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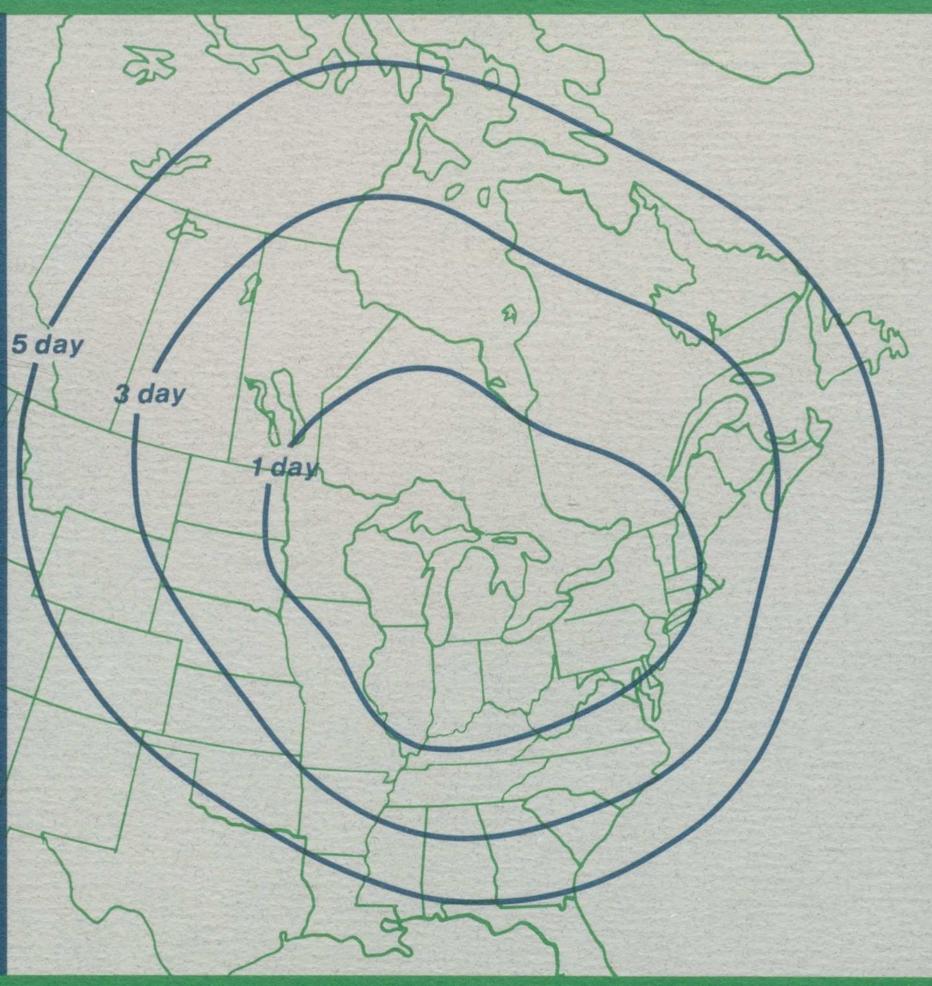
Monitoring for Integrated Analysis: Final Report by the Expert Group on Monitoring to the International Air Quality Advisory Board

International Air Quality Advisory Board. Expert Group on Monitoring

International Air Quality Advisory Board

"Monitoring for Integrated Analysis"

Final Report by the Expert Group on Monitoring



Airshed of the Great Lakes

March 1992

International Joint Commission
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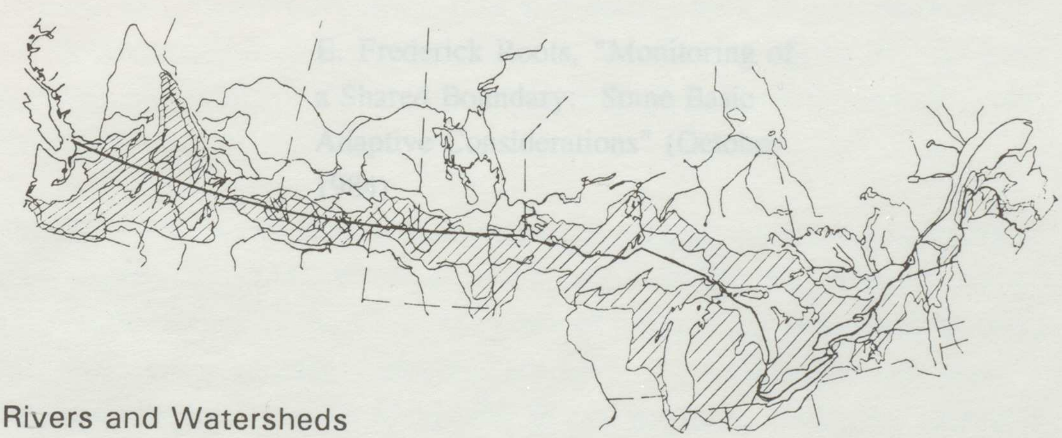
Integrated Monitoring in the U.S.-Canada Transboundary Region

"Monitoring for Integrated Analysis"

FINAL REPORT
TO THE INTERNATIONAL AIR QUALITY ADVISORY BOARD
BY THE EXPERT GROUP ON MONITORING



Rivers and Watersheds
of the Transboundary Region

October 1991

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A key objective of discussions of boundary monitoring is to explore strategies for keeping track of the state of health of the environment in the boundary region between the United States and Canada, and for improving understanding of social and ecological systems affected by the boundary or transboundary activities. The reason for wanting to do so, as made clear by the Boundary Waters Treaty and by the activities of IJC over the decades, is to obtain knowledge that will help avoid inter-country conflict and to optimize mutual benefits from developments whose effects cross the boundary. The purpose is clear.

E. Frederick Roots, "Monitoring of a Shared Boundary: Some Basic Adaptive Considerations" (October 1984)

The monitoring community finds outliers disturbing and desires to reject them.

The research measurement mind-set finds outliers intriguing and seeks to explain them.

--- Anonymous

PREFACE

The International Joint Commission was set up under the Boundary Waters Treaty of 1909. It provides a mechanism for the adjustment and settlement of questions involving rights, obligations, and other interests of either country in relation to the inhabitants of the other along the common frontier.

There are many programs that monitor environmental parameters in the transboundary region. The IJC initiated a program to evaluate the strengths and weaknesses of existing monitoring programs in the border region and to recommend how and where to improve monitoring over the long-term. A very successful workshop was held in 1984, in Philadelphia, entitled "Toward a Transboundary Monitoring Network"; in essence, this workshop started the IJC on a program of study of monitoring. Since then, there has been much activity within the groups of the IJC on developing information on existing monitoring activities and on how to work towards integration.

The International Air Quality Advisory Board (IAQAB) advises the Commission on air quality issues in the Canada-United States transboundary area and was asked to explore the benefits of integrated monitoring in order to assess the environmental well-being along the international boundary.

An early part of this work was to develop an inventory of existing monitoring networks in the transboundary region. The IAQAB sponsored a survey of monitoring projects, which culminated in the production of a report "An Inventory of Current Environmental Monitoring Projects in the United States-Canadian Transboundary Region". As a further step, the IAQAB then set up an Expert Group on Monitoring to examine these monitoring programs over the transboundary region from coast to coast. Guidance given to the Expert Group is reproduced in Appendix I; details of membership of the group are given in Appendix II.

The present document is the final report of this Expert Group. The process by which this report was developed intentionally excluded special consideration of the Great Lakes, because of the large number of independent activities already focused on this particular region of the border. The intention has been to provide a mechanism by which the needs of other parts of the transboundary region can be combined with the special requirements of the Great Lakes, so as to produce a uniform strategy for addressing the monitoring needs of the entire border region. Appendix III summarizes a final workshop conducted by the Expert Group, intended to relate Integrated Monitoring to problems arising in the Great Lakes basin.

The Expert Group began with a review of the Inventory Report and then conducted three Regional workshops to examine approaches to monitoring being used on a local basis that were generally in response to specific transboundary concerns. The Group also met with the Rainy and Red River Pollution Control Boards of the IJC. Reports of the first two workshops have already been published. The documentation relating to the third workshop is in preparation, as of the date of this report, and an Interim Report of the Expert Group was published in 1989.

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EXECUTIVE SUMMARY

An Expert Group on Monitoring was established by the International Air Quality Advisory Board (IAQAB) to examine environmental monitoring programs across the entire Canada-United States transboundary region. This action was taken to enable the IAQAB to advise the International Joint Commission (IJC) on the benefits of **integrated monitoring** as an improved approach to assess the environmental well-being along the international boundary. In response, the Expert Group conducted workshops and examined the meaning and usefulness of integrated monitoring. This report summarizes the activities of the Expert Group, its conclusions, and its recommendations.

In general, the purposes of monitoring the natural environment are (a) to establish baselines representing the current status of ecosystem components, and (b) to detect changes over and above natural departures from these baselines. The purpose of **integrated monitoring** is to detect not only changes in the components measured but also changes in other components that are affected, and more importantly changes in the ecosystem as a whole. Integrated monitoring draws together information from measurement programs that might otherwise be unconnected, by concentrating attention on specific sites or research areas where both environmental conditions and ecosystem response are monitored. The focus of integrated monitoring is on understanding and explaining changes that are detected and on providing the basis to predict future changes.

According to WMO and UNEP (see Rovinsky and Wiersma, 1987), "Integrated Monitoring" has the following characteristics:

> "The repeated measurement of a range of related environmental variables or indicators in the living and non-living compartments of the environment, and the investigation of the transfer of substances or energy from one environmental compartment to another with the aim of assessment and prediction of the environmental status.
>
> "Monitoring becomes truly integrated when the measurement of different variables or of the same variable in different compartments are coordinated in time and space, to provide a comprehensive assessment of the system under study. The variables might include chemical substances (e.g. pollutants), geophysical parameters (e.g. wind, ocean currents), biological characteristics (e.g. primary productivity) or other variables as may affect man, his natural resources, and the climate."

The distinguishing characteristics of integrated monitoring are thus as follow: (1) many components of the environment are monitored at the same location; (2) the focus is on understanding and explaining changes that are detected and on providing the basis to predict future changes; (3) interdisciplinary analyses are undertaken; and (4) "indicators" are studied as well as state-of-the-medium variables. The components of relevance are air, water (ground water and surface water — streams, rivers, and lakes), soils and sediments, and flora and fauna. All these are studied at specific locations, although studies of factors relevant to fauna and human health introduce a need for exposure measurements distributed in space.

In 1987, the IAQAB sponsored preparation of an inventory of monitoring projects underway in the transboundary region. The inventory proved to be a useful starting point for many activities of the Expert Group. However, the inventory was produced largely as an exploratory first attempt to obtain the network information that is truly required. The inventory is not complete and is limited in its frequent failure to distinguish between short-term research projects and long-term monitoring programs. Details of site locations and organizational structure are not summarized in a readily accessible manner. Generation and maintenance of an improved inventory and data base service is needed.

A series of workshops was conducted, addressing specific issues of concern in different regions of the transboundary region, but intentionally excluding the Great Lakes region — the Great Lakes region was viewed as a special case because of the high level of attention it already receives from other components of the IJC. (However, a special workshop was conducted to present the conclusions and recommendations of the Expert Group, and consider their relevance to the Great Lakes. This workshop is summarized in Appendix III.) The Expert Group also met briefly with the IJC Red River and the Rainy River Pollution Control Boards (November 1990). The first workshop was in June 1988 at St. Andrews, New Brunswick, and focused on the St. Croix River, which marks the border in the far eastern end of the transboundary region. The river basin has received considerable international attention and represents one of the successes of environmental clean-up and management. At this workshop, the usefulness of a "nested network" emerged; the concept was endorsed and recommended as a mechanism to produce a framework of truly integrated monitoring and research. It was recognized, however, that coordination and management of data from such networks would require considerable effort in both Canada and the United States.

The second workshop, held in February 1989 at Burlington, Vermont, mainly addressed issues of importance to Quebec, New York, and Vermont, and especially the Lake Champlain lowland area. An attempt was made to emphasize issues related to human health. The concept of nested networks that was developed in the previous workshop received a favorable reception. While studies associated with acidic deposition from the atmosphere seemed to be well developed in Canada, long-term efforts in the United States were less prominent. Studies of water quality along the border varied in thoroughness.

The third workshop was held in November 1989 at Victoria, British Columbia. The level of attention to monitoring problems associated with questions concerning human health was increased, but the workshop also emphasized issues concerning ozone, silviculture, and regional air quality. Needs were identified for better scientific coordination, more monitoring locations, and the development of a regional monitoring strategy.

The Expert Group has drawn several conclusions.

- Integrated monitoring is needed, but very few monitoring activities presently go beyond the requirements of specific problems.
- The existing inventory of monitoring activities in the transboundary region requires improvement. There is need for an improved and regularly updated inventory.
- Existing monitoring programs are generally effective in satisfying the needs of specific problems.
- Nested networks are required, such that more-comprehensive sites would constitute an integrated monitoring network for multidisciplinary measurement, and such that these would be operated in conjunction with less-comprehensive sites distributed over a much wider space scale.
- Network intercomparisons are required, in which the operating procedures and sampling protocols of different specialized networks are operated side-by-side at various locations (quality control and quality assurance programs need to be conducted at an international level).
- Existing integrated monitoring activities should be endorsed and encouraged.
- Integrated monitoring needs to cover the entire transboundary region; at present, monitoring activities of all kinds are concentrated in the east.
- Shared data management systems are needed, to provide ready and convenient access to data collected on both sides of the border, by all relevant organizations (national, regional, and local).

- Integrated monitoring may be extended to applications related to human health, through the use of activities such as personal monitoring conducted as one specialized level of activity within the integrated monitoring framework.

- Socioeconomic benefits of pollution control should be documented.

- Integrated monitoring may provide improved cost-benefit for monitoring programs.

- Integrated monitoring will facilitate detailed scientific investigation of important processes. In this regard, **integrated analysis** is a necessary component of integrated monitoring.

The Expert Group endorses the concept of integrated monitoring and recommends that a program of integrated monitoring should be set up across the U.S.-Canada border region. The Expert Group notes that such a program would provide a well-documented data base suitable for objective scrutiny and assessment of a wide range of environmental issues, with assured high-quality data obtained using common protocols. The Expert Group further recommends

- improved coordination of monitoring programs of all kinds, especially integrated monitoring

- that top priority be given to assuring continuity of the records being obtained at existing sites

- the development of data bases and reports (perhaps through the IJC) that show conditions and changes that CROSS the international boundary (rather than the traditional reports that stop AT the boundary)

- that formal steps be taken to assure the comparability and general high quality of measurements made at network sites in the transboundary region; and

- that a mechanism be established to maintain an updated inventory of ongoing monitoring activities in the transboundary region, and to maintain a library of related reports

Finally, the Expert Group notes that initiation of an integrated monitoring program that spans the U.S.-Canada border region would serve to improve interdisciplinary collaboration and cooperation among (and between) U.S. and Canadian scientists, but also that the design of integrated monitoring programs requires clear identification of issues. If control or regulatory actions are to be based on monitoring data, then it is only when trends in key variables have been determined and their causes identified to the extent possible from the integrated monitoring information, that policy actions should be initiated.

The report of the Expert Group summarizes the findings of the group, based both on the outcomes of the workshops that were conducted and on the independent contacts by members of the group with fellow scientists in the North American environmental monitoring community. Appendices give details of the membership of the group, and of the guidance given to it by the IAQAB. A final appendix summarizes a workshop conducted in September, 1991, at which the conclusions and recommendations presented here were examined in the context of the Great Lakes basin.

1. INTRODUCTION

There have been environmental issues associated with the Canada-U.S. boundary for many years, such as those associated with the Great Lakes that gave rise to the development of the Boundary Waters Treaty in 1909. Other examples include damage from air pollution at Trail, B.C. in the early part of this century and algae blooms and associated fish kills in Lake Erie in the 1960s. Each of these problems resulted in Canada-U.S. intervention in terms of pollution control and associated monitoring programs to ensure compliance with the resulting agreements.

It is useful to contrast the past and present public perception and awareness of environmental problems. In the past, most problems were related to an obvious cause, such as emissions from a particular source that were affecting water or air quality in a way that was found to be offensive and damaging to the environment. The effects were easily and convincingly related to the cause. Controls could be designed and the environmental responses predicted with considerable certainty.

To a large extent, at least in developed countries such as the United States and Canada, the most simple and obvious problems have been resolved. Administrative machinery has been set up to regulate and control most of the emissions that are known to have severe local consequences, such as the discharge of raw sewage into rivers and lakes and the smokestack emission of noxious materials into the atmosphere.

Now, the nature of environmental degradation is usually different. We are faced with pollutants and effects with more subtle cause-effect relationships, often characterized by larger geographic areas of interest and longer term potential damage. The environmental damages are more chronic than the acute problems of the past. This is not to say that damages are any less; indeed the potential damage of extended exposure of the environment to small modifications of the current values of air and water quality is known to be quite significant.

Acid rain and climate change are good examples; they are caused by a variety of pollutants from a number of sources and damage to ecosystems occurs over many years. It is much more difficult for both the public and for the research community to understand the nature of such complicated environmental phenomena. We can no longer focus on single pollutants in a single medium (air, water, soil, etc.). Instead, we must now consider interactions among many pollutants, mixing among the various media, and potentially affecting many components of the ecosystem in both indirect and direct ways.

Relating observed damage to specific causes requires an understanding of the physical, chemical, and biological linkages that are involved. Developing objective and workable control strategies requires that the relative importance of different causes be ordered properly, so that effort is not wasted on regulating emissions that are not the most effective. Detailed, high quality scientific information is necessary to provide a sufficient level of understanding.

A series of workshops was conducted by the IJC Expert Group on Monitoring to explore, *inter alia*, the benefits of integrated monitoring, a concept that is not new yet remains elusive. Integrated monitoring is becoming increasingly attractive and appears to be necessary to cope with the complexities of contemporary environmental issues.

The standard purposes of monitoring the natural environment are (a) to establish baselines representing the current status of ecosystem components, and (b) to detect changes over and above natural departures from these baselines. Integrated monitoring injects a new concept — the desire for coordinated multidisciplinary analysis in order to reveal the causes of changes that occur in complex environment systems. Thus, integrated monitoring includes monitoring of both ecosystem response and a range of potentially causative environmental factors. The focus of integrated monitoring is on understanding and explaining changes that are detected and on providing the basis to predict future changes.

Multidisciplinary studies are basic to the concept of integrated monitoring. Monitoring activities must therefore extend across media, in a coordinated manner. Studies of different parts of specific ecosystems, for example, typically require the application of different sampling protocols, and hence a nested network approach is fundamental. In practice, integrated monitoring stations comprise the long-term multidisciplinary linkages that join additional networks (or other research activities) generally on a larger spatial scale but with less intensive sampling addressing specific issues. In this regard, the distinguishing characteristics of integrated monitoring are as follow.

- Many components of the environment are sampled at the same site or in a shared study area.

- The focus is on understanding and explaining changes that are detected, and on providing the basis to predict future changes.
- Interdisciplinary analyses of results are undertaken, with modeling conducted at the ecosystem level.
- Indicators of environmental health may be developed.

The components of the ecosystem ("media") of relevance are air, water (ground water, streams, rivers, and lakes), soils and sediments, flora and fauna, and humans. All of these are studied at specific locations, except for some studies of factors relevant to animals which can introduce a need for measurements of exposure as experienced by members of the community at risk. In particular, exposure monitoring for people introduces a need for measurements distributed in space. Such measurements may be tied to "benchmarks" provided by integrated monitoring sites, and may eventually result in methodologies to use integrated monitoring data to assist in estimating exposure. The linkage between fixed location integrated monitoring data and personal exposure information needed for applications such as human health risk assessment is currently indistinct. Integrated monitoring as promoted here offers an opportunity to coordinate intensive, fixed station, multimedia sampling with monitoring programs involving human health and related personal exposure.

In the near term, integrated monitoring would provide a better way to invest limited resources to address emerging environmental problems. It would impose elements of organization and order on a system that has previously been rather haphazard. Initiation of integrated monitoring would not necessarily reduce total monitoring costs (although some redundancies might be eliminated), but would provide a better insight into environmental health and the causes of its decline.

In the long term, the cost to society of not adopting integrated monitoring could be large. Integrated monitoring provides a mechanism to protect against the incorrect identification of causative factors.

In practice, the ability to monitor the health of living components of the environmental lags considerably behind the ability to detect changes in the physical and chemical states of the environment. In the atmosphere, for example, there is a clear distinction between those properties that are related to local pollution (such as sulfur dioxide and nitrogen oxide concentrations) and variables that are indicative of long-term changes of the atmosphere as a whole (e.g. global temperatures, cloudiness, and carbon dioxide concentrations). The scientific community knows what is meant by "global climate," but as yet there is no analogous concept that applies to the health of the world's forests, or the quality of the global reserves of fresh water, etc. In this regard, integrated monitoring is seen as a first step to bring together different aspects of environmental monitoring so that a better understanding of ecosystem processes can be obtained and more questions can be addressed within the limited resources that are available.

2. ANALYSIS OF THE IAQAB MONITORING INVENTORY

In 1987, the IAQAB sponsored an inventory of monitoring projects underway in the transboundary region; there was no previous summary of projects that covered both sides of the border. The inventory has proven to be a useful starting point for many activities of the Expert Group, which concludes that this work should be continued and expanded. Future inventories could be improved by attention to the following considerations.

1. *Completeness of the inventory.* Discussion at the workshops conducted by the Expert Group has indicated (a) the presence of many monitoring activities that are not listed and (b) that many of the well established networks are continually being modified. It was not the original intent of the IAQAB to limit the initial inventory only to ongoing work; indeed, the listings include many cases in which work terminated before the publication. However, the treatment was uneven, with some programs described in detail but with known equivalent programs in adjacent jurisdictions barely mentioned or missed entirely. For example, approximately a dozen monitoring projects involving freshwater lakes in New York and Vermont are listed, yet only one appears to be continuing at this time. This ongoing effort requires voluntary sampling by interested citizens and institutions in Vermont. A corresponding voluntary effort in New York does not appear in the inventory. In addition, the considerable effort to monitor changes in freshwater lakes in Quebec is not well represented in the initial inventory. An inventory of this kind requires iteration within the scientific community to ensure the accuracy and representativeness of its contents.

2. *The distinction between long-term monitoring programs and short-term research projects.* Many of the short-term projects listed in the initial inventory have now ceased (although some of the sites involved will be revisited at later times to develop a data base on trends from periodic but irregular sampling). Other research sites have been set up recently, and will continue for varying undetermined periods. Any further inventory activity should clearly distinguish between continuing long-term network monitoring programs and short term investigations to obtain answers to specific questions in particular locations.

3. *The provision of information as easily-accessed summaries.* In the initial inventory, some vital information, such as details of site locations and measurement techniques, can be extracted only by reference to computer files or by questioning the original sources of the information.

- A conclusion of the Expert Group is that a living inventory should be set up as a part of the IJC system, containing a library of reports describing past and present monitoring activities in the transboundary region and capable of continuing adjustment to keep track of evolving monitoring programs in the region.

3. DESCRIPTION AND CONCLUSIONS OF WORKSHOPS

The Expert Group, in cooperation with the International Air Quality Advisory Board, conducted a series of workshops designed specifically to address monitoring issues of regional interest that affect the transboundary environment. Each workshop was organized by a local representative, who worked closely with the chairmen of the Expert Group. Meetings of the Expert Group and of the IAQAB were called to review plans and to identify key participants.

The series of workshops started in June, 1988, at St. Andrews, New Brunswick, with subsequent workshops in Burlington, Vermont (February, 1989), and Victoria, British Columbia (November, 1989). The sequence of meetings intentionally stepped past the Great Lakes area, where a large scientific community already focuses on matters related to monitoring in general and specifically to the concept of "integrated monitoring." Following initial exploratory meetings with representatives of the International Air Quality Advisory Board, it was decided to complete the sequence of regional integrated monitoring workshops with a joint meeting, involving both the International Air Quality Advisory Board and the Water Quality Board of the International Joint Commission, with the specific intention to bring together the recommendations of the Expert Group (based on a review of the entire border region but without any special emphasis on the Great Lakes basin) and those generated independently by the scientific community specializing in environmental problems of the Great Lakes basin. This joint meeting, planned to finalize the work of this Expert Group, was conducted in September 1991; it is reported in Appendix III.

A common format was adopted for the workshops conducted by the Expert Group. Each workshop started with a series of presentations from local authorities (drawn from government agencies, industry, and academia), intended to provide background information on the environmental problems of the region and on the ways in which these problems have been addressed. Speakers were given guidance, as follows.

"Several years ago, the Commissioners of the IJC initiated an effort to understand the strengths and weaknesses of the monitoring in the border region, and to recommend how and where to improve monitoring over the long-term. A very successful workshop in Philadelphia, entitled "Toward a Transboundary Monitoring Network", was held in 1984 which started the IJC effort. There has been much activity within the groups of the IJC on developing information on existing monitoring activities and on how to approach this activity.

"The next step is to focus on one region of the border, to bring together various viewpoints related to the question of multi-media, integrated monitoring of the environment in the transboundary region. The viewpoints of interest include those of the people running monitoring networks, those of the people using monitoring data, and those of the groups of the IJC. The expectation is that there are benefits to be derived both from a better understanding of the strengths and weaknesses of current monitoring efforts and from specific actions that could be recommended such as collocation of research sites and adoption of standardized measurement protocols on both sides of the border."

In addition, each speaker was asked to address four specific questions in the course of his/her presentation —

1. What are your needs for environmental monitoring data and how do you (your organization) or would you use the data?

2. Based on your understanding, do the existing monitoring efforts provide adequate information to quantify the environmental quality in the region, to detect problems in environmental quality and/or show trends?

3. Do the networks measure the variables that are necessary to address environmental quality and/or to design remedial strategies? Are the networks sufficiently flexible that they might be used to address future environmental pollutants?

4. What steps (studies or actions, short-term or long-term) could be made to improve the existing measurement programs?

Speakers were selected (jointly, by the individual workshop organizers and the chairmen of the Expert Group) to cover the range of environmental issues in each border region considered. Following these regional-issue presentations, some brief reviews relating to specific scientific developments were then given. Written papers were invited, but were not mandatory. These formal presentations accounted for the first day of each workshop, after which attendees took part in working group sessions to focus on specific areas of particular local interest. Each workshop concluded with a plenary session.

The focus of First Regional Workshop on Integrated Monitoring (St. Andrews, June 1988) was on the St. Croix River, which marks the U.S.-Canada border in the far east of the transboundary region. The St. Croix River was initially an unremarkable river of limited societal value that became a managed stream due to the demands of industry, to the detriment of wild life and to alternate human uses of the river. As population in the area grew (partly drawn by the success of the industry making use of the St. Croix), pressures developed for an environmental clean-up of the St. Croix. The river basin received considerable international attention and now is one of the success stories of environmental remediation; it constitutes an enjoyable resource for society on both sides of the border.

The second workshop was held at Burlington, Vermont, in February 1989. The workshop emphasized effects of air pollution on forests and the monitoring and control of water quality. Factors related to human health also received considerable attention.

The third workshop (Victoria, British Columbia, November 1989) attempted to raise the human health issues to an even higher level of attention, but with continuing attention to local issues concerning ozone, silviculture, and regional air quality.

In October 1990, a meeting was held with representatives of the Red River and Rainy River Pollution Control Boards of the International Joint Commission. The intention was to provide an opportunity for input regarding environmental concerns in the prairies, without holding a workshop dedicated to such issues. (It was then already apparent that the workshop format works well only if there are recognized concerns of sufficient current importance. No such "critical issue" was clearly apparent for the great plains region of the U.S.-Canada border.)

The First Regional Workshop on Integrated Monitoring

The St. Andrews workshop was designed to bring together various viewpoints related to the question of multimedia, integrated monitoring of the environment in the extreme eastern portion of the transboundary region. The participants included network operators, users of monitoring data, and representatives of appropriate IJC bodies. After a series of presentations about monitoring activities in the region, participants were divided into four working groups to discuss problems of air, water, forests, and management as they relate to the overall question of integrated monitoring.

Conclusions

Several points were repeatedly made in the papers presented by the speakers, and in the deliberations of the four working groups. Among the points made most frequently were the following.

1. Underlying many of the discussions was an increasing awareness that the maintenance of a pristine site is not always the environmental goal. Although questions of policy are not being addressed by the Expert Group, and hence this consideration is not central to its deliberations, it is now recognized that different requirements may be imposed on monitoring, according to whether the focus is on environmental maintenance, restoration or improvement. The situation in the St. Croix River region provides an excellent example; some of the sporting activities that are now important to the lifestyles and the economic development in the area are the result of management of the river system and could not be supported by a reversion to its natural condition. In particular, bass fishing is based on an imported species. Salmon have returned as the water quality has been improved, and adverse effects of industry on the presence of white water are being minimized by careful flow control strategies. Thus, local issues center on environmental management designed to satisfy the recreational and economic demands of the community rather than environmental protection in terms of reverting to a pristine state.

2. There is need to integrate many aspects of environmental study:

i) Specialists must communicate across disciplinary boundaries. This can be accomplished in specially-organized interdisciplinary workshops.

ii) Appropriate multidisciplinary programs are beneficial, especially when specialists from different disciplines are organized into groups to address problems that cross several specialties.

iii) Scientists skilled in more than one discipline are increasingly needed. By being conversant with the details of several specialties, such transdisciplinary scientists can provide objective guidance on the way that overall environmental effects can be studied and on how appropriate models can be assembled.

3. The general perception was that there are indeed social and economic benefits associated with improved water quality in the St. Croix River basin. However, further work is necessary to quantify these benefits.

4. The wide variety of existing sampling networks should not be interpreted as an indication of redundancy, although some efficiencies might result from streamlining existing activities. In particular, it is clear that we should not try to force all site operations into the same confining mold. Some sites have research as the major objective, whereas others concentrate on routine monitoring, and many fill in the spectrum that lies between these extremes. The research networks are designed to provide answers to specific scientific questions and to anticipate new problems. These questions relate to our ability to understand the environmental response to pollution stress and especially to our ability to predict the changes that will result if controls or regulations are imposed to limit emissions (or other stress). Coordination of these research networks could logically take the form of collocation of different activities and the workshop endorsed such collocation.

On the other hand, it may require some redundancy of efforts to detect spatial differences and time trends of environmental quality. In this case, the integration may take the form of combining similar activities, arranging for uniform procedures and related quality controls, and sharing data bases.

Recommendations

No clear answer was given to the general question of how we might best monitor the overall environmental and economic value of remedial actions that are taken to protect the environment. However, several general recommendations were made:

- **A "nested network" concept should be adopted.** Each working group endorsed the concept of routine measurement stations that are supported by a subset of more intensive research sites.

- **Uniformity of all operations at all sites should not be imposed.** Sites have different purposes; some have research as the major objective, whereas others concentrate on routine monitoring, and many fill in the spectrum between. We should not require every site to make every measurement with the detail required for every purpose.

- **Bioindicators should be used more widely.** The utility of selecting a few species as suitable indicators of ecosystem health was endorsed, as in the case of bioindicators monitored in the St. Croix River.

- **"Integration" should involve cooperation between industry and government.** The pollution control experience of the St. Croix River points strongly to the benefits of cooperation between governments and industry. In this context, the desired improvements may well involve a coordination of efforts, starting with a cataloging of information available from all sources, so that goals related to the best use of limited environmental resources are clearly identified and appropriate actions are taken in a cost effective manner.

The Second Regional Workshop on Integrated Monitoring

The second of the IJC Workshops on Integrated Monitoring was held at Burlington, Vermont, 6 - 8 February 1989. The meeting focused on monitoring activities related to ozone and acidic deposition and on water quality — the major environmental issues in the Quebec/Vermont/New York region.

Conclusions

1. *The working groups agreed on the general purpose of monitoring programs.* The intent of monitoring programs should be to provide regular reports on the current status of ecosystems and on factors that affect them, to detect trends with time, and to provide a sound basis for predictions of possible adverse consequences.

2. *Monitoring should include studies both of indicators of change and causative variables.* In accord with one of the conclusions of the St. Andrews workshop, the participants at the Burlington meeting concluded that there is a need to monitor both selected indicators of environmental change and those properties that might themselves be factors that cause or influence such changes. In practice, atmospheric monitoring programs tend to focus on measurement of causative factors. Measurements of indicator species tend to be made in measurement programs of the forestry, aquatics, and other effects communities. Discussion of aquatics monitoring focused mainly on the apparent lack of detailed information for Lake Champlain and Lake Memphremagog.

3. *The longevity and continuity of records is especially important.* The subject of monitoring in support of studies related to human health was a major subject of the Burlington meeting. Deliberations on the issue of human health resulted in the recognition of an additional use for monitoring data: to provide historical data to quantify past exposure regimes, such as for use in epidemiological studies. In order to meet such goals, it is necessary to ensure that networks provide comparable data, across the border, on a continuing basis, without significant interruption. A readily-accessed, quality-assured data bank is a necessary component of this kind of analysis.

In general, it was concluded that existing air quality monitoring networks provide adequate data on air concentrations of air pollutants most important in health effects studies (SO_2, NO_2, O_3, CO, and inhalable particles). More emphasis is needed, however, on monitoring toxic air chemicals and their rate of deposition in precipitation (e.g. dieldrin, dioxins, PCBs and DDT). Increased emphasis is needed on determining peak concentrations and their frequency of occurrence.

In addition, there is need for a monitoring activity that measures the health of the population. In much the same way as a need for monitoring selected indicators arose in discussions conducted at St. Andrews, the human health deliberations conducted at Burlington revealed a need for increased monitoring of the health (and/or indicators of health) of the human population. A link between the two approaches is provided by increasing the emphasis on dose assessment, such as by the use of personal monitors or by extension of measurement programs to the indoor environment.

Recommendations

The working groups developed a number of recommendations, summarized as follows.

- **Monitoring of Lakes Champlain and Memphremagog.** In comparison to the Great Lakes, little is known of the state of these important aquatic resources; if changes with time are to be detected, then monitoring activities should be expanded and refined.

- **Exploration of the benefits of "sample banking."** Long-term sample banking was proposed as a viable monitoring approach; the potential benefits remain to be fully explored. Sample banking involves the collection of samples using standardized protocols over an extended period, and storage of these samples in anticipation of some future need for analysis (perhaps using technologies not yet perfected).

- **The need to consider more chemicals.** Some expansion is needed in the properties that are monitored, and some new techniques are needed by which important chemicals are measured. Not all chemicals are measured easily, or with confidence. In particular, more emphasis should be placed on monitoring concentrations (in air and in precipitation) of toxic chemicals such as dieldrin, dioxins, PCBs and DDT.

- **Monitoring (and modeling) programs should be tailored to yield information on peak concentrations and their frequency of occurrence.** In general, allowance should be made for the need to relate concentrations to periods of exposure. (The highest air concentrations occur for relatively short times, in general.)

- **The need to maintain flexibility in monitoring programs.** Wherever possible, monitoring programs should maintain flexibility in their mode of operation, to permit new issues to be addressed without severe disruption of ongoing work.

- **The need to locate monitoring stations near where the data are most needed.** As much as possible, air monitoring stations should be located near the population (ecosystem, etc.) that is perceived to be at risk or in locations where other data are being gathered.

- **Estimating exposure and dose.** Effort should be focused on the need to convert concentrations to dose, since dose is the biologically significant parameter.

- **There should be more monitoring of human health.** Key indicators of the health of the human population should be selected and monitored.

- **The use of "personal monitors."** For purposes related to human health, there is need for the development of techniques to assess personal exposures using data derived from fixed-station monitoring data. To this end, programs using personal monitors should be linked to integrated monitoring activities.

The Third Regional Workshop on Integrated Monitoring

The third workshop, in Victoria, British Columbia, 15-17 November, 1989, focused on aspects of integrated monitoring that are of special relevance in the Pacific coastal region, with emphasis on four topic areas developed in consultation with local authorities.

1. Monitoring in support of transboundary air pollution

2. Monitoring in support of problems associated with oxidants

3. Monitoring in support of pollutants associated with human health effects

4. Monitoring in support of emergencies occurring in coastal areas

The first part of the workshop was structured to provide information on what is known about the above topics, with focus on such aspects as visibility impairment in northwestern Washington State, air quality in the boundary region (affected by emissions from sources on both sides of the border), and the impacts of oxidants on forests. Presentations emphasized the lack of knowledge concerning oxidants and their effects.

Only brief attention was given to the matter of environmental emergencies. No strong conclusions were reached, although it was agreed that offshore oil spills and similar problems require a coordinated response, making use of data from monitoring networks on both sides of the border.

Human health effects constituted a major subject for consideration at this particular workshop. The inhalation pathway was the center of most concerns; the ingestion pathway was viewed as far less important. The availability of atmospheric data was discussed in light of studies currently underway, such as those relating ozone episodes to respiratory problems, using hospital records as a source of health data. These discussions dealt with the need for specialized atmospheric data, with fine resolution in both time and space, to address some of the particular needs of the medical community. Better resolution of pollutant air concentrations in suburban areas is required, as are more data on background levels and the size distribution of relevant particles.

Conclusions

1. *The environmental situation in the far west is different from that in the east.* In general (and with the possible sole exception of ozone), the air is cleaner; hence, individual pollution plumes are more noticeable. The air pollution problems tend to be local rather than regional.

2. *The atmosphere and its pollution do not recognize the international boundary.* Emissions from both sides of the border influence the air in this region, but there are no active intensive monitoring sites nor a regional monitoring strategy.

3. *Air quality problems are widely perceived.* Even though there is a lack of contemporary monitoring data, there are recognized air quality problems or the potential for problems in the future. Perceived issues include: (1) oxidants and their possible influence on forests and agriculture; (2) "acid deposition," but related data are not definitive; (3) particles in air and possible degradation of visibility; (4) pesticides and other airborne toxic chemicals potentially injurious to human health;

4. *In the far west, the movement of air pollutants is greatly affected by the terrain.* There was general agreement that the level of knowledge about the movement and deposition of pollutants is not sufficient, because of the complex topography. This lack of understanding underlines the need for more data on basic meteorological properties in the transboundary region, both at the surface and aloft.

5. *Issues related to human health require special attention.* Monitoring for health effects imposes the need for a different set of considerations. For example, data obtained at a fixed

sampling station are not indicative of the experience of most members of the human population, and so close correlations between site-specific monitoring data and human health indices are unlikely. For human health applications, the most useful air monitoring data relate to the environments in which greatest exposure occurs (typically air breathed by people outdoors, in the home or at the workplace) and not to remote locations where monitoring for other reasons might be most desirable.

Recommendations

- **The need for interdisciplinary comprehensive monitoring sites.** A few sites are required to monitor relevant environmental indicators and causative properties, so as to reveal cause-and-effect relationships. The existence of such sites would help improve interdisciplinary communication. Because of its location relative to the rest of North America, intensive monitoring of the chemical composition of air in the western transboundary region could provide much-needed information on the atmospheric "background" appropriate for North America.

- **The need for better scientific interactions.** Improved mechanisms are needed to promote the exchange of data between Canadian and U.S. agencies in this part of the transboundary region.

- **The need for more monitoring locations, for some purposes.** Particular issues require operation of more sites where fewer properties are monitored. These stations would monitor variables of relevance to the specific issues, such as forest decline, regional hydrology, oxidants, and toxic chemicals.

- **The need for a regional strategy.** A regional monitoring strategy that crosses the international border is required. Optimizing the monitoring strategy is important and should make use of historical data and guidance from available computer models. **In general, an interactive monitoring and modeling approach is needed to reveal the cause/effect relationships that are most important.**

A number of recommendations were made regarding the need for increased monitoring of persistent and bioaccumulating pollutants, specifically in the context of human health effects.

- **The use of indicators.** Bioindicators and biological markers should be used to help estimate exposure.

- **"Dose" and "exposure".** Monitoring activities should be augmented in order to improve the quantification of exposure. The techniques used should involve a mix of fixed-site and personal monitoring.

- **Limitations of existing health registries.** Registries of human health (birth defects, mortality, cancers, etc.) should be improved.

- **Intensive surveys of specific human populations.** Studies should be implemented on target populations in the Canada-U.S. border region, that have dietary exposure to transported pollutants, using intensive physical, biological, and health effects monitoring.

- **Studies of animals in the wild.** There should be increased measurements of bioaccumulation in, and health of, wild animal populations. Data obtained might be used to assess risk to humans.

Meeting with the Rainy River Advisory Board

The Rainy River is a woodlands river about 130 km long, on the border between Ontario and Minnesota, flowing WNW from Rainy Lake into Lake of the Woods. These two Lakes are also on the border between Ontario and Minnesota, with Rainy Lake mostly in Ontario; Lake of the Woods is also partially in Manitoba. These waters later flow into Lake Winnipeg in Manitoba, and eventually into Hudson Bay via the Nelson River. At one time, flow of the Rainy River was controlled extensively to provide power for mills downstream. Its flow remains under control, although now primarily to maintain fairly constant flow for safety and recreational purposes.

The Rainy River has become relatively unpolluted in the last 10-15 years, mostly as a result of cleanup of discharges from paper mills. Prior to that, the Rainy was not very suitable for recreational purposes for a period of from 30 to 40 years. This cleanup should be viewed as a success story; the Rainy is now used extensively for recreational purposes, including sport fishing. The primary contemporary concerns with regard to pollution in the Rainy River are driven by human health risk assessment, apparently via water and biological (ie., food) media. The concerns center on chlorinated hydrocarbons (especially PCBs, including dioxins, and possibly even toxaphenes and other pesticides) and mercury. The sources appear to be discharges from paper mills on both sides of the Canada-U.S. border.

Monitoring of the Rainy River consists of routine sampling for standard water chemistry and bioassay in the water column and sediments. This sampling includes effluents from the mills.

Whole benthic surveys are also conducted from time to time; fish, clams and leeches are likewise sampled occasionally. In addition to the improvements in water quality, benthic organisms (especially macroinvertebrates) have recovered in the last twenty years since controls went into place.

The use of bioindicators in the Rainy River has been developed and tested, e.g. caged fish, leeches, and clams. The caged leeches were effective in dioxin studies. Bioassay techniques have been used as well. Air sampling programs are mainly operated by industries in the area. It appears that air quality data are at least partially available and need to be tied into overall monitoring efforts. There is a need to distinguish between local sources and long-range transport of important pollutants in the water.

Recommendations on sampling locations, monitoring frequency, and variables to be monitored have been made by the Rainy River Advisory Board and accepted by the member agencies. In addition, federal agencies have networks that supplement the provincial and state networks, presumably with more modern techniques, e.g., Environment Canada, and the U.S. Army Corps of Engineers.

Recommendations

- **The need for review of QA/QC procedures.** The QA/QC measures and data compatibility of various networks should be reexamined. Protocols need to be established in order to provide better confidence in existing data (e.g., on very low levels of hydrocarbons measured in water).

- **The need for expanded air quality monitoring.** Air quality monitoring programs should be initiated to distinguish between the consequences of local and distant polluters.

Meeting with the Red River Advisory Board

The Red River is a prairie river running northward on the border between North Dakota and Minnesota into Manitoba. Its watershed in North Dakota, South Dakota, Minnesota, and Manitoba is quite large. It flows through Winnipeg and into Lake Winnipeg in Manitoba.

Assessment of the risk to human health due to water pollution from agricultural practices is presently one of the major driving concerns. Currently, the flow of the Red River is not significantly controlled and the Red is not considered a major recreational resource. Being a prairie river, the Red has fairly large seasonal variations in flow and usually carries considerable suspended sediments. There is local pressure to dam some of the tributaries for recreational purposes.

Standard water quality measurements are emphasized for the Red River. PCBs and other organics are not much investigated, although pesticides are a concern. There is evidence that coliform bacteria counts have been reduced substantially in the Red River since sewage control and treatment were implemented.

A basin-wide water quality assessment, led by the U.S. Geological Survey, is taking place with a consortium of state, provincial, and federal agencies. It is expected that ground water will be sampled; atmospheric sources of dioxins might also be considered.

The water quality standards and techniques seem to be somewhat outdated. Toxics are not now factored in and the biological diversity in the rivers is not fully considered. "Biocriteria," perhaps bioassay or some types of composite indices to establish criteria against which to evaluate water quality, need to be developed. In addition, interpretative analysis techniques need to be developed; it seems likely that the EPA Region 8 would take the lead in this.

The wider geographic scope should be factored into these considerations. For example, Bilateral Agreements of importance exist outside the IJC. One is between Saskatchewan and Montana on the Poplar River, a tributary of the Missouri River. Another deals with the Souris River, which feeds the Assiniboine River and ultimately the Red River in Manitoba. The Red River Board has considered the Souris River but will take no action in its regard while the relevant Bilateral Agreement is in place.

Recommendations

- **The need for review of QA/QC procedures.** Steps should be initiated to establish QA/QC and data compatibility, especially for new and proposed programs. Protocols for sampling need to be established and used by the various networks (e.g., sampling of low levels of organics in water, fish, and sediments).

- **The need for expanded air quality monitoring.** As with the Rainy River, there is a need for studies to distinguish between local sources and long-range transport of air pollutants into the river basin. Some of the existing air quality stations can be easily moved in response to reassessment of needs or to short-term surveillance needs. Canadian stations appear to be less easily moved, but have more flexibility in adding new variables to be measured. The impact of resuspension of particles from agricultural areas is a difficult and neglected problem.

- **Consideration of data from other sources.** Other sources of data need to be identified and examined (e.g., the Saskatchewan Power Corporation). In general, existing sources of data need to be identified, examined, and made available to the parties concerned.

- **"Seed money" is needed for new efforts.** Overall, one of the greatest limitations is funding. It is impractical to attempt to save money by reducing monitoring efforts because they are now at a minimal level. Federal funding in the U.S. appeared to have decreased by 40% at the start of fiscal year 1991.

4. OBSERVATIONS ON THE WORKSHOP PROCESS

In its charge to the Expert Group, the International Air Quality Advisory Board instructed the Group "to advise... [the Board] ...on scientific and technical matters pertaining to transboundary monitoring...". Accordingly, and in consultation with the Board, it was decided to host a series of workshops at strategic locations across the United States-Canada transboundary region in order to draw on regional expertise. A total of three workshops were held: St. Andrews, New Brunswick (June 1988); Burlington, Vermont (February 1989); and Victoria, British Columbia (November 1989). The Great Lakes region was not included because the Group believed the region was well served by other committees and organizations within the IJC structure.

For each workshop, a local convener was appointed several months in advance of the proposed workshop date. In the case of the first two workshops, the conveners were affiliated with the IJC; in the case of the third, an organizer was recruited by the Group. In each case, the convener worked with the Group in the development of the program, the selection of speakers, etc. As much as possible, the subject matter of each workshop was region-specific. Approximately fifty persons attended each of the first two workshops; slightly fewer participated in the third. At each workshop, invited speakers reviewed various air, water, forest and human health monitoring problems and programs from a local or regional perspective. Participants then formed into discussion groups to further explore issues of relevance within the region. Reports and recommendations from these discussion groups were incorporated along with the invited papers into published proceedings from each workshop.

In content, the three workshops varied somewhat, depending on perceived environmental issues in the region, the way in which these were being addressed, and on the researchers attending (the St. Andrews Workshop was, in part, built around the St. Croix River program; much attention at the Burlington Workshop was devoted to maple decline). Because of more-defined environmental issues in the east, the first two workshops were more focused, hence yielded more specific recommendations. It is concluded that, to ensure success, workshops should be issue-oriented.

Participation by individuals from many backgrounds underscored the multi-disciplinary nature of much environmental monitoring. Additional monitoring efforts were identified for inclusion in the Inventory. Useful suggestions were advanced regarding integrated monitoring. The workshops were useful in terms of heightening awareness of the state of environmental monitoring, and in terms of putting forward the concept of "integrated monitoring." A further by-product of the workshops from a resource manager and researcher perspective was the development of cross-disciplinary personal contacts at the regional level.

The workshops were successful in attracting a number of participants engaged in regulatory work and in attracting local government scientists. The relatively short notice may have precluded greater participation by members of the local academic community, though a number of university scientists did attend.

The importance of local issues is underlined by the continuing success of workshops addressing problems of the Great Lakes. In the Great Lakes border region, the magnitude of the overall environmental problem is such that there are well-recognized and organized scientific and activist communities, with scheduled meetings and formal journals. Such communities appear to be lacking elsewhere. However, one product of this series of workshops might well be the generation of new nuclei for discussion and cooperation.

Issues related to human health presented a problem both for the Expert Group and for the workshops it conducted. It is clear that integrated monitoring could provide insight on the relationship between human health and the environment, but it seems unlikely that fixed-site integrated monitoring data could be used alone to explain observed human health effects. In essence, the problem is that humans as receptors are moving targets.

The best way to assess the exposure of humans to their environment is by use of personal monitoring, which eliminates many of the assumptions made when attempting to use data from stationary environmental monitoring stations. Since it is not feasible to equip large numbers of people with personal monitors, there remains a need to learn how to relate personal exposures to characteristics of the environment as revealed by stationary monitoring activities. If human health concerns are to be addressed in an integrated monitoring program, then the sampling strategy must include a personal monitoring component.

Both the temporal and the spatial characteristics of exposures must be taken into account. Static or fixed sample times may not adequately represent exposures if short-term, high-level peaks are missed; this is obviously important if the peaks represent exposures that are sufficient to cause adverse health effects. The location of sampling stations is important, because most people live in urban areas. Also, the distance between sampling locations could be of prime importance if area exposures are to be computed; large distances between sites may result in missing local variations of importance to moving receptors.

The concept of a nested network is especially relevant in this context, since for purposes of monitoring human health it may prove advantageous to consider population exposure monitoring using personal monitors as a monitoring level that is adjunct to (and is supported by) the fixed-site integrated monitoring that is the main topic of this report.

For purposes of human health studies, integrated monitoring programs should measure a number of chemicals, so as to develop a profile of pollutants that are present. This is important to assess possible synergistic interactions among compounds or classes of compounds.

5. EXAMPLES OF INTEGRATED MONITORING PROGRAMS

Examples of the Value of Integrated Monitoring

The value of integrated monitoring is demonstrated by two particular examples. In their report "Recent Changes in the Phytoplankton of the Bay of Quinte: the relative importance of fish and phosphorus" Nichols and Hurley (1987) reviewed monitoring data for the period 1972 to 1986. Phosphorus inputs were significantly reduced in 1978. There was a corresponding decrease in phosphorus concentrations and algae growth as shown in Figure 1 (Figure 2 of their report). However, from 1982 to 1985 the May to October average phytoplankton biomass increased to amounts very similar to what had occurred before phosphorus control was applied, even though phosphorus concentrations have remained lower. In order to explain this apparent contradiction, the authors further analyzed changes in fish populations. The numbers of white perch and alewives have varied, and the authors hypothesized that this contributed to changes in the grazing rates of zooplankton and/or zoobenthos on phytoplankton and that this has also been a major influence on the phytoplankton concentrations in the Upper Bay of Quinte. The relative effects of phosphorus and fish populations are shown in Figure 2 (Figure 6 of their report).

Figure 3 summarizes the overall effect; arrows indicate the expected increases and decreases in the numbers of the various trophic levels in response to changes in nutrient supply and in fish populations (Figure 9 of Nichols and Hurley, 1987). The comprehensive set of monitoring data has provided the basis to show how both nutrient supply and food chain characteristics influence algae numbers. The Expert Group believes that this is a fine example of the value

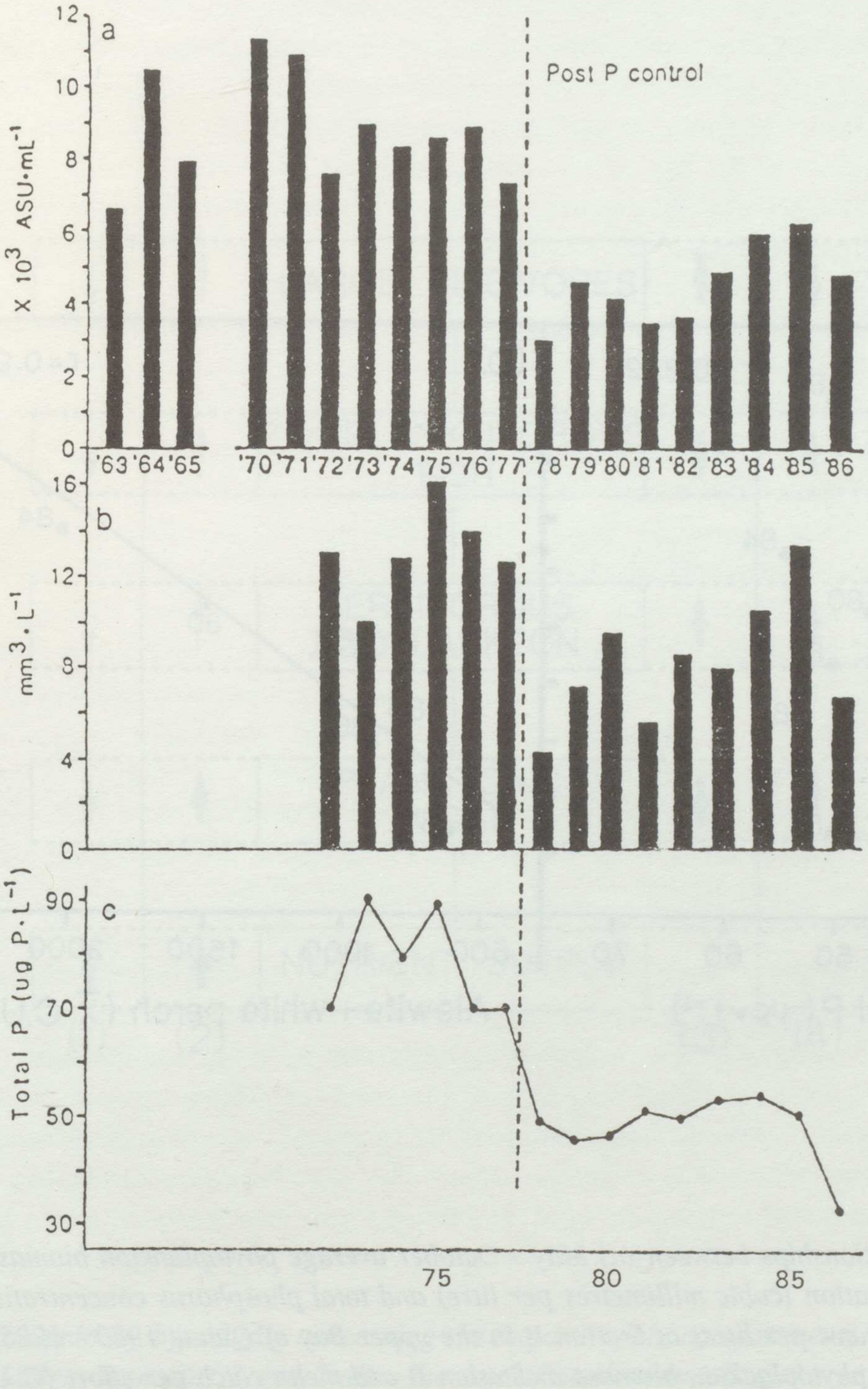

Figure 1. Average May-October densities of total phytoplankton in samples collected (a) through the Belleviulle water treatment plant intake and (b) at Station B in the upper Bay of Quinte. Also shown (c) are average total phosphorus concentrations over the same time period at Station B. (Diagram from Nicholls and Hurley, 1987.)

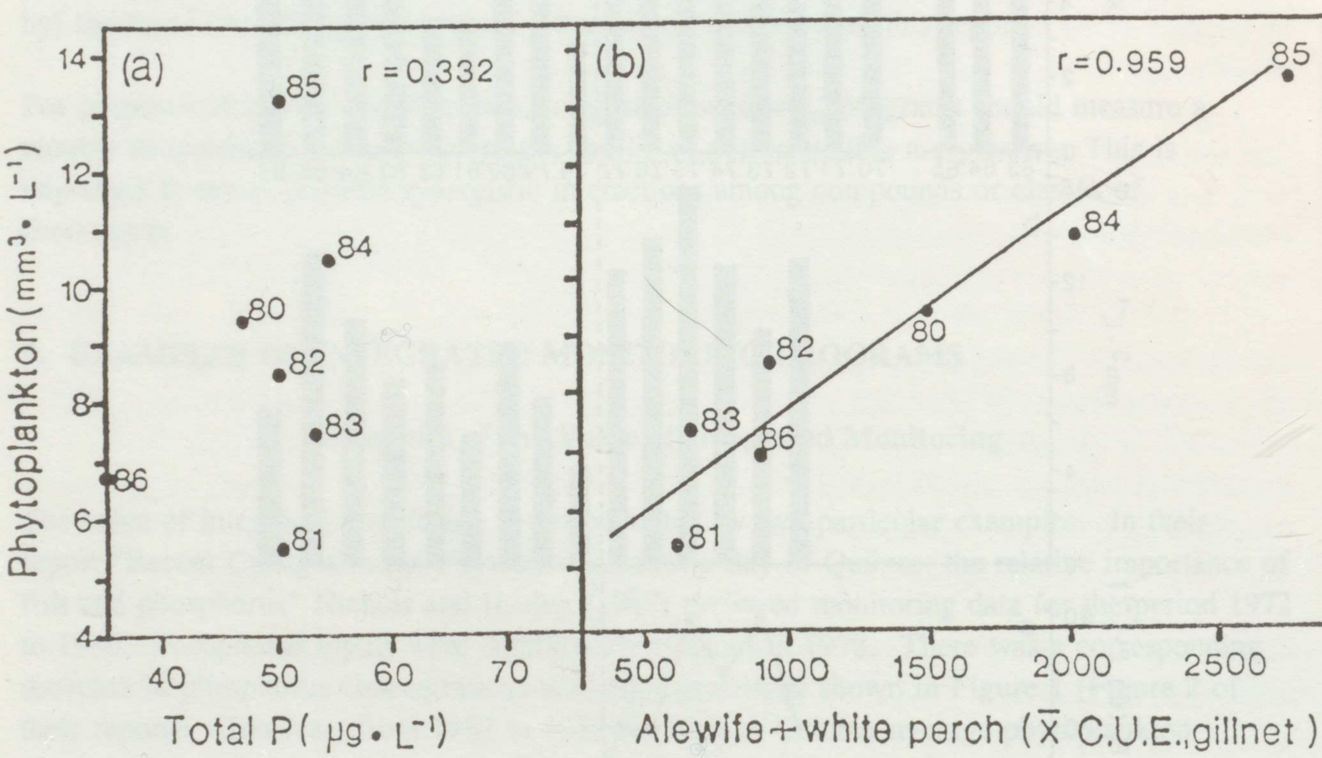

Figure 2. Relationships between (a) May - October average phytoplankton biomass concentration (cubic millimetres per litre) and total phosphorus concentration (micrograms per litre) at Station B in the upper Bay of Quinte 1980 - 1986, and (b) average phytoplankton biomass at Station B and mean catch per effort (C.U.E.) of the dominant planktivores (alewife and white perch) for standard experimental gill net lifts from the Bay of Quinte. There was no trawling in 1982, and gill nets were not set in the upper Bay in 1985, so data from the middle Bay of Quinte gill net sets were used here. (Diagram from Nicholls and Hurley, 1987.)

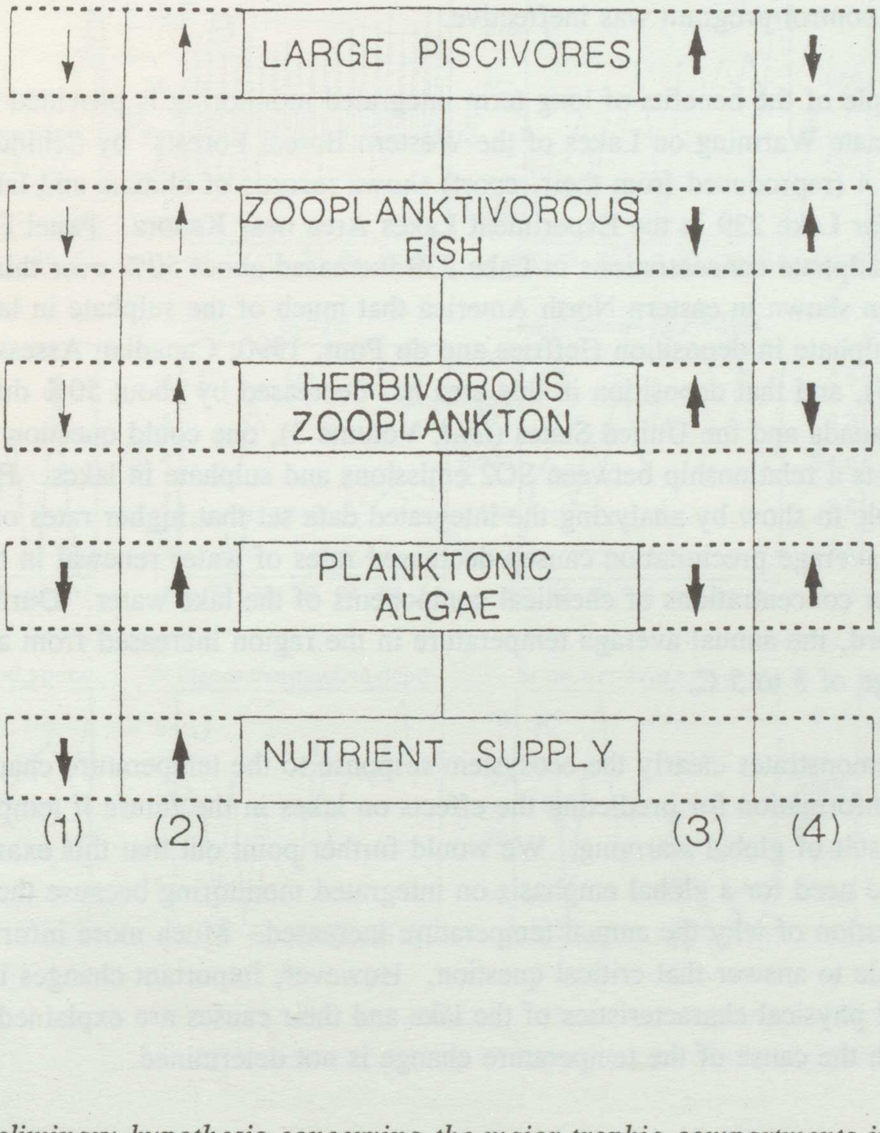

Figure 3. Preliminary hypothesis concerning the major trophic compartments in the upper Bay of Quinte. Scenarios 1 and 2 alter the rate of nutrient supply and scenarios 3 and 4 hold nutrient supply constant but alter the abundance of large piscivores. In the Bay of Quinte, the benthic community (insect larvae, ostracods, etc.) may be a more important functional link between forage fish and phytoplankton than herbivorous zooplankton. (Diagram from Nicholls and Hurley, 1987.)

of long term monitoring across a broad scale of environmental variables. In this particular example, the multidisciplinary and closely organized monitoring programs succeeded in providing evidence that has led to a more complete and accurate explanation of the effects of the phosphorus control program, as well as to new insights into the fundamental ecological processes taking place in the Bay. If monitoring programs had simply measured phosphorus concentrations and algae growth, one might have been drawn to the erroneous conclusion that the phosphorus control program was ineffective.

A second example of the benefits of long term integrated monitoring is provided in the report "Effects of Climate Warming on Lakes of the Western Boreal Forests" by Schindler et al. (1991). Figure 4 (reproduced from their report) shows records of climate and lake measurements for Lake 239 in the Experiment Lakes Area near Kenora. Panel F in Figure 4 shows that the sulphate concentrations in Lake 239 increased about 50% over this time period. Since it has been shown in eastern North America that much of the sulphate in lakes can be related to the sulphate in deposition (Jeffries and du Pont, 1990; Canadian Assessment of Acid Rain, Volume 5), and that deposition in this area has decreased by about 50% due to emission reductions in Canada and the United States (*ibid*, Volume 3), one could question whether or not there really is a relationship between SO2 emissions and sulphate in lakes. However, the authors were able to show by analyzing the integrated data set that higher rates of evaporation and lower than average precipitation caused decreased rates of water renewal in the lakes leading to higher concentrations of chemical components of the lake water. During the monitoring record, the annual average temperature in the region increased from a range of 1 to 2 C to a range of 3 to 5 C.

This data set demonstrates clearly the ecosystem response to the temperature change and provides solid information for predicting the effects on lakes in the future if temperatures increase as a result of global warming. We would further point out that this example demonstrates the need for a global emphasis on integrated monitoring because the results raise the obvious question of why the annual temperature increased. Much more information is needed to be able to answer that critical question. However, important changes in chemical constituents and physical characteristics of the lake and their causes are explained by this data set, even though the cause of the temperature change is not determined.

Examples of Existing Integrated Monitoring Activities

Using the definition of Integrated Monitoring developed here (requiring the simultaneous measurement and analysis for any single location of the physical/chemical/biological properties of two or more components of an ecosystem), the Expert Group identified a small number of

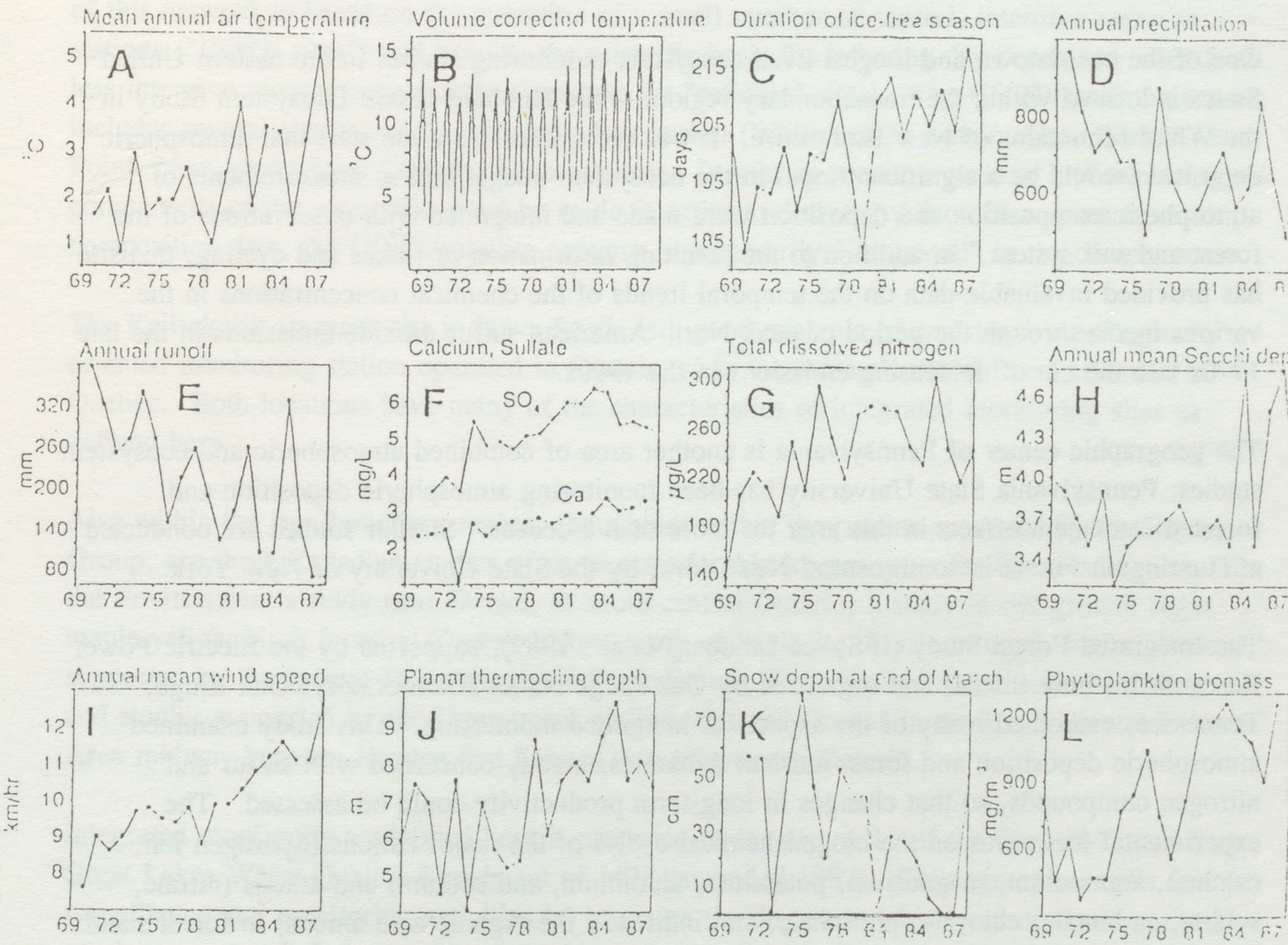

Figure 4. Long-term records of variables related to the water quality and biological productivity of Lake 239 in the Experimental Lakes Area, near Kenora, Ontario, together with records of selected climatic variables. (Diagram from Schindler et al., 1991)

existing integrated monitoring sites in both North America and Europe. At these sites, limited integrated monitoring has been going on for some time and in some cases plans for major expansion of integrated monitoring are now in preparation.

North America

One of the best-known and longest-lived ecosystem monitoring studies in the eastern United States is located within the transboundary region — the Hubbard Brook Ecosystem Study in the White Mountains of New Hampshire. It was recognized from the start that atmospheric deposition would be a significant input to the ecosystem budget and so measurements of atmospheric composition and deposition were made and integrated with observations of the forest and soil system. In addition to the resulting information of fluxes and cycling, this site has provided invaluable data on the temporal trends of the chemical concentrations in the various media through the period of peak North American sulfur dioxide emissions in the late 1970s into the era of decreasing emissions in the 1980s.

The geographic center of Pennsylvania is another area of combined atmospheric and ecosystem studies; Pennsylvania State University has been monitoring atmospheric deposition and forested catchment effects in this area for more than a decade. Similar studies are conducted at Huntington Forest in south-central New York, by the State University of New York.

The Integrated Forest Study (IFS, see Lindberg et al., 1989), supported by the Electric Power Research Institute (EPRI) and organized by Oak Ridge National Laboratory, Oak Ridge, Tennessee, embodied many of the aspects of integrated monitoring. This study examined atmospheric deposition and forest nutrient dynamics, mainly concerned with sulfur and nitrogen compounds, so that changes in long-term productivity could be assessed. The experimental focus was on the biogeochemical cycles of the major cations (hydrogen ion, calcium, ammonium, magnesium, potassium, aluminum, and sodium) and anions (nitrate, sulfate, carbonate, chloride, phosphate, and indirectly the organic acid anions) in forest stands at a number of sites in the U.S.A. and abroad. The studies involved monitoring the amount and chemistry of precipitation, throughfall, stemflow, forest floor and soil percolate, litterfall, etc., over a three year time period in the mid-1980s, as well as measuring the organic and mineral content of the major ecosystem components (overstory and understory vegetation, roots, litter, and soil) at these same sites. Several of the sites were within the U.S.-Canada boundary region: in the U.S.A., the Thompson-Findley Lake site in Washington, the Whiteface Mountain and Huntington Forest sites in New York, and the Howland research site in Maine; in Canada, the Turkey Lakes site in Ontario. These sites remain active, although at a somewhat reduced level of activity.

The nested network characteristics of integrated monitoring are exemplified by the National Oceanic and Atmospheric Administration's deposition monitoring network, set up during the 1980s in the United States (but extending with one station that is no longer operational into Canada; see Hales et al., 1987). This network focuses on dry deposition, for which methods of routine measurement are not yet available. Hence, the dry deposition research component of this network is based on the operation of a small number of central, intensive research stations ("CORE sites") that provide the scientific basis for inferring dry deposition rates from less intensive measurements made elsewhere (at "satellite" sites). The CORE/satellite network includes several stations in the transboundary region (Whiteface Mountain, New York; West Point, New York; State College, Pennsylvania). Insofar as measurements of critical biological components of the ecosystem must be made in order to derive dry deposition rates from air composition data, the CORE/satellite network is necessarily "integrated" in the current sense.

The Kejimkujik research site in Nova Scotia is a good example of an intensive ecologically oriented monitoring station operated in Canada, as is the research site at Lac Laflamme in Quebec. Both locations have many of the characteristics of integrated monitoring sites as defined here.

Also within the transboundary region, though not within the portion surveyed by the Expert Group, are three Canadian studies of some considerable longevity — the Ontario Ministry of the Environment's study near Dorset, in south-central Ontario; a study in old-growth sugar maple-yellow birch forest at Turkey Lakes, north of Sault Ste. Marie in north central Ontario, supported by the federal Departments of Environment, Fisheries and Oceans, and Forestry; and studies supported by the Department of Fisheries and Oceans in the Experimental Lakes Area midway between Dryden and Kenora in northwestern Ontario.

Integrated monitoring as defined here is proposed under Annex 11 of the Canada-United States Great Lakes Water Quality Agreement of 1978 (amended 1987). This agreement calls for surveillance and monitoring activities (a) to assess the degree to which jurisdictional control requirements are being met; (b) to provide definitive information on the location, severity, extent, frequency, and duration of violations of the general and specific objectives of the water quality agreement; (c) to provide information for measuring local and whole lake response to control measures using trend analyses and cause/effect relationships; (d) to determine the presence of new or hitherto undetected problems in the Great Lakes Basin ecosystem; and (e) to support the development of remedial action plans.

The Great Lakes International Surveillance Plan (GLISP) was developed by the Surveillance Subcommittee of the International Joint Commission's Water Quality Board to serve as a model for an integrated joint surveillance and monitoring program. The program includes baseline data collection, sample analysis, evaluation, and quality assurance programs to allow assessments of (a) inputs from tributaries, point source discharges, atmosphere, and connecting channels; (b) whole lake data including that for nearshore areas, shorelines, open waters, fish, and wildlife; (c) outflows; (d) total pollutant loading to, storage and transformation within, and export from the Great Lakes System; (e) the adequacy of proposed load reductions and schedules contained in Lakewide Management Plans; and (f) contributions of various exposure media to the overall intake of toxic substances in the Great Lakes Basin ecosystem. Although designed to address problems specific to each of the Great Lakes, the major activities under GLISP are motivated by general concerns for human health and well being and for the status of the aquatic ecosystem.

On a continental scale, the U.S. Environmental Protection Agency (EPA), in conjunction with other federal agencies (especially the U.S. Forest Service and the National Oceanic and Atmospheric Administration) is designing a national monitoring strategy in which many sites would have the attributes of integrated monitoring. Canada has also developed a proposal for a National Integrated Monitoring Program.

Europe

The Scandinavian countries have led the development and application of integrated monitoring. In Sweden, the National Swedish Environmental Monitoring Program (PMK) was established in 1978, based on long previous experience in monitoring various components of the ecosystem. The network was based on the selection of twenty small watersheds (usually in national parks or nature reserves) spread across the entire country. Under the auspices of the Economic Commission for Europe Convention on Transboundary Air Pollution, an international workshop was held in Stockholm in 1987 to begin the process of developing an integrated monitoring network for the whole of Europe.

Other

Through the auspices of the United Nations, several symposia on the topic of integrated monitoring have been conducted, starting in 1978 and culminating in a technical document "Procedures and Methods for Integrated Global Background Monitoring of Environmental Pollution" prepared by the World Meteorological Organization and the United Nations Environmental Program in 1987 (see Rovinsky and Wiersma, 1987).

Summary

The concept of integrated monitoring has been discussed for about twenty years. Some aspects have been implemented on a small scale during this period, but only in the last few years has the concept gained wide acceptance as an essential part of characterization of the ecosystem in a way that maximizes our ability to learn about the overall system and man's impact upon it.

6. OVERALL CONCLUSIONS

Building upon the results of debate conducted during the workshops, the Expert Group has developed the following general conclusions.

1. There is need for integrated monitoring. The workshops supported the concept of integrated monitoring as explained earlier. However, in spite of enthusiasm for the principle of integrated monitoring expressed at all of the workshops and meetings, the Expert Group actually found very few examples of monitoring beyond that which was required to deal with specific problems.

2. Existing integrated monitoring activities need to be endorsed and encouraged. Several existing research stations can be classified as integrated monitoring sites (see Figure 5). These sites offer an existing long-term record, and continuing operation of such sites is necessary to reveal changes that are expected to follow from newly-imposed emission controls and regulations.

3. The initial inventory of transboundary monitoring programs should be improved and expanded. The initial IAQAB inventory of monitoring activities in the transboundary region should be used as a starting point for constructing a "living inventory," perhaps as an ongoing IJC activity.

4. Existing monitoring programs are generally effective. The monitoring programs that were discussed at the workshops appear to be meeting the needs of many of the user groups, which leads the Expert Group to conclude that problem oriented monitoring should be maintained as needed. The Expert Group also recognizes that an overswing towards integrated monitoring might detract from existing effective specialized monitoring programs.

5. Nested networks are required. It has been a general conclusion that there should be nested networks, such as already exist in some areas (see discussion in Section 5). The smaller number of most comprehensive sites would constitute an integrated monitoring network for multidisciplinary measurement. But, anchored to and surrounding these would also be other networks (such as precipitation monitoring networks) which measure a smaller number of parameters on a much wider space scale.

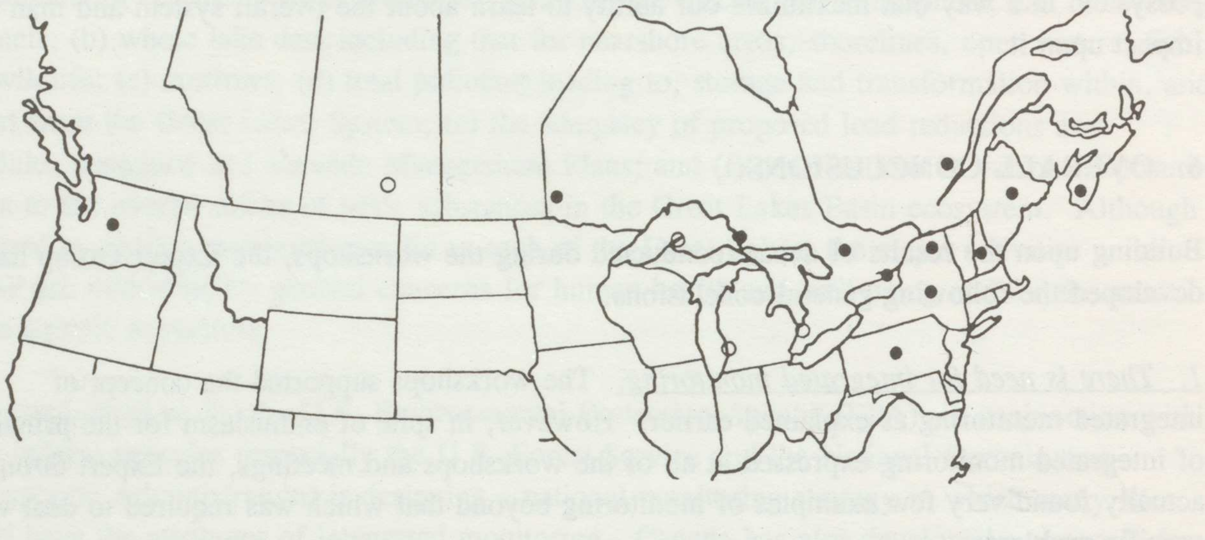

Figure 5. Existing stations presently operating as integrated monitoring sites in the transboundary region, and (as open circles) indications of some possible new sites. Existing sites are discussed in the text; possible new sites are no more than indications of where sites that were discussed may be set up. In the Great Lakes region, the sites shown are a few of those now being considered elsewhere.

If monitoring is also to help us determine causes of changes in the environment, then the notion of a multi-tiered monitoring system is required.

- The broadest level of monitoring (i.e. involving networks that measure relatively few variables at a large number of stations) can detect changes in spatial patterns from a baseline pattern. The identification of risk to specific parts of the ecosystem provides the rationale for largescale monitoring to characterize that state of the environment.

- If the monitoring system is integrated and coordinated, then correlations among different sets of observations at one location should give some clues to causality of changes. Identification of the causes of any impacts and design of remedial strategies requires highly detailed and often multimedia monitoring.

- To really determine causality, a more detailed level of monitoring will be needed to enable understanding the processes of change in the environment that are being monitored. Many ecosystem processes occur over long periods of time. Continuing study over the long term is, therefore, the only way to understand these processes. In many cases, it is only after years of monitoring that we can even hope to develop serious hypotheses to test experimentally.

6. Network intercomparisons are required. Comparisons among network measurement systems and operating protocols were also strongly recommended. Such work is already going on at the government agency level and there are already sites at which several different networks are running collocated samplers. For example, there are three sites in Canada and three sites in the U. S. where CAPMoN and NADP/NTN networks are being compared. Quality control and quality assurance programs need to be implemented at an international level and expanded so that environmental monitoring data are compatible.

7. Interdisciplinary collaboration and cooperation needs to be promoted. The Expert Group concludes that an automatic consequence of integrated monitoring is increased collaboration and improved communication among scientists of different disciplines. This improved communication is a factor that contributes to the overall enhanced capability to determine why observed environmental changes actually occur.

8. The design of integrated monitoring programs requires clear identification of issues. Issues in question must be clearly identified when designing an integrated monitoring program. Monitoring over the long term is a way to track environmental conditions to enable sound resource management or regulatory decisions. Clearly, monitoring sites should not be overdesigned in the sense that all physical, chemical, and biological parameters one can think of are measured. However, all sites in a network should have a basic (or minimum) set of parameters and these could be supplemented at individual sites depending on the particular issue to be addressed. It is also important to be proactive, and to attempt to identify emerging or future issues and include appropriate measurements. Striking the correct balance between what should or should not be included at a given site will require considerable scientific judgement in order to obtain the most efficient use of available resources.

9. Integrated monitoring needs to be coast-to-coast in the transboundary region. Changes in emissions that are known to have transboundary implications are occurring at a national level in both the U.S. and Canada. The environmental repercussions of these changes will vary according to the geography, regional meteorology, and long-term climatic variability; results of control programs obtained in the east will not necessarily be representative of the west, and *vice versa*. The response needs to be investigated using common procedures in both countries, especially in the transboundary region. Integrated monitoring is required to minimize the risk of incorrect identification of causative factors.

10. Shared data management systems are needed. Systems for managing the data from monitoring networks are already in existence. However, integrated monitoring imposes requirements that are not necessarily compatible with existing national or continental data bases, which tend to be focused on a single-medium or a specific issue. Very few of the state network measurements are presently included in the major national data base in the U. S. —

the Acid Deposition System (ADS) of the National Acid Precipitation Assessment Program and the Environmental Protection Agency. In Canada, there is an existing national data base; efforts are now taking place to include Provincial network data in this data base. An important next step is to make sure that Provincial and State network data are included in the national data bases, on both sides of the border.

11. Results of integrated monitoring may have limited application to issues of human health. Integrated monitoring data will provide a valuable source of background or historical environmental exposure information that could then be used for risk assessment and management purposes. Personal monitoring information plus data from integrated monitoring locations would allow for a more complete investigation of the risk to human health.

- It is unlikely that integrated monitoring data alone will explain observed health effects.

Figure 6 shows the relationships between environmental (integrated) monitoring, personal monitoring, and biological monitoring. Calculation of absorbed dose and exposure is less difficult using personal and biological monitoring than when environmental monitoring data alone are available.

12. Socioeconomic benefits of pollution regulations and controls should be quantified as essential complementary activities to integrated monitoring programs. The St. Croix and Rainy rivers were identified in the workshops and meetings as two places where economic activity, mainly recreational, has increased significantly in response to improving water quality of the rivers. In fact, the management of the competing recreational uses has become a matter of some difficulty in the St. Croix River area. However, the Expert Group was unable find much documentation of the economic benefits being derived from these improved environmental conditions. While there are many references to clean environments being conducive to a good economy, there are few data on which to base actual cost-benefit evaluations.

13. Integrated monitoring will provide improved cost-benefit for monitoring programs. Establishing integrated monitoring sites may or may not save money for sponsoring agencies in absolute terms. However, we see considerable economic and technical benefits from combining existing resources from presently separate and distinct programs. For example, if basic ecological data are being collected by government agencies, then this information is of great value to universities, who may wish to conduct specific research and monitoring activities in association with the main program with obvious overall savings and improvements in the quality of the work.

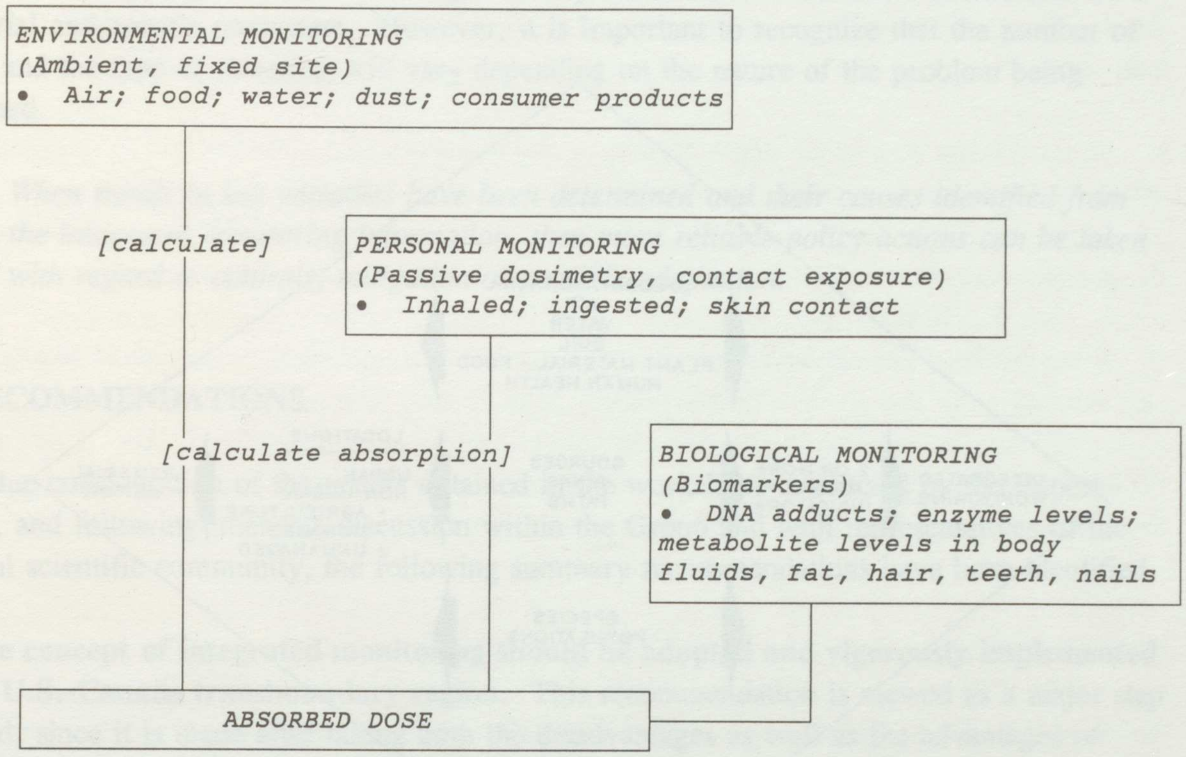

Figure 6. A schematic representation of the linkages among different components of an integrated monitoring program addressing questions of health effects. Note that both fixed-site and personal monitoring are required to help assess the dose received by the target population, and biological markers are required to track changes in the condition of the population.

<u>14. *Integrated monitoring will facilitate detailed scientific investigation of important processes.*</u> The scientific community tends to draw, in our view, too much of a division between monitoring programs (often viewed as data collection activities only) and scientific studies (often lumped in the category of "process research"). In the view of the Expert Group, monitoring and process science are complementary and parallel scientific activities which are necessary to understand complex environmental issues.

Our overall concept of integrated monitoring is shown in Figure 7. The number of media to be sampled at an integrated monitoring site varies considerably, from as few as two in the case of measuring the effect of acid rain on buildings (atmospheric conditions and materials

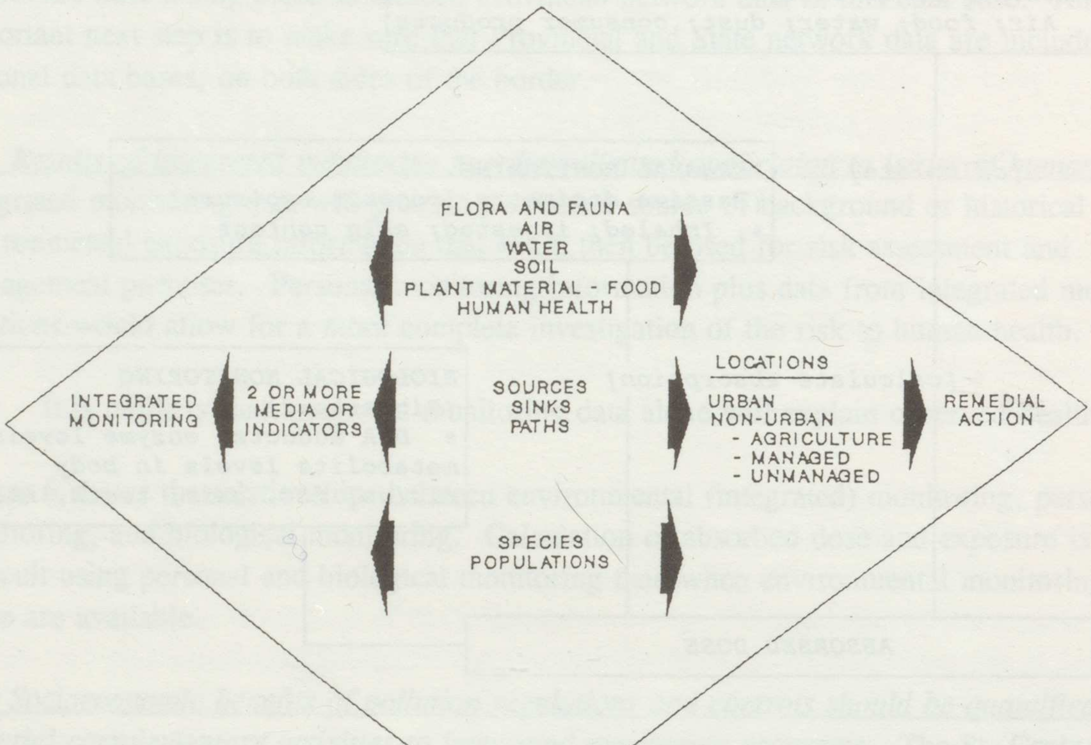

Figure 7. A schematic depiction of the view of integrated monitoring developed by the Expert Group. The diagram indicates a central level of narrow-focus monitoring directed to detection of changes in ecosystem variables, served by a nested network of fewer stations where more variables are monitored in order to reveal the roles of different processes, and served finally by an even smaller (in number) array of multi-media and multi-disciplinary integrated monitoring stations. The left hand side of the diagram shows the process-oriented nested network that is envisioned. On the right, the diagram shows how the large system-trends network is coupled to smaller networks addressing specific issues in special areas, such as urban areas and different kinds of non-urban areas. These issue-related nested networks deliver information that directly leads to the refining of remedial actions.

effects) to a very large number of ecological components such as the effect of acid rain on a terrestrial and aquatic ecosystem. However, it is important to recognize that the number of media and the type of sampling will vary depending on the nature of the problem being examined.

When trends in key variables have been determined and their causes identified from the integrated monitoring information, then more reliable policy actions can be taken with regard to controls, mitigation or possible adaptation.

7. RECOMMENDATIONS

After due consideration of the results obtained in the workshops conducted by the Expert Group, and following intensive discussion within the Group and with representatives of the external scientific community, the following summary recommendations have been identified.

1. The concept of integrated monitoring should be adopted and vigorously implemented in the U.S.-Canada transboundary region. This recommendation is viewed as a major step forward, since it is made after taking both the disadvantages as well as the advantages of integrated monitoring into account. In essence, the critical contribution of integrated monitoring is that it permits multidisciplinary analysis that can reveal causative factors in complicated environmental systems.

2. The United States and Canada should work toward improving coordination of monitoring programs of all kinds, especially integrated monitoring. The existing situation appears disorganized, and the use of special scientific committees would help improve coordination among the many contributing agencies in both Canada and the United States.

3. Top priority should be given to assuring continuity of observations being made at existing sites, especially those with a decade or more of data. That is, it is most important to ensure the continuation (and augmentation) of records from existing integrated monitoring stations. Second priority should be given to increasing the number of such integrated monitoring sites in the transboundary region, firstly by bringing together pieces of ongoing monitoring programs and secondly by setting up new sites at locations where special needs exist. Locations of relevant sites identified and recommended by the Expert Group's sequence of workshops are shown in Figure 5.

4. Data bases and reports should be prepared to show conditions and changes that cross the international boundary, rather than the traditional reports that stop at the boundary).

5. Formal steps should be taken to assure the comparability and general high quality of measurements made at network sites in the transboundary region.

6. Socioeconomic benefits of pollution control should be documented.

7. A mechanism should be established to maintain an updated inventory of ongoing monitoring activities in the transboundary region, and to maintain a library of related reports. This mechanism would provide researchers with a path by which they could gain access to network data, and would provide regulators and planning agencies with access to the scientific resource represented by the monitoring community.

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APPENDIX I

A. TERMS OF REFERENCE OF THE EXPERT GROUP

1. Duties and Responsibilities

(i) The Expert Group on Monitoring (hereafter referred to as the Group) shall advise the international Air Quality Advisory Board (hereafter referred to as the Board) on scientific and technical matters pertaining to transboundary monitoring networks and their data bases and specifically to:

   (a) Develop methods to integrate monitoring data which could be used to report to governments and jurisdictions on the state of the environment within the entire transboundary region.

   (b) Recommend the need for new or modified networks which optimize components of existing networks.

   (c) Define, if a new or modified network is desirable, its purpose, structure, size, activities, costs of establishment and maintenance.

(ii) The Group shall prepare, in close consultation with the Board, a workplan during its first 120 days and present it to the Board for approval. The Group shall keep the Board informed of any changes in the workplan, and any developments, actual or anticipated, which are likely to impede or otherwise affect them carrying out the Group's responsibilities.

(iii) The Group shall undertake such studies as may be necessary or appropriate to advising the Board.

(iv) To the extent possible and relevant, the Group shall make maximum use of available resources, information and technical data from the agencies of Canada and the United States, as well as from other sources.

B. TECHNICAL GUIDANCE FOR THE EXPERT GROUP ON MONITORING

Part B supplements and forms part of the statements on Duties and Responsibilities of the Expert Group on Monitoring (hereafter the Group) which appear as Part A of this document.

1. The Board takes a broad view in its initial consideration of ongoing or proposed monitoring programs to watch the environment using in-situ instrumentation, sample collections, surveys, etc. This document suggests bounds to the Group's recommended monitoring efforts. Arguments by the Group for greater stringency or relaxation will be resolved jointly by the Group and the Board as they arise.

2. The purpose of the Group's report is to advise the Board and the Commission on how existing or future resources can be most efficiently used to describe the current state of the environment and to suggest what new efforts are needed for the same purpose. The geographical area covered by the ongoing and proposed monitoring efforts include the regions within about 400 kilometres of the Canada-United States border. The dimensions of this area are subject to change. One may assume that suggested monitoring will continue for at least a decade into the future unless there are reasons for earlier cessation.

3. The Board suggests that the Group consider two or more categories of recommendations for monitoring. Monitoring ideas which might be considered somewhat remote in time because of technical limitations, high cost, or uncertainties of need should be placed in one category. In the second category will be those for which relatively immediate implementation and improvement of existing monitoring networks (in terms of protocol, numbers of stations, etc.) should be sought. Within each category, each project should be ranked in terms of cost and technical feasibility.

4. There should be a reason for each set of measurements. However, even if a quantity might have a potential but currently unknown or uncertain impact--if that likelihood is reasonable in the opinion of the Group--it may he included in the second (more remote) of recommendations. Effects research necessary to decide whether a monitoring program is needed should not be recommended.

5. Monitoring programs should he identified as to their likely applicability to one or a few urban areas, to many urban areas, to broader regions, or widespread geographical interest. Concern about a given substance or impact requiring monitoring should be expressed on both sides of the U.S. - Canada border.

6. Monitoring of the atmospheric transboundary horizontal flux of pollutants (e.g., U.S. to Canada or vice versa) should be considered if the Group feels that the winds can carry significant amounts of pollution beyond the 400 kilometre transboundary region in which monitoring is to be recommended.

7. Monitoring should be directed not only to chemicals in the atmosphere but to those chemicals which find their way into soil or water bodies from the atmosphere or from other human activities.

8. Quantities already measured as part of ongoing "acid rain" monitoring can be included.

9. Where an ongoing measurement program is designed for a purpose found necessary by the Group but the instrumentation or its protocol is inadequate, this should be so reported.

10. Instrument development - if the Group believes the development can be successfully accomplished in a reasonable time can be recommended. Instrument improvement for current deficient instrumentation can likewise be included.

11. It is recommended that experimental, prototype, test or other limited measurement programs precede actual operational network implementation. Thus, it maybe more feasible to phase-in a monitoring program rather than a single step full implementation.

12. In general, where a hierarchy of progressively more sophisticated instrumentation can be used, it is suggested that simpler, more understandable measurements precede more detailed sophisticated ones.

13. Recommendations are solicited with regard to quality assurance, data formatting, and archiving and dissemination to other scientists and the public.

14. Recommendations are also requested for mechanisms to insure that the data are analyzed and interpreted. Suggestions for action standards, danger level or other setting of standards for possible regulation should be avoided at this time.

APPENDIX II

Membership of the IJC "Expert Group on Monitoring"

Dr. Tom Brydges
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M3H 5T4

Dr. Brydges is a senior member of the Canadian Acid rain research community. He conducts research on the environmental effects of air pollution, primarily involving data analysis related to aquatic ecosystems and recently involving integrated research on aid deposition and its effects.

Mr. Bruce Hicks, Director
NOAA/Air Resources Laboratory
1325 East West Highway
Silver Spring, MD 20910
U.S.A.

Mr. Hicks is director of NOAA's Air Resources Laboratory, which conducts research on atmospheric pollution transport, dispersion, and deposition. These programs involve field and laboratory measurements, and modeling. Mr. Hicks served as chairman of the Atmospheric Chemistry Task Group of the U.S. National Acid Precipitation-Assessment Program.

Dr. Ken Demerjian, Director
Atmospheric Sciences Research Center
State University of New York at Albany
1400 Washington, NY 12222
U. S. A.

The Atmospheric Sciences Research Center is part of the research system of the State of University of New York; Dr. Demerjian is the Center director. He is an atmospheric chemist, managing and conducting research on measurement and prediction of atmospheric exposure regimes, involving both field programs and modeling.

Dr. Claire Franklin, Chief
Enivironmental and Occupational Toxicology Division
Environmental Health and Welfare Canada
Room 118, Environmental Health Centre

Tunney's Pasture
Ottawa, Ontario, Canada
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Dr. Franklin is chief of a division that has both research and regulatory responsibilities in the area of toxic chemicals and human health effects. One of the major programs in the division is to assess the risk to health posed by airborne pollution that is subjected to long-range transport and to monitor the influence of abatement programs.

Dr. Ian Morrison
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Great Lakes Forestry Centre
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Dr. Morrison is a research scientist with the Great Lakes Forestry Centre, where he conducts research within an integrated watershed study, viz. the Turkey Lakes Watershed Study. His own specialty is forest biogeochemistry, with emphasis on forest soils. His work is part of the Canadian program on the Long Range Transport of Air Pollutants.

Dr. David Radloff
Forest Fire and Atmospheric Science Research
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Dr. Radloff manages field research and modeling programs conducted by the U.S. Forest Service in the general area of the detection and assessment of air pollution effects. He recently served as chairman of the Terrestrial Effects Task Group of the U.S. National Acid Precipitation Assessment Program. He is currently leading the development of a Forest Health Monitoring Program for all forest lands in the U.S.

Dr. Peter Summers
Senior Research Scientist
Atmospheric Environment Service Environment Canada
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Dr. Summers is a meteorologist with the Canadian Long Range Transport of Air Pollutants research program. His work mainly involves field studies and data analysis and interpretation, with current emphasis on integration of air quality data with water quality and health effects data.

Dr. Marvin Wesely
Head, Atmospheric Research Section
Building 203, Environmental Research Division
Argonne National Laboratory
Argonne, IL 60439
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Dr. Wesely is a meteorologist specializing in research on atmospheric transport and air-surface exchange. He has conducted research on dry deposition for the U.S. National Acid Precipitation Assessment Program and is currently active in the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Program.

Secretary:

Ms. Barbara Levinson
U.S. EPA, RD-680
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Ms. Levinson served as the EPA representative to the Task Groups on Atmospheric Chemistry, Materials Effects, and Deposition and Air Chemistry Monitoring of the U.S. National Acid Precipitation Assessment Program.

APPENDIX III

Workshop on Integrated Monitoring for the Great Lakes

On September 30th, a workshop was held as part of the International Joint Commission 1991 Biennial Meeting to review the findings of the Expert Group and consider their conclusions and recommendations within the Great Lakes context.

Four presentations were given that elaborated on the definition of Integrated Monitoring, discussed the main conclusions of the Expert Group, and elaborated on Integrated Monitoring for terrestrial and aquatic systems within the Great Lakes basin.

During the lively discussion that followed, three main conclusions were developed.

- There is need for Integrated Monitoring sites within the Great Lakes basin.

- Inter-agency coordination needs to be encouraged and improved, with particular emphasis on including the full food chain within the monitoring activities. Concern was expressed that the wildlife component is not presently given sufficient emphasis.

- The development of new networks (or revisions to existing programs) needs to be approached with an "integrated mentality." There was particular reference to the development of the U. S. Environmental Monitoring and Assessment Program (EMAP).

There was a concern for inclusion of unique ecosystems (islands important for nesting birds, shoals for fish spawning, modifications to lakeshore areas, etc.) in monitoring programs. Such emphasis is certainly warranted, and special studies of this kind should be part of the nested network activity that is promoted here.

As an overall observation, the Expert Group wishes to make clear that Integrated Monitoring sites are only one tool in the design of an environmental monitoring and evaluation program. Integrated sites are a component of a nested network, in which complementary information is collected less intensively over a large geographical area.