sheraton Cleveland City Centre Hotel, Cleveland, Ohio
   - The mission, role statement and reorganization of the Board developed from the 84th meeting was discussed and approved. A new organizational structure, comprising three workgroups was developed to replace the Board’s standing committees: a Workgroup on Ecosystem Health, a Workgroup on Parties Implementation, and a Workgroup on Emerging Issues.
   - Presentations on the Cuyahoga Area of Concern outlining the approach and Stage 1 Remedial Action Plan were made by John Beeker of Northeast Ohio Areawide Coordinating Agency; Greg Studen, Chairperson, Cuyahoga Coordinating Committee; Mary Beth Binns of the Cuyahoga River Community Planning Organization; and Keith Linn and Lester Stumpe of Northeast Ohio Regional Sewer District. Don Killinger and Leslie Whelan of the Cuyahoga County Board of Health, Julia and Laura Nagy of Oberlin College and Steve Tuckerman of Ohio Environmental Protection Agency were observers at the meeting.

4. 86th MEETING
   May 15, 1992, IJC, GLRO, Windsor, Ontario
   - This one-day meeting followed the first meetings of the new workgroups held May 14. The Board heard presentations from each of the workgroup’s chairs, Drs. Fessenden...
McDonald and Bertell from the Workgroup on Ecosystem Health, Mr. Lyon and Dr. Heathcote from the Workgroup on Parties Implementation, and Dr. Magnuson and Mr. Slivitzky from the Workgroup on Emerging Issues, which outlined the proposed terms of reference and proposed activities for each of the workgroups.

6. **87th MEETING**  
**September 17, 1992, Michigan League, University of Michigan, Ann Arbor, Michigan**

- The 87th meeting was held following the Workshop on Ecosystem Health. A status report on SAB activities under the IJC Priorities and other proposed workgroup contributions toward the 1993 Science Advisory Board report were presented and discussed.

6. **88th MEETING**  
**December 16, 1992, Waterfront Regeneration Trust, Toronto, Ontario**

- Commissioner David Crombie, Deputy Commissioner David Carter, Suzanne Barrett and Grant Mills welcomed the Board to the Waterfront Regeneration Trust (WRT), formerly the Crombie Commission, and provided the Board with an overview of the work of the Royal Commission on the Future of the Toronto Waterfront and its evolution to the WRT.

7. **89th MEETING**  
**February 24, 1993, Cleary International Centre, Windsor, Ontario**

- The workgroup input to the 1993 Science Advisory Board Report was presented and discussed.

8. **90th MEETING**  
**May 18-19, 1993, Cleary International Centre, Windsor, Ontario**

- A special two-day meeting of the Board was held to review and approve the 1993 Biennial Report.

9. **91st MEETING**  
**In conjunction with the 1993 Biennial Meeting, October 22-24, 1993**  
**Cleary International Centre, Windsor, Ontario**

- Public presentation of the 1993 Science Advisory Board Report to the Commission