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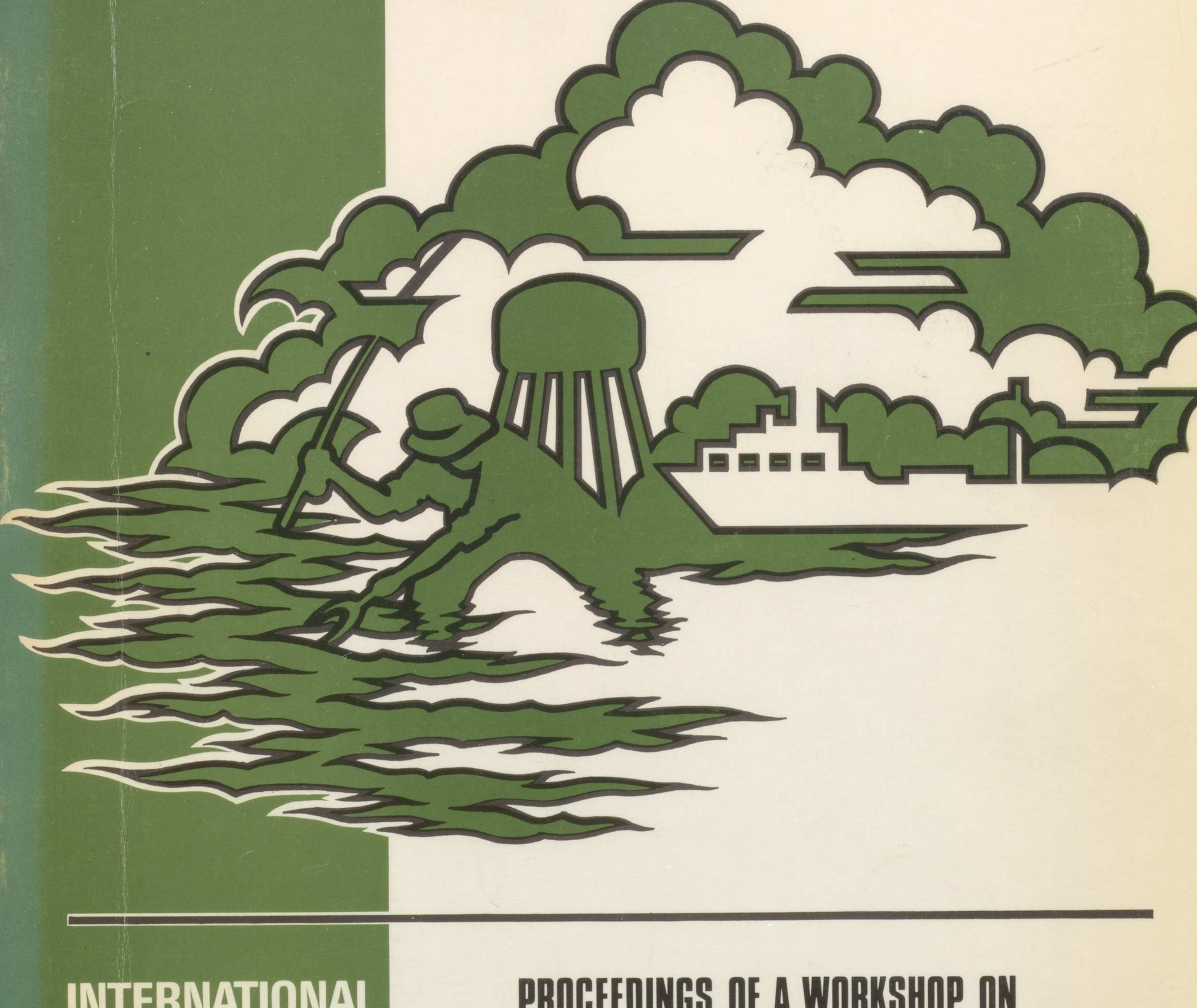
Great Lakes Surveillance and Monitoring: Proceedings of a Workshop held in Windsor, Ontario, January 20-21, 1976.

Great Lakes Water Quality Board

State University College Buffalo, New York. Great Lakes Laboratory

Norma Gibson MacDonald

GREAT LAKES
WATER QUALITY BOARD



INTERNATIONAL
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PROCEEDINGS OF A WORKSHOP ON GREAT LAKES SURVEILLANCE AND MONITORING – 1976

Proceedings of a Workshop held in Windsor, Ontario, January 20-21, 1976. Sponsored by the Surveillance Subcommittee of the Great Lakes Water Quality Board. Prepared under contract by the Great Lakes Laboratory, State University College, Buffafo, New York.

GREAT LAKES SURVEILLANCE AND MONITORING

Edited by
NORMA GIBSON MACDONALD

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NOTICE

Statements and views presented in these proceedings are totally those of the workshop participants and do not necessarily reflect the views and policies of the International Joint Commission, the Water Quality Board or the Surveillance Subcommittee.

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ACKNOWLEDGEMENTS

The Surveillance Subcommittee wishes to thank all of those who participated in the workshop. Subcommittee members hope to continue the dialogue they initiated with the attendees. The Subcommittee also thanks its contractor, Robert Sweeney of the Great Lakes Laboratory, State University College, Buffalo, for his part in the workshop and in the preparation of the original report.

The Subcommittee gratefully acknowledges the effort by the IJC Regional Office in organizing the workshop and documenting the proceedings. Particular thanks are extended to David Rosenberger, Laurence O'Leary and Norma Gibson MacDonald.

Finally, without the cooperation of those within the Great Lakes agencies who responded to the Great Lakes Laboratory's request for information on their surveillance and monitoring programs, neither the workshop nor these proceedings would have been possible. To all of you, the Surveillance Subcommittee members extend their appreciation.

PREFACE

Appendix B of the 1974 Report of the International Joint Commission's Great Lakes Water Quality Board lists three primary problems that the surveillance programs of each lake must address:

1. The acceleration of eutrophication or maintenance of a particular trophic state;

2. The presence and impact of toxic substances in the system;

3. The impairment of water quality by total dissolved and suspended solids introduced into the lake by man's activities.

In response to these problems, the Water Quality Board has established three surveillance goals:

1. To measure directly the loading from sources affected by remedial programs;

2. To monitor in the receiving water the frequency and intensity of violations of water quality objectives in both localized areas and in the open lake where changes in problem conditions are to be established;

3. To provide sufficient data to permit valid interpretation of water quality conditions in order to distinguish the impact of remedial programs from natural changes, both near to and remote from sources. This goal entails documentation of the loadings not under control of present remedial programs as well as monitoring ambient water quality or impacted biota in the system in order to distinguish the impact of controlled loadings from the impact from other causes.

The Water Quality Board has charged the Surveillance Subcommittee with developing surveillance and monitoring plans to meet these goals. The workshop reported in this document was designed to assist the Surveillance Subcommittee in carrying out that charge.

INTRODUCTION

An important goal of the 1972 United States-Canada Great Lakes Water Quality Agreement is the design and implementation of a coordinated international surveillance program. This program will prevent duplication of effort and provide compatible data for scientifically valid evaluations of Great Lakes water quality.

The Surveillance Subcommittee, consisting of representatives of the Great Lakes governments, has been struggling with the difficult task of developing such a program since 1973. An initial plan outlining the program was presented in the 1974 Water Quality Board Annual Report, Appendix B. However, much more detail was still required, including a definite schedule for sampling, a complete parameter list, detailed rationale and refined cost estimates. The Subcommittee members also wanted more input from the research community and more interaction with the other Water Quality Agreement institutions.

As a result, on January 20-21, 1976, the Surveillance Subcommittee sponsored a surveillance design workshop in Windsor, Ontario for the purpose of obtaining the ideas and opinions of the many agencies and organizations involved with the Great Lakes. The workshop was not intended to produce a "final plan" however, since that is the Surveillance Subcommittee's responsibility. The workshop was attended by forty representatives of federal, provincial and state agencies with an on-going International Joint Commission monitoring program and by seven university researchers engaged in monitoring efforts in the Great Lakes. After a morning plenary session at which papers were presented, work groups were formed to focus on specific areas or problems.

The Great Lakes Laboratory of the State University College at Buffalo was contracted to assist the Surveillance Subcommittee with the workshop. To do this, the Great Lakes Laboratory organized the event and solicited information from agencies currently engaged in surveillance and monitoring programs. (Appendix I lists the agencies which responded to these enquiries. Their responses are on file at the IJC's Regional Office). The Laboratory also contracted Great Lakes investigators from universities to lead the discussions in the work groups and to assist in the compilation of material on specific areas in these proceedings. These individuals and their areas of expertise were:

Lake Michigan	Dr. Alfred Beeton University of Michigan
Lake Erie and Detroit River	Dr. Charles Herdendorf Ohio State University

Nearshore Regions	Dr. H. B. N. Hynes University of Waterloo
Lake Superior	Dr. James Kramer McMaster University
Lake Ontario and St. Lawrence River	Dr. Donald McNaught State University of New York, Albany
Lake Huron, Lake St. Clair and St. Clair River	Dr. Claire Shelske University of Michigan
Lake Erie and Niagara River	Dr. Robert A. Sweeney State University College at Buffalo

These proceedings do not necessarily reflect the consensus of the Subcommittee but were used to prepare the second iteration of the Surveillance Plan as documented in Appendix B of the 1975 Water Quality Board Annual Report.

CONCLUSIONS & RECOMMENDATIONS

A. General

I. Monitoring and surveillance of the Great Lakes and connecting waterways are necessary to evaluate the degree to which the objectives, including non-degradation criteria, of the Canada - United States Great Lakes Water Quality Agreement are being achieved. As part of the above, monitoring and surveillance are needed to assess the effectiveness of pollution abatement measures. A surveillance program is required to ascertain the nature and degree of changes in Great Lakes water quality, particularly as a consequence of pollution from existing or new direct and indirect human activities. The program can also identify previously undetected contaminants before they have an adverse affect on the Great Lakes environment. Surveillance provides valuable inputs for establishing and revising limits and criteria for both loading and aquatic contaminants.

II. It is not possible to routinely survey in detail all sections of the Great Lakes and connecting channels concurrently. Therefore, to make the best use of available resources, two levels of monitoring are necessary. A less intensive monitoring program should be developed for those parameters and problems requiring more or less continual examination, while a more intensive program should be formulated to focus on a single lake or river.

Prior to initiating an intensive survey, sufficient time and funding should be given to preliminary planning in order to optimize the survey and its design.

III. While there is a need to monitor some of the same parameters, particularly major nutrients, in each lake and connecting waterway, surveys should also be designed for problems unique to specific areas.

IV. Within United States federal and state environmental agencies, monitoring has been given a low priority. Until this situation is changed, most likely through fiscal and other federal actions, a Great Lakes monitoring program sufficient to provide scientifically adequate data for an assessment of Great Lakes water quality is unlikely.

V. While there are numerous surveillance programs being conducted on the Great Lakes, some of which have amassed years of data, it is difficult to combine the findings of different agencies because of a lack of agreement on the parameters being measured, sampling frequencies and analytical procedures. Therefore, it is generally not possible at present to assess the quality of an entire lake or connecting channel. This problem could largely be overcome by more coordination of the groups involved in these activites, including the development of inter-laboratory comparisons.

VI. At the present time, a disproportionately small amount of funding and manhours is being spent on the analysis and interpretation of monitoring and surveillance data. A greater effort is also needed to remove unreliable information from both Canadian and U.S. Great Lakes data storage systems.

VII. To conserve resources and improve the design of monitoring programs, more use should be made of mathematical models. These should be formulated and verified on the basis of intensive surveillance of limited geographical areas as well as whole lake or river-wide analyses of some conservative elements.

VIII. Routine reassessment of each monitoring program and the mechanisms for storing and exchanging data is necessary, as is more interaction, including exchanges of data, between those involved in research and those engaged in monitoring.

IX. There is a special need to assess the biological significance of numerous chemical measurements, particularly the use of algal bioassays for quantifying the possible impact of the various chemical forms of phosphorus currently being discharged in the Great Lakes system.

X. Biological monitoring should be intensified, with particular emphasis on using organisms such as *Cladophora* and benthic macroinvertebrates as indicators of water quality.

XI. Exchanges of nutrients and toxicants between the Great Lakes and the atmosphere also require monitoring in greater detail.

XII. Despite the fact that the nearshore region is the most intensely used for water supplies, recreation and the dispersion of pollutants, in the United States these regions are the least monitored. Interphasing of nearshore and open-lake surveillance programs in the same waterbody has been virtually non-existent, while monitoring of water intakes is irregular, particularly in the United States. By comparison, the open-lake surveys, which have been largely coordinated by the Canada Centre for Inland Waters and the U.S. Environmental Protection Agency, generally have yielded the most comprehensive results.

B. Area Specific

I. Lake Ontario and the St. Lawrence River

Lake Ontario should be intensively monitored at least once every four years. More routine sampling should emphasize nutrients, toxicants, water quality indicators (i.e. Biological Oxygen Demand, chlorophyll) as well as thermal inputs, radioactivity and *Cladophora*, which may be more of a problem in Lake Ontario than in other regions of the Great Lakes. New York State, with the aid of the U.S. Environmental Protection Agency, should develop a nearshore monitoring program, particularly in the area of Nine Mile Point where a number of electric generating plants are being constructed. Surveys are needed to determine the impact of short-term events, such as storm run-off on Toronto Harbour.

II. Lake Erie and the Detroit and Niagara Rivers

Since it appears to be undergoing more rapid changes in quality than the other Great Lakes, Lake Erie requires the most comprehensive annual monitoring of all the Great Lakes. Intensive monitoring should take place at least once every five years. Problems demanding special attention include oxygen depletion in the hypolimnion, *Cladophora*, nutrient regeneration from sediments (particularly in the shallow western basin), and contamination of sport and commercially valuable fish. New York State should develop a monitoring program for nearshore areas and expand its Niagara River surveillance efforts.

III. Lake Michigan

Lake Michigan should be intensively monitored at least once every five years with routine surveillance expanded to include several harbours currently not being examined. The nature of exchanges between Lakes Huron and Michigan through the Straits of Mackinaw warrant closer examination as do Green Bay, Milwaukee Harbor and the Calumet area. Polychlorinated biphenyls and chlorinated hydrocarbon insecticides along with the red alga, *Bangia*, also need special attention.

IV. Lake Superior

Intensive monitoring of Lake Superior should take place at least once every twenty years. However, there are numerous areas such as Duluth, Thunder Bay, Wawa, as well as the region affected by red clay, which require special attention. The possible impact of taconite tailings should also be examined.

V. Lake Huron

Lake Huron should be intensively monitored at least once every five years. Nearshore areas requiring priority attention include

Saginaw Bay, Collingwood, Bayfield-Goderich, Owen Sound, Spanish River and Penetang-Midland. In addition to investigating the role of silica as a limiting nutrient, sampling of water intakes, particularly those located in the United States, should be intensified.

VI. Other Connecting Channels

The proposed monitoring program which appeared in Appendix B of the Great Lakes Water Quality Board's Annual Report for 1974 should be implemented.

CHAPTER 1

SURVEILLANCE AND MONITORING OBJECTIVES

One factor making it difficult in the past to formulate a monitoring and surveillance program for the entire Great Lakes Basin is that different agencies, and frequently individuals within those agencies, do not agree on the objectives of such a program. Most scientists and engineers define surveillance and monitoring objectives in terms of the needs or obligations of their agency or department. For example, the U.S. Environmental Protection Agency and the Canada Centre for Inland Waters largely base their monitoring and surveillance efforts on the objectives of the Canada-United States Great Lakes Water Quality Agreement. State and provincial agencies, on the other hand, are concerned more with problems such as the safety of beaches and drinking water and future shoreline construction. These issues may have little direct bearing on a whole lake and/or a connecting channel.

During the plenary session J.P. Bruce, Inland Waters Directorate, Fisheries and Environment Canada, and A.M. Beeton, Great Lakes and Marine Waters, University of Michigan, discussed the overall objectives of the Great Lakes surveillance program in support of the Agreement. G.K. Rodgers, Canada Centre for Inland Waters, Fisheries and Environment Canada, presented some pertinent comments on the 1975 International Joint Commission Surveillance Plan.

GREAT LAKES MONITORING AND SURVEILLANCE

by

J. P. Bruce *

It is a great pleasure to be with you for this very important workshop and to have an opportunity to make a few opening remarks on behalf of the Water Quality Board. Monitoring is one of three main cornerstones of the 1972 Canada-U.S. Great Lakes Water Quality Agreement and the optimum design of monitoring and surveillance programs is essential to our cooperative success in water quality management of the Great Lakes. Why does the Water Quality Board consider a well-conceived monitoring program so essential?

To answer we should review the philosophy and concepts of this remarkable international agreement. We are all involved in one way or another in carrying out various aspects of the Water Quality Agreement. But sometimes it is valuable to pause in the pursuit of our specific activities to reflect on the conceptual framework in which we are working. The concept of the Great Lakes Agreement can be summarized as consisting of three steps: (1) the establishment of specific numerical water quality objectives which both countries agree are required to protect the various uses of the water resource and the aquatic ecosystems of the Great Lakes. Article IV of the Boundary Waters Treaty of 1909 says that neither country shall pollute the waters of the other to the extent of "injury to health or property". How do you define this degree of pollution? The two countries in the Agreement have chosen to say that if agreed water quality objectives are not being met, injury to health or property is occurring. Thus, the water quality objectives are our agreed goals. In our national, regional and local planning and development activities in each country we must begin to think of these objectives as an external constraint that must be met to protect our neighbors across the border. Step (2) is the construction of sewage treatment plants and completion of other pollution control measures designed to achieve these water quality objectives. Step (3) is the monitoring of the quality of the boundary waters to ensure that objectives are being met and to permit changes in emphasis on various pollution control measures as required to achieve these goals.

Let us look at each of these three cornerstones of the Agreement and see how we are doing. Some specific objectives such as dissolved oxygen, iron, bacteria and phosphorus loading, were incorporated in the original 1972 Agreement. The Water Quality Objectives Subcommittee has been working hard to provide specific numerical objectives for a wide range of additional pollutants. The Water Quality Board has accepted some of their recommendations and others are being reviewed for their implications for pollution control and monitoring programs.

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*Canadian Chairman, Great Lakes Water Quality Board, until October 1, 1976

A large number of municipal and industrial pollution control projects have been completed or started in both countries. While not all we had hoped for has been achieved in the way of municipal and industrial waste control, more than $2 billion worth of treatment projects have been completed or are underway. The total expenditures on pollution control measures will certainly exceed $3 billion.

Perhaps the most difficult problem to come to grips with has been the design and execution of an effective international monitoring and surveillance program for the Great Lakes. The difficulty is that, on the one hand the program must serve a number of important purposes, and on the other, it must be carried out with a severely limited number of people and dollars. To complicate matters further, the program must be conducted in a coordinated way by eleven different governments: eight state, one provincial and two federal, and often by several agencies within each government.

The goals of the surveillance program are viewed by the Water Quality Board as:

1) Provide definitive information on when, where and how frequently agreed water quality objectives are being violated, in the lakes and in the interconnecting channels.

2) Provide information on trends in water quality parameters in the Lakes and connecting channels, in response to pollution control measures and new or continuing pollution loads.

3) Identify new or hitherto undetected contaminants or environmental problems in the lake system, leading to adoption of appropriate additional pollution control measures.

These three objectives would provide a difficult challenge to the program designer who has unlimited resources at his disposal. To design an effective program with the limited manpower and dollars available is a challenge for the best scientific and technical brains we have. I am delighted to see the possessors of many such brains here at this workshop, and am particularly pleased to note the number of outstanding academics here to discuss these matters with their government colleagues.

The Great Lakes Water Quality Agreement represents the greatest effort ever made by man, anywhere, to reverse a serious case of environmental degradation. The world is watching the successes and failures of our cooperative venture. But the ultimate measure of our success is not how much concrete is poured for sewage treatment plants or how much money goes into waste management projects. What really matters is the improvement or lack of it, in the quality of water in the lakes system. This is easy to say but very difficult to measure.

In one sense, our two countries are engaged in a very costly experiment to reverse or prevent water quality degradation in the Great Lakes. We must have information on lake and river responses to make corrections in pollution control strategies and to measure successes and failures. In addition, for the sake of water managers everywhere, and for the scientific community around the world, we must clearly and carefully document the outcome of the experiment.

You, today and tomorrow, are charged with helping to define the nature and number of measurements needed to answer the questions about the responses of the Great Lakes system. On <u>your success</u> here will depend in no small measure the ultimate success of the Great Lakes Water Quality Agreement.

THE 1975 INTERNATIONAL JOINT COMMISSION SURVEILLANCE PLAN: ITS CONTENT, RATIONALE, STRATEGY AND ADEQUACY

by

G. K. Rodgers

Review of the 1975 Plan

The starting point for Workshop discussion is the surveillance plan in the Water Quality Board's 1974 Annual Report, published in July 1975, supplemented with detailed plans subsequently drawn up by Task Groups of the Surveillance Subcommittee. Because the plan contains many elements, both explicit and implicit, which are important to our discussions, the policy and intent of the Subcommittee should be clarified by detailing what is and is not in the program.

1. Surveillance and monitoring are referenced in the Water Quality Agreement in the context of the entire Great Lakes System including all streams, rivers, lakes, etc. in the drainage basin of the St. Lawrence River. However, the terms of reference for the Surveillance Subcommittee deal only with the boundary waters plus Lake Michigan. Thus water quality within and incident (loading) to these waters is identified in present plans while mixing zones, contaminants in fish, aquatic birds and sediments are excluded.

2. In addition to excluding these items, the plan does not mention municipal and industrial sources upstream from the mouths of tributaries, industrial monitoring, surveillance of regulations or enforcement activities except as they relate to the boundary waters, or the reporting of point source inputs to these waters upstream from the mouths of the tributaries. That is not to say that they do not exist; rather, they are taken as given without identification by the Subcommittee.

3. The 1975 plan excludes surveillance such as aerial reconnaissance for oil spills and the like, or the type of continuous automatic or visual monitoring designed to warn of short duration, high intensity industrial spills. Despite the lack of surveillance and enforcement here, it is possible that some of the longer term integrated effects of spills may be evident in the data for biota or sediment quality.

4. The plan assumes that the interpretation role of the Surveillance Subcommittee is carried out solely within the context of the available models. Consequently, it does not include the cost of any research to improve models or understanding of the Lakes System except insofar as the data collected in the Surveillance Plan might be utilized by quite separate research activities. Some research needs are specified and have been communicated to the Research Advisory Board. Surveillance

is so broad in its application, however, that most of the priority research areas identified for the Great Lakes have application to surveillance. Certain pilot studies included in the Surveillance Plan are designed to establish variability in some specific concentration or loading component of the program through more intensive sampling, and each will last from one to two years. It is likely that such studies will be required in a number of locations over several years.

5. Costs entered in the 1975 design cover a number of prorated elements. That is, they assume continually available facilities such as ships or laboratories, which are not necessarily used on a full time basis for International Joint Commission (IJC) surveillance. Obviously, curtailment of the programs supporting these facilities will have a strong impact on the plan's "overhead".

6. While the plan emphasizes continuity of resources, care will have to be taken to realize the advantages of this approach by coordinating the resources available.

7. The design has been drawn up with minimum dislocation of existing programs in the agencies except where they have some discretionary funds or new funding specified for IJC surveillance. As a result, little innovation is evident although there are some added programs.

8. Since additional components will be necessary as new problems are identified, there must be a continual review of the design.

Commentary

The 1975 plan lacks strength in identifying resources needed to provide answers to Water Quality Board referrals of new water quality objectives, to respond to the recommendations of the Research Advisory Board, or to carry out an in-depth analysis of questions on interpretation of the data. Research to develop new knowledge is not required here, but simply the application of existing knowledge.

Much is made of the need to integrate data systems for efficient data exchange between agencies. While there is an undoubted need for comparisons to be made, and a reference data bank is absolutely required, experience with matters of data quality, documentation, and the fact that agency methodology is unlikely to be changed simply at IJC request, suggest that the strategy should be to establish agency programs which are integral units of data collection and interpretation and that these be linked largely at a general program level with other agencies. Consequently, data collection-interpretion would be an individual unit task and objective, reducing the considerable effort presently expended in multi-agency integration for reports. This would also provide a link between staff collecting the data and staff engaged in its interpretation. It is not suggested however that these units of the program be completely separated. Rather, the Surveillance Subcommittee has to ensure that these studies, methods and data are comparable and compatible. Furthermore, there are elements of data interpretation that necessitate close coordination. For example, the whole lake trophic level interpretion requires a reasonable phosphorus loading record. Nonetheless, as far as is practical, there should be distinct agency data collection and interpretation study units in the program.

The program design reflects agency and facility constraints too strongly. While these have to be recognized, there is far too little rationale built around the issues which the surveillance plan should address. Finally, priorities should be set for the various components of the plan.

Principles of Surveillance

Before reviewing the rationale for surveillance, the principles to be agreed on for surveillance should be discussed. The following list is drawn from a variety of sources, in particular, the Global Environmental Monitoring System Phase I Action Plan and G. Fred Lee's paper, "Great Lakes Water Quality Monitoring Strategy".

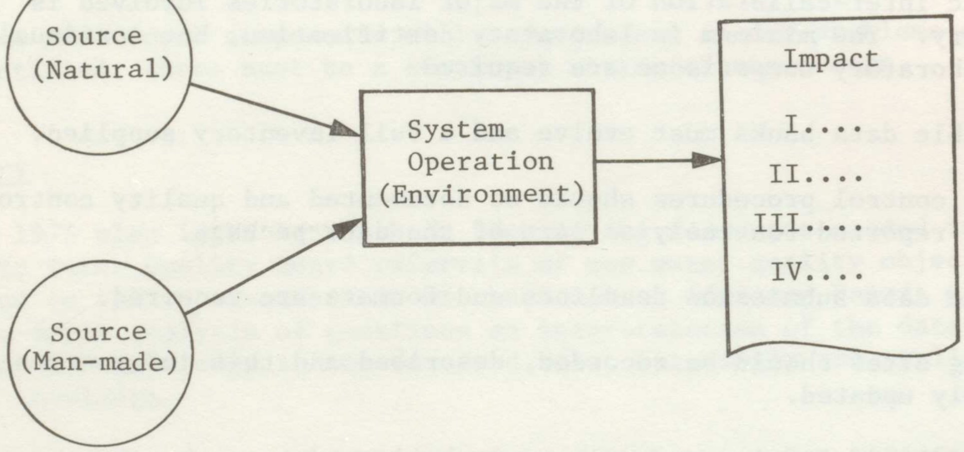
1. Agencies must use comparable sampling techniques but not necessarily identical methods.
2. Periodic inter-calibration of the major laboratories involved is necessary. The minimum is laboratory certification, but continual interlaboratory comparisons are required.
3. Comparable data banks must evolve and a full inventory supplied.
4. Quality control procedures should be documented and quality control data be reported routinely as part of the data package.
5. Specific data submission deadlines and formats are required.
6. Sampling sites should be recorded, described and this information routinely updated.
7. The details of station operation must be logged.
8. Procedures should be documented and updated regularly. This should include sampling techniques and sample storage as well as the analytical methods.
9. If techniques are modified, an overlap of data by old and new techniques for one year is necessary.
10. Once a station has been established, variability of surveillance parameters should be tested or assessed.
11. Because it is not always possible to foresee their future use, the highest quality data should be obtained. (Highest quality means as good as specified or even better, if economically feasible).

12. Data assessment must be carried out on a continuing basis in terms of quality control review, optimization of sampling, examination of data for trends, comparison with standards and eventually, development of predictions.

While some of these are detailed at one place or another in the Surveillance Subcommittee presentation, they should be drawn together for an integrated statement of agreed principles.

Towards a Rationale for Surveillance Program Design

In dealing with water quality issues that should come under surveillance, we generally recognize a source of material (or energy) and some undesirable impact of that material. It is understood that man has certain control over the source material. The relationship between these two can be expressed in some "model" that would take account of the natural processes that parallel the source impact, transformations of the material beyond the point of introduction into the environment, and the pathways of the material through the environment. Schematically it may be seen as follows:



The development of surveillance strategy depends heavily on our knowledge of these relationships. The better our understanding of the environment, the more efficient or economical surveillance may be. An example may help to illustrate its application.

Issue A: Heat input from industry and power plants (associated with kinetic energy inputs).

Impacts: I Average surface temperature rise

II Increased evaporation

III Alteration in thermal structure (heat plumes, localized thermal structure alterations)

IV Biological impact (entrainment effects, alteration of habitat, fish, bottom fauna, etc.)

Surveillance Rationale

Issue: Since man-made heat sources are generally power plant effluents, they are easily monitored directly at their origin, by just logging the plant's electric output with an efficiency factor included.

Impacts: I and II. Average lake surface temperature rise and evaporation due to the added heat are well enough known to provide a reasonable estimate of what these impacts will be. The extent of the impact is small and is usually masked by natural variations in water temperature. Consequently there is no need for surveillance in the lake and because there are no practical means to do so, the program only needs to include monitoring of heat inputs.

III and IV. In addition to a lack of quantitative estimates on the impact of heat inputs on thermal structure and biota, the issue is complicated by being site-specific to a degree. As a result, if a signficant potential impact is foreseen, there are at least two choices. The impact could be modelled or quantified before instituting surveillance, or a program containing sufficient data to ensure that a good measure of the effect is obtained can be undertaken. The latter resembles a research program but is really only surveillance of anticipated parameters with a view to empirically testing the degree of impact and could serve as the data base for research into quantifying effect. Where no quantitative model exists, where it appears practical to sort impact from environmental "noise", and where the potential impact is sufficiently important to merit attention, then surveillance must include such a program, even though there is a strong similarity in the empirical and research approach. In fact such a program should have an identified research component to develop a more efficient set of indicators in the area. Surveillance in such a situation is likely to be heavily dependent on many observations and will profit by study of its efficiency and efficacy.

In summary, where source-impact relations are well known, monitoring the sources is sufficient. Where the relationship is poorly understood and the impact is high priority, we have to compensate for lack of knowledge by additional observations in the surveillance program. Without this the Surveillance Subcommittee should at least identify the problem and specifically state the degree to which the plan is limited in this regard.

There are several variations on the above procedure for developing a rationale for surveillance design. In cases where source data are inadequate, but the model relating the source to impact is known, it may be more efficient to monitor the impact and infer the source characteristics. An example of this situation is in the July 1975 Water Quality Board Report. Here the survey of chloride in Lake Erie along with routine measurements of inflow and outflow volumes, but not a complete set of chloride concentrations, made it possible to infer average chloride loadings and explain trends in lake concentrations. Where the material is conservative and/or sources are diffuse, and hence costly to monitor accurately, this approach may be the most efficient.

For each technical issue to be addressed, there are several impacts that could be monitored. Eutrophication, an issue with many aspects, can be expressed in terms of total biomass, chlorophyll *a* concentrations, species composition in phytoplankton, species present in the microbiological community, Particulate Organic Carbon - Particulate Organic Nitrogen, oxygen depletion, optical properties such as change in secchi disc readings, nutrient levels, nutrient depletion, total dissolved solids, *Cladophora*, etc. While it may be necessary to monitor more than one of these to characterize the changes adequately, not all are required in a surveillance program. The alternatives here have to be examined carefully within the context of each lake, and for the lakes as a series in the Great Lakes System.

Statistical Validity and Indexing

There are many attempts in the program to obtain valid estimates of the total amounts of materials, whether it be the content of a lake or the total weight of a contaminant loading. The adequacy of spatial or temporal sampling is a subject of continual debate and statistical arguments are frequently drawn into the discussions. Depending upon the precision and accuracy desired, the time over which an estimate is required (the integrating period) and the variability of the material concentration, the sampling program will be more or less intense. We are facing many serious problems in defining practical sampling intensities for these integral needs and we shall have to compromise on the periods over which our data are to be considered as adequate estimates.

The alternative approach to a full systeam of measurements is the more common "indexing" methodology in which a series of observations are made representing the changes in the system without measuring the whole. This approach may consist of using an indexing parameter such as chlorophyll *a* for biomass or using one location as representative of a much larger area (e.g. Davis' characterization of Lake Erie biomass from samples collected at the Cleveland waterworks over many years). If there is confidence in this latter type of approach it can be most efficient. Although confidence can usually be generated only by demonstration after the fact, particularly because representativeness cannot be tested in the short term, we may initially need extensive ancillary data collection. Of course the index methodology does not necessarily quantify any absolute measure such as lake volume averages. It should simply indicate whether things are getting better or worse and represent a significant portion of the body of water, rather than a small area, unless designed that way.

Parameters which represent the problem directly could be chosen for the surveillance program. The frequency or amount of alum used in a water treatment plant, chlorine usage or the frequency of filter backwashing, all of which relate to the impact of remedial programs to improve the quality of water available to the water treatment plant, could be useful surveillance data in some instances. However these are not now included in the Surveillance Plan.

Types of Monitoring

Because "monitoring and surveillance" have a variety of definitions, various types should be designated and identified with activities noted above. According to the National Academy of Sciences report Principles for Evaluating Chemicals in the Environment, four types can be defined.

1. Reconaissance monitoring involves periodic observations to establish trends over time. It can also be used for determining violations of water quality standards.

2. Surveillance monitoring relates to enforcement in ambient waters. Violation of water quality objectives has a direct relation to assessment of the local effect of regulations.

3. Subjective monitoring is spot checking for problems. A type of detective job, this activity appears in the 1975 Plan as periodic intensive sampling or assessment, though usually in a whole lake system context rather than on a problem or issue basis.

4. Objective monitoring is used for developing and confirming quantitative models and assisting with system simulation. Unfortunately, this is not generally accepted as a part of monitoring. Bound up in this are the discussions on research versus surveillance. Within the IJC, a close link between Surveillance Subcommittee specifications of research needs and the Research Advisory Board's identification of programs in which research is viable and their subsequent invitation of research studies should overcome this deficiency in older monitoring programs.

Summary

A review of the 1975 Plan for surveillance of the Great Lakes has been prepared to explain its scope and to identify deficiencies. One major difficulty has been the planning of resources needed to review interpretations of changes observed and the incorporation of additional sampling as required by new water quality objectives.

Any surveillance plan draws heavily upon our quantitative understanding of the impact of various cultural loadings to the lake system. For certain high priority issues, a more intensive observation program may be required to compensate for inadequate quantitative knowledge of potential impact.

Coordination of the data collection and data interpretation units of a surveillance plan within a single agency is highly desirable provided the general principles of surveillance are agreed upon and the program design is integrated.

The Surveillance Subcommittee must place greater emphasis on the development of a rationale for the plan around issues rather than around existing agency plans or operational constraints. Included in the rationale would be considerations of the priority of a given issue or parameter, knowledge of the impact of materials that have been or could be subject to significant remedial action, and knowledge of the variability and likely trend of that parameter under a natural or man-made impact.

While statistical approaches to design should be applied to some critical components of the program, an index can be developed for many components for reasons of economy.

Design components should have their planned use clearly defined in terms of reconnaissance, surveillance, subjective or objective monitoring so that there is minimal confusion in the identity and purpose of the plan.

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MONITORING THE QUALITY OF THE GREAT LAKES

by

A. M. Beeton

Rationale for a Monitoring Program

Establishment of a monitoring program implies that we have the ability to characterize some aspects of the environment using certain parameters such as dissolved oxygen, conductivity, temperature, transparency, and total phosphorus. Other parameters may be included in a monitoring program because they are known to be toxic from laboratory studies, but we have limited knowledge of their significance in the natural environment. Furthermore, we need a much better understanding of lake processes and the importance of these parameters.

In view of these considerations, a monitoring program will establish baseline conditions to which additional sampling parameters will be added as research provides more information about the system and new or improved methods for detection. The emphasis of any monitoring program will be, however, on the detection of significant changes, particularly trends in the quality of the lake. The program should be flexible enough to detect new environmental and/or public health hazards.

Nature of the Monitoring Program

The nature of the monitoring program depends on the system. Some field techniques and procedures may have broad application to a wide range of aquatic systems; others may be developed primarily for the uniqueness of a specific situation. In all cases, it is certainly a mistake to allocate large sums of money for a monitoring program and in turn use sampling equipment and/or laboratory methods which will give biased data.

In dealing with the Great Lakes we find that the equipment and field procedures developed for use in the marine environment are more suitable to the Great Lakes than those for small bodies of water. Because of the size of the lakes, boundary conditions, sediment-water interaction, the shoreline, and tributaries are of major importance. Conditions in large bays such as Green Bay and Saginaw Bay and western Lake Erie closely resemble those in estuaries.

A monitoring program should not only be directed towards the results of nutrient loading, inputs of toxic substances, and other materials, but also towards detecting changes in their sources. There are two important sources: point sources, that is tributaries, harbors, municipal and industrial outfalls; and diffuse sources, including atmospheric inputs, surface runoff, ground water discharges, and recycling of materials from the sediments by chemical action and solution or by active transport by organisms.

Point Sources - Tributaries and harbors serve as integrators for pollutants and as settling basins or traps for suspended materials. In fact, most of the major tributaries have harbors at their mouths which contain many sewage and industrial outfalls. In addition, there are outfalls in nearshore areas which can exert a significant impact on local conditions.

Diffuse Sources - Information is lacking on the importance of these sources, particularly from surface runoff and ground water discharge. If lake sediments are included as a diffuse source, then the potential for these sources to greatly affect overall water quality is immense, especially in view of materials released from the sediments under anoxia as has occurred in Lake Erie.

Atmospheric inputs of nutrients, heavy metals, pesticides, and other toxic materials carried in dry fallout and rainfall, may equal or exceed those from point sources.

Characteristics of the Lakes Pertinent to Monitoring

The size of a lake relative to its drainage basin is important. Unlike small lakes which may occupy 10 percent of their drainage area, the Great Lakes cover about 30 percent of their drainage basins. As a consequence, direct atmospheric inputs are very important to the quality of their waters.

The lakes are essentially monomictic or dimictic depending on the extent of ice cover. Stratification is relatively short, lasting from late June to September and it influences the vertical distribution of some chemicals and the biota. Mixing extends to the bottom in shallow areas most of the year. Some thermal discontinuity exists into early December in deep waters, but there is no evidence that it is of great importance to the distribution of chemicals and biota.

Along-shore currents tend to keep point source inputs nearshore, while the thermal bar may limit mixing of nearshore and offshore waters in the spring. Because conditions can change rapidly in a short time, the importance of upwelling must also be considered in the nearshore environment.

The open waters, which make up most of the volume of the lakes, have been arbitrarily divided into offshore and inshore or nearshore. One definition has offshore waters as being greater than 10 miles from shore while another states that nearshore waters are two miles off shore. Nonetheless, the important aspect is that the waters near shore differ from those off shore chemically and biologically. It has been stated that the nearshore waters form a more or less distinct well-defined entity promoted primarily by the strong along-shore currents. This is true in part, but it is obvious that the pronounced inshore-offshore differences do not occur throughout the lakes, particularly in the vicinity of large metropolitan areas and major tributaries.

The offshore waters have the lowest concentrations of contaminants and require very large inputs of these materials to cause deterioration in quality. Because of the very low levels of pollutants actually present in the soluble phase it is essential to measure contaminants in fish and other aquatic organisms in open lake monitoring. Such organisms are integrators and because of their ability to concentrate material either directly or through the "food web", analyses of tissues may provide the best approach for detecting water quality problems.

The nearshore waters have great importance since these waters are used for recreation and water supplies, as well as nursery and spawning areas for many fish. Yet, despite their significance, few studies have been made of nearshore areas in the past. The nearshore is difficult to monitor since, in addition to containing higher concentrations of contaminants, the waters have varying composition from changing discharge rates, along-shore currents, and upwelling of deep water. Such variability is a function both of the land and land-use, and the physical characteristics of the lake. The physical boundaries are highly variable and offshore water may impinge on the shore, or water of poor quality may extend for ten or more kilometres into the lake. Factors such as wind force, direction and duration, lake bottom topography, shoreline morphology, changing current and man-made structures must all be considered. In some situations useful data may not be obtained unless conditions are monitored daily.

The areas of greatest concern from the standpoint of obvious deterioration are harbors and other urban waters. Water quality in these areas is usually significantly different from either the open lake or nearshore mainly because of very high waste loadings and restricted exchange with the open lake.

Recommendations for Whole Lake Monitoring

Emphasis should be on a sampling program which would detect any progressive long-term changes, especially those which might be obscured by extreme conditions observed in harbors, tributaries and other discharge points. Consequently, the lake-wide program should be separate from surveillance of critical areas.

Considerable physical, chemical, and some biological data are available from water intakes (Beeton and Strand 1975). Municipal intakes in particular provide a means of sampling the lake as part of the intensive study and also routinely between whole-lake monitoring surveys. The main problems are the reliability of the data and determining what waters are being sampled by the intake, e.g., nearshore, a nearby harbor and open lake. One should be very careful in the use of intake data. A University of Wisconsin-Milwaukee evaluation of data from five intakes showed laboratory results ranging from only 38 to 78 percent agreement. Methods and procedures used at intakes should be assessed and periodic checks made.

In a November 1973 paper, "Great Lakes Water Quality Monitoring Strategy", G. Fred Lee offered 14 points to consider. These points are summarized here because of their importance to any sound monitoring program.

1. Clearly define specific, not general, objectives for the study.

2. Determine the level of confidence to be achieved for each objective.

3. Select parameters to be measured and justify their potential significance.

4. Examine previous studies to establish variability in each area to be studied.

5. List factors which can influence results of studies.

6. Determine the number and location of samples to be collected in each area under study.

7. Where no previous data are available, conduct a pilot study.

8. If the purpose of the study is to determine changes in water quality, specify the magnitude of change to be detected.

9. Select sampling techniques and analytical methods in accord with the objectives and level of confidence chosen.

10. Check analytical methods for each area at various seasons to ensure their applicability to the system under study.

11. Study the variability of the system.

12. Critically examine the relationship between present and past sampling and analytical methods.

13. Analyze data as collected.

14. Analyze and interpret data (sufficient funds should be made available to do this).

In addition to the recommendations on the nature of monitoring programs, some useful special studies are recommended for designing future monitoring programs.

Cladophora

Identified as a major problem by the Research Advisory Board, *Cladophora* demonstrates the progressive advancement of eutrophication. Remote sensing appears to be the most rapid means for determining distribution and biomass of *Cladophora* based on results from Lake Ontario. Further studies are necessary to relate results from standard techniques to those obtained through remote sensing.

Bangia

This red alga appears to be associated with increased nutrient loading and has spread to several lakes. Suitable sampling techniques and studies are needed to determine its distribution and response to greater availability of nutrients.

Mysis relicta

This small opossum shrimp is an indicator of good water quality and its distribution becomes restricted as a lake eutrophies. Better sampling procedures and equipment are essential to give valid estimates of its abundance.

Shoreline Erosion

Research into the significance of shore erosion for water quality in the lakes is necessary.

Importance of Sediments to Water Quality

The extent of exchange between sediments and the overlying waters must be determined. In particular, how much of the material now in the sediments will be recycled to the lake waters?

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CHAPTER 2
SURVEILLANCE AND MONITORING PROGRAMS

Each work group was asked to design a set of priorities for surveillance activities for each lake or area under consideration. Design components to be considered included:

1) Material Loadings,
2) Nearshore,
3) Open Lake,
4) Intakes,
5) Special Problem Areas,
6) Studies in support of surveillance,
7) Data Management/quality assurance.

In order to do this, the work groups discussed current or proposed surveillance parameters of each agency in terms of a uniform set of design objectives provided by the Surveillance Subcommittee. The objectives were established in order to comply with the assessment provisions of the Great Lakes Water Quality Agreement:

1) Compliance with objectives,
2) Determine trends,
3) Determine material loadings,
4) Determine impact of remedial programs,
5) Determine cause-effect relationships

The work groups were chaired by members of the Surveillance Subcommittee as follows:

Area	Chairman
Lake Erie and Detroit River	William Richardson U.S. Environmental Protection Agency Large Lakes Research Station
Lake Ontario and St. Lawrence River	John Kinkead Ontario Ministry of the Environment
Lake Huron	J. Kent Crawford, U.S. Environmental Protection Agency Large Lakes Research Station (formerly)

Area	Chairman
Lake Michigan	Robert Bowden U.S. Environmental Protection Agency Region V
Lake Superior	G. Keith Rodgers Canada Centre for Inland Waters
Fish Contaminants	Joseph Leach Ontario Ministry of Natural Resources

Individuals who were primarily concerned with radiation and shorelines circulated among the work groups.

This section contains reports of discussions in the work groups.

LAKE ONTARIO & ST. LAWRENCE RIVER

WORK GROUP REPORT

The participants in this work group summarized important surveillance parameters for Lake Ontario and the St. Lawrence River, noted specific parameters for nearshore, open water, tributary and water intake surveillance, outlined future studies required in the support of surveillance activities, and discussed data management. Specialists in radioecological problems and fish contaminants led discussions in these areas.

On-going surveillance parameters predominated during our session; however, some new parameters were suggested and will be specifically outlined in the following pages. While the rationale and benefits, as well as the priorities of surveillance programs were discussed, little attention was given to the cost and implementation of these programs. This problem was essentially left to the responsible agencies.

Resumé of Surveillance Parameters

For an overview of the importance placed on various surveillance criteria, an outline of suggested application and frequency is useful (Table 1). Parameters for routine surveillance, usually yearly or even monthly sampling, and detailed assessment of changes, including those related to remedial action (at least once every four years) were discussed. Generally, routine measurement of chemical-physical parameters was considered for surveillance, whereas assessment requires specific measures of biological parameters, including in most cases, standing crops of plankton and benthos.

Material Loadings

From the detailed program for tributary material loadings to Lake Ontario which had been given previously to participants, four questions were raised:

1. What research must be undertaken to evaluate the usefulness of measuring phosphorus loading including total phosphorus and reactive phosphate? It is vital that this question be answered, for data on this must be used in any analysis of abatement programs for all the lakes.

TABLE 1

RÉSUMÉ OF SURVEILLANCE PARAMETERS
AREA OF USE AND FREQUENCY

PARAMETER	SAMPLING FREQUENCY	AREA OF UTILIZATION: NEARSHORE	OPEN WATERS	WATER INTAKES	LOADING	SUMS OF ROWS
Nutrients, plant	yearly	x	x	x	x	4
Toxicants, water	yearly	x	x	x	x	4
Fish contaminants	yearly	x	x			2
BOD, COD	yearly				x	1
Benthos	fourth year	x	x	x		3
Phytoplankton	fourth year		x	x		3
Zooplankton	fourth year	x	x	x		3
Bacteria:						
coliform	five/month	x	x			3
heterotrophic	fourth year	x	x	x		3
Chlorophyll	yearly	x	x	x		3
Dissolved Oxygen	yearly	x	x	x		3
Cladophora	yearly	x				1
Thermal	yearly	x				1
Radioactivity	yearly	x	x	x	x	4
Chloride	yearly	x	x	x	x	4
TOTAL, columns		14	12	11	5	

2. What do measurements of total phosphorus provide during periods of peak loading? How much of the total phosphorus measured during routine surveillance is biologically active, that is soluble, reactive phosphorus?

3. What new methods are available for calculating phosphorus loading based on variations in flow?

4. What industrial sources other than those with discharges greater than 1mgd phosphorus should be measured? In addition to industrial discharges, the Niagara River and the Welland Canal are of particular concern.

The principal parameters stressed for loading included:

a) phosphorus (total and reactive)
b) chloride (materials balance)
c) conductivity
d) suspended solids
e) forms of N (NO_2, NO_3, NH_4)
f) temperature flux
g) dissolved reactive silica
h) BOD

Nearshore Waters

Since the initial impact of loading via rivers is felt in the nearshore, numerous key issue were raised for this area, including:

1. Public health criteria. In the nearshore waters, counts of coliform bacteria provide a key measure of water quality.

2. Toxicants, especially those such as PCBs found in fish, are of particular concern.

3. Growths of *Cladophora* may provide the most useful indication of perturbation from loadings of N and P.

4. Estimates of plant nutrients should be emphasized in nearshore waters.

5. Thermal problems deserve greater attention.

Note was made of important nearshore problems in the Bay of Quinte and Hamilton Harbour. However, there was little interest in the problem of defining inshore waters.

Open Waters

Compliance surveys for the parameters in Table I should be run each year (8 cruises). In contrast, assessment cruises should be conducted every four years.

Key issues in open waters included:

1. Trophic state as determined by routine measurements of chlorophyll *a*, especially for monitoring effects of phosphate loading. It was strongly suggested that zooplankton indicators and measurements of heterotrophic bacterial activity be used to provide a more immediate index of trouble.

2. Contamination of fish populations with toxic substances is a critical problem.

3. Oxygen depletion should continue to be monitored.

A detailed "Open Lake" program was submitted by the Canada Centre for Inland Waters (CCIW), and is available from the International Joint Commission's Regional Office.

Water Intakes

Water intakes can provide important baseline information at a lower cost than by ship, particularly if the monitoring is constant. New York State is currently sampling the following parameters at Rochester and Oswego:

a) coliform bacteria

b) pH

c) alkalinity

d) DO

e) chloride

f) turbidity

g) orthophosphate

h) NO_2, NO_3

i) phosphorus

j) COD

k) BOD

Intake surveillance should include contaminants. Moreover New York State should monitor intakes to isolate the effects of thermal pollution. Other potential parameters would be:

1. phytoplankton by major group,

2. radioactivity (isotopes common to power production)

3. chloro-organics

St. Lawrence River

Major water quality problems include: 1) the high potential for oil spills in this area, 2) fluoride discharges, 3) *Cladophora*, and 4) mercury in fish. Important localized problems include mercury pollution at Cornwall and fluoride atmospheric inputs associated with Reynolds Aluminum. Particular attention should be given to the following parameters, to be sampled monthly at the headwaters and below major loadings:

a) phosphorus, soluble reactive phosphate

b) NO_2, NO_3, T-N

c) reactive silicate

d) fluoride

e) toxic substances (especially mercury)

In a similar fashion, the participants drew attention to the potential use of biological indicators, including:

a) zooplankton index species (ratio Cladocera:Calanoidae)

b) phytoplankton indicators (ratio blue-greens:diatoms)

c) bacterial counts (coliform) and kinetics (heterotrophs)

Because of special problems with sampling for fluorides, it was suggested that all available CCIW data be analyzed for variability (ANOVA).

Studies in Support of Surveillance

1. The development of water quality models should be encouraged with surveillance data being used to validate model simulations before attempting to develop management feedback. The use of these validated models to estimate required precision for sampling loading parameters should be determined.

2. The use of remote sensing should be promoted especially where optical problems exist (suspended solids).

3. Support should be given to the development of biological indicators for eutrophication such as bluegreen:diatom ratios; and zooplankton indices.

4. The frequency for optimal sampling of various parameters must be determined.

5. Improvements in surveillance of short, storm-related events is necessary. Is non-compliance during the short-term important?

6. The use of bacterial uptake kinetics as opposed to counts of standing crops of bacteria must be encouraged.

7. Limnochemists must be supported and encouraged to improve our knowledge of phosphorus kinetics.

Data Management

1. The standardization of techniques and intercomparability of data continue to be important.

2. Archiving of data on all of the Great Lakes in the Regional Office is to be encouraged; concomitantly, this implies standardization of data formats and improving the availability of such data to investigators.

3. Because it is a problem of particular importance to the data management for Lake Ontario, orthophosphate data deserves critical review.

COMMENTS

D. MCNAUGHT

Lake Ontario is characteristic of the more eutrophic of the large lake ecosystems of North America. Situated downstream of productive Lake Erie, it is influenced both by nutrient inputs from that eutrophic system and its own morphometric tendencies towards oligotrophy (mean depth = 91 m). Another unique characteristic of Lake Ontario is its large volume-to-surface ratio. There are also certain localized problems, for example, the increase of eutrophication in the Bay of Quinte. The nature of local watermasses is likewise changing in the Oswego, New York area from the large nuclear power generating stations. All of these influences on the lake must be continually monitored.

Surveillance today generally measures standing crops using either chemical (total P) or biological parameters (chlorophyll). Both of these monitoring parameters are, by nature, stable and conservative, again largely due to the long hydraulic retention time of Lake Ontario. One advantage of using conservative parameters is that many have been measured for over 50 years, thus providing a historical baseline to measure recent changes. However, engineers and biologists have not yet stressed the importance of including some measurements of critical biological and chemical fluxes in the current surveillance program. I do not suggest major changes in surveillance procedures since these depend on long-term continuity, but I do suggest the inclusion of one or two measurements of the flux of carbon through the biota, and the use of community indices to denote changes in the community composition of planktonic organisms. Often the biota may reflect ecosystem perturbation within a year whereas more conservative chemical parameters such as total P may not respond to major increases in nutrient input for five to forty years.

Use of Limited Flux Parameters in Surveillance

The ecological implications drawn from modern simulation modelling are similar to those resulting from studies during 1940-55 of energy flow in aquatic ecosystems. Very simply, fluxes or rate constraints describe system dynamics, whereas simplified measures of standing crops may mislead even the most informed manager. Some good integrative measures of perturbation are currently employed as measures of deficits in dissolved oxygen, but these are too limited in scope. Because they are difficult to measure precisely, carbon fluxes are more risky than dissolved oxygen.

Surveillance procedures are beginning to emphasize human health aspects of water quality. Thus, as well as using previously standing crops of coliform bacteria, bacterial kinetics such as the uptake of ^{14}C-glucose by heterotrophic bacteria should be measured (Wright and Hobbie 1966). Another example along these same lines would be to use ^{14}C primary productivity measurements in place of or in addition to chlorophyll.

Reduced Attention to Nutrient Loading

The response of an aquatic ecosystem to nutrient loadings is the result of a complex simultaneous series of fluxes. The precise estimate of nutrient loadings, especially phosphorus and nitrogen, currently occupies a generous piece of the surveillance budget. It is possible however that simulation of models can suggest the precision required and the dollars to be expended in surveillance of nutrient loading.

The current Manhattan College model, termed Lake I (Thomann, Winfield, Di Toro and O'Connor, 1976), suggested that internal fluxes, such as the excretion of soluble phosphorus by the animal plankton, combined with the retention time of the lake and the rate of nutrient loading, must be considered in planning remedial actions in response to surveillance findings. Three of their theoretical conclusions are worth considering:

1. Without increased loading, the spring peak of phytoplankton will increase 45% before reaching a constant level.

2. Nitrogen limitation will predominate over phosphorus limitation of algal growth. This finding should be an immediate indication to increase surveillance of all forms of nitrogen.

3. Reduction in nutrient loading will not result in a visible decrease in phytoplankton standing crop. (Using parameters of the U.S.-Canadian Agreement with a 22% reduction in loading, simulation output suggested only a 6% reduction in phytoplankton after ten years).

At the very least, these conclusions, based on theory and not on fact, suggest that we should not promise the public anything on the consequences of remedial action. At most, these conclusions suggest that we should place less emphasis on examining loadings in the surveillance program.

Biological Indices are Sensitive to Local Perturbations

Biological indices should be used in the standard surveillance program as integrative measures of the impact of localized sources of pollution. Biota, particularly smelt and coho, are important to the surveillance of toxic materials since these organisms are capable of biomagnification.

The use of zooplankton and phytoplankton indicators to identify critical areas of nutrient and thermal pollution was demonstrated during the International Field Year for the Great Lakes (IFYGL) when a single organism, *Bosmina longirostris*, identified thermal input in areas such as Nine Mile Pt., east of Oswego (McNaught, Buzzard and Levine, 1975).

Conclusions

Conservative parameters, such as total phosphorus and chloride, employed in traditional surveillance programs, must continue to embody the largest percentage of surveillance effort. Non-conservative, sensitive parameters, including measures of critical fluxes and the use of key groups of index organisms, when added to our surveillance effort will provide precision in estimating changes over brief periods of time. While more research is needed for the second suggestion, both will lead to better surveillance and faster remedial action.

Lake Ontario, Open Lake (Canada Centre for Inland Waters)

1. In the compliance surveillance program, the number of stations (80) exceeds the IFYGL density and appears excessive.

2. In the assessment program, the dependence upon measurements of chlorophyll *a* could be disasterous. It is suggested that algal community composition be expressed in terms of simple bluegreen: diatom ratios, providing a faster (and more expensive) index than chlorophyll.

3. More emphasis upon the chemistry of contaminants would provide information vital to human health problems.

4. Proposed indices of bacterial density should be complemented with measurements of bacterial kinetics.

Lake Ontario, Nearshore (Canada Centre for Inland Waters)

1. This program was designed with special reference to the New York shoreline, and awaits the cooperation of the U.S. Environmental Protection Agency. Special attention is required for thermal problems in the area of Nine Mile Pt.

Lake Ontario, Intakes (Ontario Ministry of the Environment)

1. Proposed phytoplankton identification for intake samples will add extremely vital information. Appropriate indices to be used in presenting these data and for planning remedial action are suggested.

2. Water chemistry will hopefully emphasize the reactive forms of phosphorus.

3. The addition of a zooplankton study with attention only to pollution indicators is needed.

4. If there are thermal problems on the Canadian shoreline, a thermal study linked to collection of data via intakes would be valuable.

Lake Ontario, Impacted Areas (Ontario Ministry of the Environment)

1. Measuring chemical parameters during short, storm-related events, especially in Toronto Harbour, is a necessary expansion of the proposed program.

2. Additional biological data for parallel studies have apparently been developed for the Bay of Quinte. This data base should be utilized in biological ecosystems modelling, with direct application to remedial planning.

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Wright, R. T. and Hobbie, J. E. "Use of glucose and bacteria and algae in aquatic ecosystems". Ecology, 47:447-64 (1966).

Lake Ontario, Intakes (Ontario Ministry of the Environment)

1. [illegible] phytoplankton identification [illegible] intake [illegible] [illegible] information. Appropriate indices [illegible] [illegible] data [illegible] planning remedial action are suggested.

2. [illegible] hopefully [illegible] the reactive forms of phosphorus.

3. The addition of zooplankton [illegible] pollution indicators is needed.

4. If there are thermal problems on the Canadian shoreline, thermal study linked to collection of data via intakes would be valuable.

Lake Ontario, [illegible] (Ontario Ministry of the Environment)

1. [illegible] chemical parameters [illegible] [illegible] [illegible] proposed program.

2. Additional biological data for parallel studies have apparently been developed [illegible] data [illegible] be utilized in biological ecosystems modelling, with direct application to remedial planning.

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LAKE ERIE & DETROIT RIVER

WORK GROUP REPORT

Surveillance Plans

Prior to the workshop, each government agency or contractor participating in a phase of the International Joint Commission surveillance network for Lake Erie prepared a draft plan which was circulated to all the participants in the Lake Erie work group. The following plans for 1976 were considered:

A. Lake Erie/Tributaries

1. Corps of Engineers/Buffalo District
2. Pennsylvania Department of Environmental Resources
3. Michigan Water Resources Commission
4. Ohio Environmental Protection Agency
5. Ontario Ministry of the Environment

B. Lake Erie/Water Intakes

1. Pennsylvania Department of Environmental Resources
2. Michigan Water Resources Commission
3. Ohio Environmental Protection Agency
4. Ontario Ministry of the Environment

C. Lake Erie/Nearshore

1. Canada Centre for Inland Waters
2. Pennsylvania Department of Environmental Resources
3. Ohio State University/U.S. Environmental Protection Agency
4. Ontario Ministry of the Environment

The frequency of measurements and the parameters to be measured are noted in Tables 1 to 21 in Appendix II.

The U.S. Army, Corps of Engineers, Buffalo District plan calls for monitoring water quality near the mouths of four tributaries in northwestern Ohio (Maumee, Portage, Sandusky and Huron Rivers) during the period

January - June 1976. To be conducted at six hour intervals during peak flow periods and once per week during low flow, the sampling will determine nutrients and solids. The program is specifically designed to provide reliable tributary loading for runoff events. The major criticism of the study is that the monitoring stations are up to twenty kilometres inland from the lake.

The Pennsylvania Department of Environmental Resources, in cooperation with the Erie County Department of Health, plans to monitor seven stations in Lake Erie and two in Presque Isle Bay by boat, the city water intake at Erie and three stations located on tributaries (Sixteen Mile, Walnut, and Elk Creeks) to Lake Erie. In addition to a wide range of water quality parameters, biological surveillance will be conducted in 1976. Because the Pennsylvania plan contains tributary, water intake, nearshore and open lake components, it is the most comprehensive state program.

The Michigan Water Resources Commission (WRC) monitoring plan includes three tributaries to Lake Erie/Detroit River (Rouge, Huron and Raisin Rivers) and five water intakes (Detroit-Jefferson Avenue, Detroit-Wyandotte, Detroit-Allen Park, Monroe, and the Enrico Fermi Power Plant). These locations are sampled monthly with no specific attempt to obtain samples during peak flow conditions. There appears to be considerable controversy between Michigan WRC, Corps of Engineers/Buffalo, and the International Joint Commission Regional Office over the statistical method for calculating loadings to Lake Erie from the Michigan tributaries.

The Michigan WRC and the Ontario Ministry of the Environment jointly conduct a monitoring program of the Detroit River from its head at Lake St. Clair to its mouth at Lake Erie. The two agencies alternate monthly sampling at 54 stations on 10 ranges across the river. Michigan WRC is responsible for computing nutrient loadings to Lake Erie using a model developed by the Lake Survey Center of the National Oceanic and Atmospheric Administration. This approach appears to be adequate and is generally accepted by the scientific community. Monthly sampling is appropriate for this river because of the fairly uniform flow throughout the year. In addition to this program, the U.S. Environmental Protection Agency Large Lakes Research Station, Grosse Ile, plans to continue daily monitoring of phosphorus in the Detroit River at the Free Bridge to Grosse Ile.

In addition to the Detroit River sampling, the Ontario Ministry of the Environment is monitoring six tributaries (Grand River, Kettle Creek, Lynn River, Big Otter Creek, Big Creek and Catfish Creek), three water intakes (Kingsville, Blenheim and Dunville) and 108 nearshore stations along the Ontario shore of Lake Erie. In 1976, emphasis will be placed on the eastern basin of Lake Erie because of significant urban and industrial development underway there. Thirty additional stations in this area will be sampled during spring runoff events for five consecutive days. In addition, the impact of improved water treatment of municipal and canning wastes at Leamington will be assessed in Pigeon Bay of western Lake Erie. The Ontario plan appears to be adequate with the exception of water intake surveillance which includes only five water quality parameters.

The Ohio Environmental Protection Agency monitoring program for the Lake Erie basin consists of monthly measurements for a comprehensive list of parameters at 12 tributaries (Maumee, Portage, Sandusky, Huron, Vermilion, Black, Rocky, Cuyahoga, Chagrin, Grand and Ashtabula Rivers and Conneaut Creek) and four water treatment plant intakes (Oregon, Sandusky, Cleveland-Crown, and Painesville). Although this plan calls for a comprehensive list of parameters, there is no provision for peak runoff sampling. Another criticism of the Ohio program is that many of the tributaries are not actually sampled on a monthly basis for a variety of reasons.

Since no plans were received from the State of New York for monitoring tributaries, water intakes, nearshore or the Niagara River, it is the only jurisdiction not included in the surveillance plans developed at the workshop for Lake Erie and its connecting waterways.

The plan of the Canada Centre for Inland Waters (CCIW) and the Large Lakes Research Station, (in conjunction with the Ohio State University, Centre for Lake Erie Area Research (CLEAR) and the New York State University College at Buffalo, Great Lakes Laboratory (GLL)) calls for extensive investigations of the nearshore and open lake portions of all three basins of Lake Erie. CCIW will visit 106 stations and CLEAR/GLL will visit 80 stations on a monthly basis during the ice free period of the year. In addition to routine surveillance, these efforts will (1) determine the extent and duration of dissolved oxygen conditions less than IJC objectives and the oxygen depletion rate, (2) estimate biomass (3) provide measurements of nutrients to be used for calculating quantities in the lake compared to loading records (4) determine the amount of nutrients regenerated from the sediments and (5) estimate the magnitude of resuspended sediment in the western basin of Lake Erie. The surveillance plans appear adequate to achieve these objectives.

Surveillance Priorities

The Lake Erie/Detroit River work group considered the plans of each agency in terms of the uniform set of design objectives provided by the Surveillance Subcommittee. The following consensus of priorities for a Lake Erie/Detroit River Surveillance Program evolved from the discussion.

1. Oxygen depletion problem, particularly the anoxic region of the central basin.

2. Phosphorus loading from all sources, including tributaries, municipal/industrial and atmosphere.

3. Nearshore localized problem areas, including bacterial contamination, *Cladophora*, radionuclides and turbidity.

4. Fish contamination by organic compounds and metals.

5. Long-term trend assessment of water quality, particularly continued monitoring of water intakes.

The work group recommended that these priorities be incorporated into an overall surveillance plan for the lake and associated waterways, with the first four being the minimum for a satisfactory program. The parameters listed in Appendix B of the 1974 Report of the Great Lakes Water Quality Board were judged to be generally acceptable by the various agencies. The frequency and period of sampling proved to be a controversial issue which was not resolved by the work group.

COMMENTS

C. HERDENDORF

Tributaries

The tributary monitoring programs proposed by Michigan, Ohio, Pennsylvania and Ontario appear to be adequate to determine compliance with IJC objectives. No information is available on the New York plan. However there is considerable controversy on two issues: (1) calculation from surveillance data of the annual loading to Lake Erie and (2) spring runoff event sampling versus uniform monthly sampling. The calculation question could be resolved as a staff function of the IJC, Regional Office. While some progress has been made in this direction, more effort and additional staff should be concentrated on developing a universally acceptable approach.

The problem of event versus monthly tributary sampling seems to center on the biological availability of phosphorus carried to the lake during spring runoff. Special research efforts are needed to resolve this question. The Large Lakes Research Station presently has a research project underway which will provide an impartial answer to questions on a case by case basis with each stream tested separately. Another approach to this problem is contained in the proceedings of the Research Advisory Board Workshop on *Cladophora* in the Great Lakes. It appears that the state agencies are unlikely to convert from a monthly sampling schedule to spring event sampling unless it can be shown that a significant amount of the spring phosphorus load is available for biological production.

Another issue which requires attention is the more general use of surveillance data to assess the effectiveness of remedial programs in improving water quality. Some work of this nature has been attempted by the Corps of Engineers in northwestern Ohio.

The estuary-type mouths of most of the Lake Erie tributaries present a particularly difficult problem in calculating reliable loadings to Lake Erie. Special research projects are required to develop a model which will permit accurate estimates within an estuary with a minimal number of samples.

Water Intakes

The Lake Erie work group established a low priority for continued monitoring of water intakes. However, water intake data, because of their long and continuous nature, provide one of the basic tools for long-term assessments of water quality trends. This activity should be continued and data analyzed periodically to determine the impact of remedial measures.

Nearshore

The Ontario and Pennsylvania nearshore areas appear to be adequately monitored, but similar coverage is not planned for Michigan and Ohio. No plans were presented for New York. U.S. Environmental Protection Agency sponsored projects will provide some general information on the nature of the nearshore water on the American side, but specific problem areas will not be routinely monitored. Results of recent research projects in the vicinity of Cleveland and Toledo could provide the information necessary to develop effective surveillance plans for nearshore problem areas. Remote sensing techniques developed by the National Aeronautics and Space Administration (NASA) Lewis Research Center would facilitate surveillance of specific problems, such as the impact of tributary runoff during peak spring flow. The cost of remote sensing will be greatly reduced in 1978 when the Nimbus G satellite, equipped with an ocean color scanning system, is launched and begins to provide every-other-day coverage of the Great Lakes. NASA is presently undertaking studies with a similar scanning system aboard aircraft in order to perfect assessment techniques which can be utilized once the satellite is in position. It is desirable that total suspended and volatile solids data be gathered as often as possible during all ongoing surveillance programs to provide ground truth for satellite imagery.

While *Cladophora* is extensive in Lake Erie, the problem is not as serious as in Lake Ontario and does not yet require a detailed surveillance program. If and when the costly surveillance techniques used in Lake Ontario are perfected on an economical basis, they should be considered for Lake Erie.

The radiological surveillance program proposed by the Radioactivity Subcommittee appears to repeat some aspects of the program presently being conducted by the Nuclear Regulatory Commission, particularly in sampling along a one kilometre arc at the perimeter of active nuclear power plants. The Radioactivity Subcommittee's recommendations should be reviewed carefully before implementation.

Open Lake

The open lake plans proposed for Lake Erie are the outgrowth of research projects designed to study the effectiveness of nutrient controls in limiting lake eutrophication. Techniques have been developed to make routine surveillance measurements of the annual oxygen depletion rate possible.

Because of the seriousness of this problem and the wide variability of the area affected, an annual monitoring effort of modest intensity should be continued. The plans proposed for 1976 will satisfy this need.

Because of its relatively small volume, Lake Erie has a water retention time of less than three years. As a result, intense monitoring programs are needed every five years.

Dr. Nelson Watson, CCIW, suggested that for open lake surveillance it is important to establish a few intensive stations where water quality and biological parameters are monitored on a daily or at least weekly basis. Such surveillance is not intended to obtain data for balance calculations, but would produce a valuable record of change.

Detroit River

The sampling plan proposed for the Detroit River has a long historical basis. The joint US/Canadian program initiated in 1966 appears to be working well and provides the loading information necessary to determine compliance with the IJC objectives. Although a plan was not submitted for the Niagara River, a similar approach should be considered.

General Assessment

Each agency involved in Lake Erie surveillance would be able to do a better job in designing and coordinating their programs if the Water Quality Board would provide a better definition of the IJC objectives. More effort should be spent on showing the various state and provincial agencies how their programs fit into the overall scheme for Lake Erie, or better still, giving them an active role in developing the scheme.

At present, biological indicators are not extensively used in surveillance because they are costly and time consuming. However, data on the appearance or disappearance of sensitive fish species are readily available from most wildlife agencies on both sides of the border. As well, these agencies routinely develop year class strength indices for many species. Coordinated through the Great Lakes Fishery Commission, such indices could be integrated into the total Lake Erie surveillance effort. Organization of the fish contaminants surveillance program by this Commission is also a possibility.

Data management and quality assurance are chronic problems which can always be expected in a large, multi-agency surveillance program. A task force with at least one representative from each agency should be established to develop better procedures. Also required are a surveillance manual which could be updated periodically and funds for uniform logging of the data. These steps will not resolve all of the inherent problems but they could provide a common basis for standardizing data outputs.

LAKE HURON

WORK GROUP REPORT

The nearshore is the only area of Lake Huron presently experiencing water quality problems. Therefore, it should be given priority for surveillance in terms of sampling station placement and sampling frequencies. Specific nearshore areas requiring attention are Saginaw Bay, Penetang-Midland area, Collingwood, Bayfield-Goderich, Spanish River, and Owen Sound.

Including biota in the surveillance design is a second priority since they serve as sensitive monitors to the more subtle changes in water quality. All biological communities: benthic, shoreline benthic, phytoplankton, zooplankton, and fish should be considered. Fish are particularly important for monitoring the accumulation of toxic substances. These substances exist in the water at levels which are frequently too low for measurement but can be magnified through the food chain to levels in fish flesh that are harmful to human health.

Using strictly controlled methodology, water intakes because of their convenience, should be sampled on a frequent (at least weekly) long-term basis. The samples could either be analyzed at the collecting laboratory or preserved on site and sent to another lab with the proper expertise to conduct the analysis.

Although it is beyond the scope of surveillance design *per se*, inter laboratory comparability of data is essential and should be the object of a continuing effort in support of surveillance. Included in this effort should be a common data storage system.

Because most of the material loadings to problem areas come from tributaries, studies to account for changes of loading should concentrate there. As well, tributaries will show the results of remedial measures where open water or even nearshore sampling may not. Since a justification for remedial actions will be expected, tributary studies can be used to show improvements from these programs.

Preliminary work at the U.S. Environmental Protection Agency Large Lakes Research Station, Grosse Ile, has demonstrated that monthly sampling is inadequate to identify all material loadings from tributaries. Consequently, daily sampling should be considered, particularly for some selected tributaries.

Parameters to be studied in Lake Huron include the obvious problems of phosphorus and hazardous materials. In addition, silica depletion, presently occurring in the epilimnion in late summer, requires study because it can result in a shift toward a bluegreen-dominated plankton community.

Certain other recommendations evolved from the Lake Huron session. While not priorities for design, these items are important to surveillance.

First, certain parameters for which objectives were established in the Great Lakes Water Quality Agreement are seldom a problem in the open waters of Lake Huron and as a result, their study should be de-emphasized. Included in this group are oxygen, pH, and bacteria.

Second, there are some other parameters requiring objectives. Silica and nitrate, because of their role in determining the amount and kinds of phytoplankton present, fall into this category. More meaningful bacterial parameters such as aerobic heterotrophs or *Pseudomonas* counts should replace the unreliable total coliform measure.

Finally, the objective for iron, 300 μg/1, should be changed to a lower value.

COMMENTS

C. SCHELSKE

The following are some additional comments on the six points discussed in the workgroup.

1. Nearshore Areas:

Many localized areas fall into this category. Because spatial and temporal changes can be great, extensive and perhaps continuous monitoring is needed to evaluate water quality. The number of potential problems can be reduced by carefully determining the amount and extent of surveillance required for each site.

2. Biota:

The biota can serve two purposes in surveillance. One is their ability to accumulate many hazardous substances such as PCBs and DDT which are found in greater concentrations in the biota than in the surrounding water. The other is their sensitivity to subtle changes in environmental conditions that may not be detected by chemical and physical measurements. This sensitivity can be attributed in part to the small tolerance of many species to variations in environmental conditions. Any change in species composition then would be due to environmental change even though the causal mechanism may be unknown or poorly understood. For the purposes of this report, I can summarize this point by stating that the relationships described above will generally be accepted by many biologists.

Biologists may not agree on what organisms would be most suitable for surveillance, although historically phytoplankton may have been used most widely. In the Great Lakes, changes in phytoplankton species composition have been documented by Davis and Hohn for Lake Erie, and by Damann, Stoermer and Yang for Lake Michigan. Responses of different groups of organisms, including phytoplankton, zooplankton, and benthos, to environmental stress in the Great Lakes have been reviewed a number of times, most recently at the Second Conference of the Interagency Committee for Marine Science and Engineering held at Argonne National Laboratory, March 25-27, 1975. Noel Hynes, at this workshop, developed an excellent rationale for using periphytic communities on rocky, wave-exposed shores to detect environmental changes.

I would strongly recommend that data on biological communities be included in surveillance plans. Data must be collected regularly at frequencies determined by the types of organisms being sampled. Annual sampling is probably adequate for many benthic forms, while weekly samples of the plankton might be required to provide a comprehensive analysis of the seasonal variation in species composition. Three collections per year would be the minimum for biological sampling.

Sufficient time and funding should be given to testing the design of the biological monitoring and surveillance program in order to ensure that as much data as possible can be utilized. If feasible, the same type of devices for sampling biota should be employed in different sections of Lake Huron. Otherwise, the limitations and comparability of collections from different instruments should be determined.

Very precise estimates of abundance may not be required to determine whether species composition changes with time. Given the constraints of sampling biological populations, extensive quantitative studies may also be impractical. Using relatively crude quantitative estimates on the dominant organisms, it is possible to detect changes in species composition with time. A program for detecting changes in species composition is more economical than a program which would also provide data on changes in abundance of many species. Both, of course, are important and could provide useful data for surveillance.

Phytoplankton appear to be the best group of organisms for biological surveillance since there are many more species than in other groups, the trophic relationships are relatively well known and they respond directly to nutrient enrichment.

Another goal of biological surveillance is to eventually determine which organisms are most susceptible to individual contaminants.

In summary, environmental change is a complex problem that must be viewed from many standpoints. In Lake Huron, the open lake presents one case whereas the nearshore areas and bays present several problems.

3. Municipal Water Intakes:

Although the usefulness of data from these sources for surveillance is presently unknown, the few studies done (Beeton on chemical changes and Davis on phytoplankton, for example) have shown the importance of analyzing relatively long term series of the data. These studies, it must be noted, employed data which was not collected specifically for surveillance purposes. Formal plans to utilize these sources for data are necessary and should include parameters to be measured, frequency of measurement, methods for quality control, and means for reporting and storing data. How much work of this type is needed will be determined in part from the general surveillance strategy for the Great Lakes.

Since the parameters measured at intakes reflect quality of drinking water and in some cases represent only localized conditions, the data could be used to assess water quality in potential or actual nearshore problem areas, but not trends in the entire lake.

Special attention should be given to Detroit's new intake in southern Lake Huron to determine whether data from this intake will be representative of conditions in the open lake.

At present, Lake Huron water intakes located in the United States appear to be undersampled with the Michigan Department of Natural Resources sampling some intakes bimonthly. On the Canadian side of the lake however, the Ontario Ministry of the Environment has been collecting monthly samples from certain intakes. Considering that intakes in other lakes are sampled daily, at least some of the intakes on Lake Huron should be monitored more frequently.

4. Data Comparability:

Additional attention should be given to the need for coordinated data collection, storage and analysis. In particular, models such as the one included in the "General Surveillance Design Guidelines" distributed at the meeting require uniform data input from all sources.

5. Material Loading Studies:

When planning programmes for nearshore areas and bays, priorities for assessing material loadings must be established as well as exactly what is being sought from the program. Since the best strategies and designs vary according to the sources being sampled, they must be given careful attention site by site.

6. Surveillance Parameters:

In Lake Huron, where water quality is excellent compared to the lower Great Lakes, surveillance parameters should differ from those for Lake Erie and Lake Ontario. The quantity and potential significance of hazardous materials is one of the most important considerations. If hazardous materials originate from localized sources then surveillance can possibly be restricted to the relatively small affected areas.

Phosphorus is the most significant contributor to eutrophication. It increases growth of phytoplankton and silica uptake by diatoms. In oligotrophic environments like Lake Huron it is easier to quantify silica depletion in the euphotic zone than to determine the changes in phosphorus concentrations causing the increased growth of diatoms. Utilization of silica by diatoms then is a much more sensitive indicator of phosphorus enrichment.

Depletion of nitrate, like depletion of silica, is also a more sensitive indicator of phosphorus enrichment in the upper Great Lakes than any parameter evaluated to date. These subjects are discussed in greater detail in my paper "Silica and nitrate depletion as related to eutrophication in lakes Michigan, Huron and Superior" (in Hasler, A. D., ed. Coupling of land and water systems. New York, Springer - Verlag, 1975. pp. 277-298).

In summary, the indirect effects of phosphorus enrichment are greater from the standpoint of environmental change than first might be expected from relatively small increases in phosphorus concentrations. The magnitude of the phosphorus increase needed to produce the change is not known, but it could result from an average increase of only a few tenths of a microgram per litre, which might be impossible to detect in the lake. Processes of this type in large aquatic systems with relatively long residence times point to the need for limiting phosphorus inputs as much as is practically possible.

It makes little sense to measure parameters such as dissolved oxygen, pH and bacteria which are not problems in Lake Huron, particularly when other environmental conditions, namely silica and nitrate depletion and biological communities, may be affected by environmental stresses. The examples cited indicate the possible need for different objectives for the upper and lower Great Lakes.

In addition to the priorities mentioned above, my recommendations for surveillance are:

1. A separate surveillance program should be established for each area; Saginaw Bay and Georgian Bay are defined as nearshore areas. Several different designs will be needed depending on the nature of the problems in specific areas and should include provisions for obtaining comparable data for all areas.

2. A unified surveillance program should be designed for the open waters of the three upper Great Lakes which, by logic, can be considered collectively since the major inputs to Lake Huron are the outflows from lakes Superior and Michigan. This program should furnish data for a model of material balances in the lakes, emphasizing as few as four parameters: chloride, total phosphorus, dissolved reactive silica and nitrate nitrogen. Chloride would be measured to provide data on a conservative substance. The measuring nutrients would determine concentrations and mass balances of phosphorus as well as mass balances and depletion of silica and nitrate in each lake. Two sets of samples

would be required annually, although sampling could be reduced greatly if Lake Superior were considered as a tributary thereby eliminating the need to measure its mass balances of nutrients.

3. Surveillance sampling should be conducted annually until there is reasonable assurance that baseline conditions have been established. Afterwards, less frequent sampling might suffice. Knowing the problems of sampling large bodies of water and that the baseline may be changing, one would expect intuitively that more than three points would be needed to fit a curve to the data. It is therefore evident that several years of sampling would be necessary and that long-term data would also be desirable for other purposes.

4. An attempt should be made to determine whether annual sampling could meet certain surveillance requirements. It is possible that the design proposed under the second recommendation could be accomplished by winter sampling of the open lake when homogeneous conditions are approached. Thus mass balances in the lakes can be calculated from a relatively small number of samples.

5. The usefulness of water intake data in surveillance models must be determined through the use of data from intakes and the open lake. This may be possible if data comparable to that from open lake collections on Lake Huron in 1971, 1974 and 1975 are available from the intakes.

6. Statistical indices based on several parameters should be investigated to determine their utility for surveillance. While these indices might be more useful in the lower lakes, they could also be applied to the upper lakes.

7. Finally, I would again recommend that surveillance designs include the analysis of biological communities.

LAKE MICHIGAN

Point Sources

Significant point sources for Lake Michigan are tributaries, harbors and municipal and industrial outfalls.

The tributary monitoring program now carried out in the states should be expanded to include conditions in the following harbors: Sheboygan, Manitowoc, Racine, Benton Harbor, Grand Haven, Muskegon, Ludington, Manistee, Traverse City and Manistique.

Tributaries should be monitored at least twice-monthly when the intensive whole-lake program is underway, so that lake conditions - at the minimum, estimates of loading - can be related to sources. Monitoring should include unusual discharge conditions.

Loading from outfalls in the lake proper should be included in the tributary monitoring program.

Diffuse Sources

Diffuse sources for Lake Michigan include atmospheric inputs, surface runoff and recycling of materials from the sediment by chemical action and solution or by active transport by organisms. The work group focussed particularly on atmospheric sources.

Monthly, integrated, bulk precipitation samples are being collected at 20 locations around Lake Michigan by the University of Wisconsin. These stations plus several established by the State of Michigan should be maintained during 1976. Emphasis in the Wisconsin project is on phosphorus loading, although analyses are also being made for pH, specific conductance, sulfate, silica, chloride, total-N, total dissolved-N, total organic carbon, dissolved organic carbon, Ca, Mg, Na, K, and total particulates. Arrangements should be made to include analyses for heavy metals.

The atmospheric monitoring program for the Great Lakes calls for a total of 20 stations throughout the basin. Until more data are available from the Wisconsin project, it is premature to select atmospheric monitoring stations for Lake Michigan. One of the recommendations from the Wisconsin project should be the number and location of such stations.

Characteristics of Lake Michigan Pertinent to Monitoring

Lake Michigan is the sixth largest lake in the world in surface area and volume. The lake proper has two major depressions, the deepest off Frankfort and another in the southern half of the lake. Because of this morphology, there has been speculation that there may be restricted exchange between the southern and northern parts of the lake. If this is true, it is not easily demonstrated and should not be of major concern in a monitoring program.

Because the lake is so large in relation to its drainage basin, direct atmospheric inputs are important to its quality.

Bays--Two bays, Green and Grand Traverse, are prominent features of the lake. Green Bay is sufficiently different from the lake proper as to warrant a separate monitoring program. The Fox River, the lake's major tributary, empties into southern Green Bay. Severely polluted, the river is a predominant cause of degradation in the Bay.

Grand Traverse Bay has been included in the lake monitoring program because it is not serious degraded.

Lake Proper--Within the past few years, pronounced inshore-offshore (> 10 miles) differences in chemical content and biota have been documented. This is not surprizing since major inputs are near shore. There must be naturally occurring differences between inshore and offshore waters because of the shallowness of neashore areas, surface runoff and inflow of tributaries. The natural differences are enhanced or masked by inputs of pollutants.

Exchange between lakes Huron and Michigan through the Straits of Mackinaw has been recognized for some time. In fact, there is some evidence that Lake Superior water from the St. Marys River extends to the Straits. The importance of this exchange has not been determined however.

Physical--The lake is essentially monomictic, with stratification lasting from late June to September and influencing the vertical distribution of some chemicals and the biota. Mixing extends to the bottom in shallow areas most of the year. Some thermal discontinuity exists into early December in deep waters, but there is no evidence that it is of great importance to the distribution of chemicals and biota. The lake proper mixes from October to mid-June.

Along-shore currents tend to keep point source inputs nearshore. The thermal bar may also limit nearshore and offshore mixing in the spring. Upwelling must be considered in the nearshore environment, especially along the western shore where conditions can change rapidly from this.

The bays are dimictic, since they are ice covered in winter. Pronounced stratification in summer and ice cover in winter restrict vertical mixing and permit depletion of dissolved oxygen in southern Green Bay.

The flushing of Green Bay and its exchange with the lake proper is similar to an estuary during most of the year (Modlin and Beeton 1970). The importance of under-ice exchange between bays and the lake has not been established, except for Little Bay de Noc (Mayhew 1972).

Whole-Lake Monitoring Program

Lake Proper--The lake-wide program should be separate from the surveillance of critical areas to detect any progressive long term changes. Several studies have shown that the offshore waters are of very good quality, seasonal fluctuations are small, and variations from place to place are not great. Therefore, only a relatively few offshore sampling localities are included in the proposed plan. A greater number of stations are recommended for the nearshore waters since they usually are quite different from the offshore waters. The following proposed program should be undertaken every ten years, especially if suitable water intakes are monitored for nearshore conditions.

The program includes 41 of the stations (Table 1, Figure 1) recommended by the Monitoring Committee for the Conference on the Matter of Pollution of Lake Michigan and Tributary Basins (1968). Most of these locations were sampled by the Federal Water Pollution Control Administration (FWPCA) and Environmental Protection Agency (EPA) in 1963, 1970 and 1974. Twelve stations sampled by the U.S. Fish and Wildlife Service in 1954-55 and 1960-61 (Table 2) are also included. These stations were sampled from 3 to 23 times a year for temperature, transparency, chemistry, benthos and plankton. Thirty-one new stations for two and five miles from shore are recommended to give greater coverage of the nearshore waters (Table 3). An additional group of stations, bringing the total to 84 is proposed for the Straits area to obtain data on the exchange between Lakes Huron and Michigan. Sixteen stations could be eliminated as part of an ongoing monitoring program, especially if the Straits region is treated as part of a special study.

Samples should be taken at the surface, at depths of 5, 10, 20, 30, 45, 65 m, and 1 m from the bottom. Only certain analyses need to be made on samples from all depths. Chlorophyll is a good example since pronounced seasonal changes have already been demonstrated in its vertical distribution (Torke 1975). Other parameters will require samples for analyses from a few depths (Table 4). Vertical tows commencing 5 m off the bottom should be made for zooplankton. A tow with a number 6 mesh 1/2 metre net will be needed for planktonic crustacea while a tow with a number 20 mesh 1/2 metre net will capture small larval forms and rotifers. A PONAR grab should be used to collect a minimum of three benthos samples per station. A sub-sample of the sediment from each station should be preserved for analyses of particle size, organic content and possible analyses for oil and heavy metals. Suitable sterile bacteriological samplers should be used for bacteria.

Each station should be sampled once during March, May, June, July, August, September and November as a minimum. A maximum program would require sampling each station twice a month throughout the year, weather and ice conditions permitting. A reasonable compromise would be for sampling each station once a month in January, March, July, August, September and November and twice a month in April, May and June.

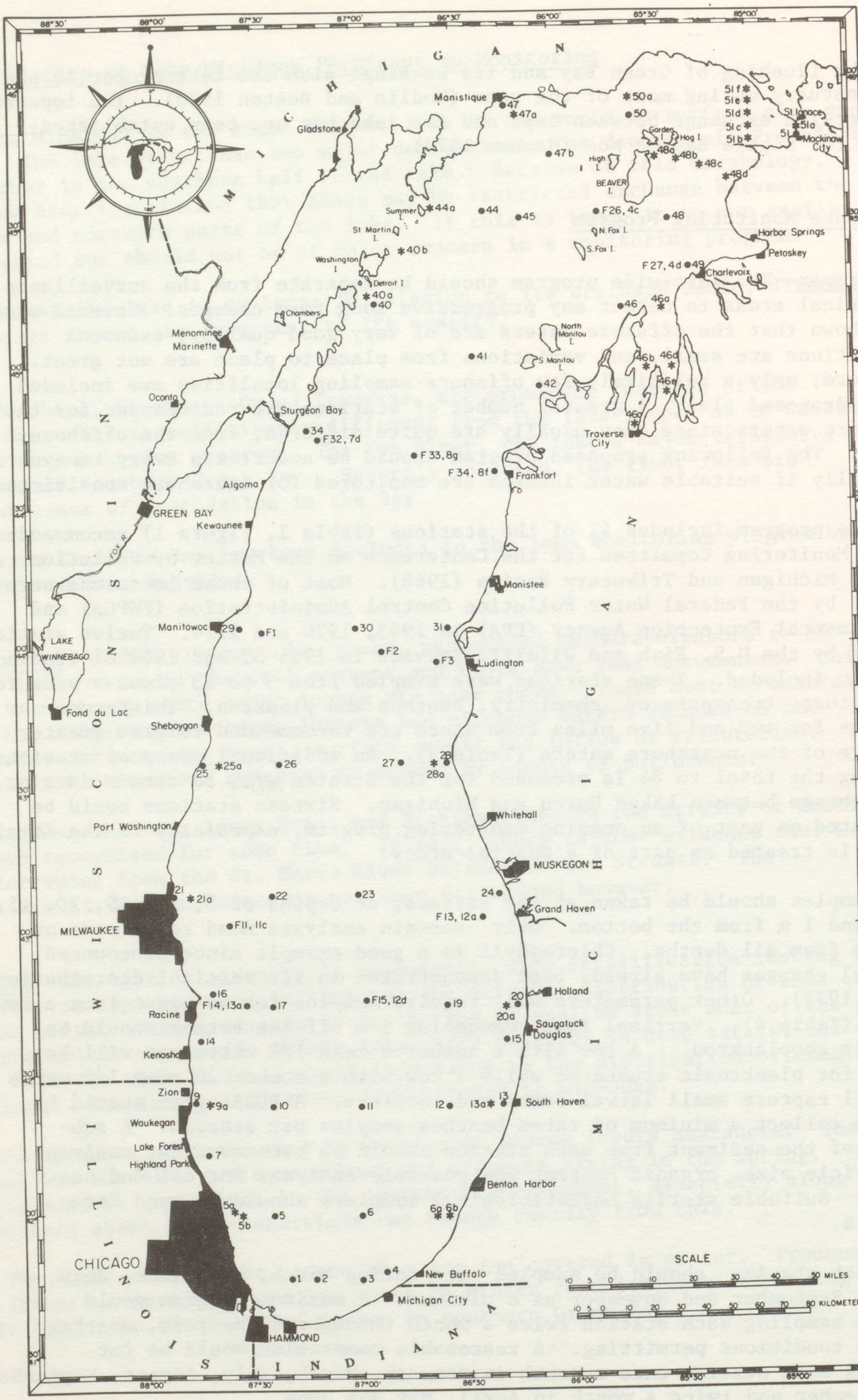

Figure I - Lake Michigan open water monitoring stations

TABLE 1

LAKE MICHIGAN OPEN WATER MONITORING STATIONS

Station	Lat.	Long.	Previous Visits (1963)
1	41°46'00"	87°20'00"	3
2	41°46'00"	87°13'00"	4
3	41°46'00"	87°00'00"	3
4	41°48'00"	87°53'00"	1
5	42°00'00"	87°25'00"	2
6	42°00'00"	87°00'00"	3
7	42°12'00"	87°43'00"	3
9	42°24'00"	87°47'00"	3
10	42°23'00"	87°25'00"	2
11	42°23'00"	87°00'00"	2
12	42°23'00"	86°35'00"	4
13	42°23'00"	86°20'00"	1*
14	42°37'00"	87°45'00"	1*
15	42°37'00"	86°18'00"	1*
16	42°47'00"	87°41'00"	2
17	42°44'00"	87°25'00"	1*
19	42°44'00"	86°35'00"	3
20	42°44'00"	86°15'00"	4
21	43°08'00"	87°53'00"	3
22	43°08'00"	87°25'00"	3
23	43°08'00"	87°00'00"	3
24	43°08'00"	86°19'00"	4
25	43°36'00"	87°44'00"	3
26	43°36'00"	87°22'00"	3
27	43°36'00"	86°47'00"	2
28	43°36'00"	86°33'00"	4
29	44°05'00"	87°34'00"	3
30	44°05'00"	87°00'00"	2
31	44°05'00"	86°33'00"	2
34	44°47'00"	87°14'00"	2
40	45°14'00"	86°53'00"	1*
41	45°02'00"	86°24'00"	1
42	44°56'00"	86°05'00"	3
44	45°34'00"	86°21'00"	2
45	45°32'00"	86°10'00"	2
46	45°13'00"	85°40'00"	2
47	45°56'00"	86°14'00"	3
48	45°31'00"	85°25'00"	3
49	45°21'00"	85°20'00"	2
50	45°53'00"	85°36'00"	3
51	45°48'00"	84°45'00"	3

*Only one visit was made to actual position but several other positions within one mile were also sampled in 1963.

TABLE 2

LOCATIONS SAMPLED BY THE U.S. FISH AND WILDLIFE SERVICE
(Beeton and Moffett 1964)

Station	Lat.	Long.	Years Sampled
1	44°04'10"	87°27'00"	54,55
2	44°00'00"	86°52'05"	54,55
3	43°58'20"	86°37'45"	54,55
13	43°03'00"	86°24'40"	54,55,60
11	43°01'50"	87°37'15"	54,60
14	42°44'25"	87°31'40"	54,60
15	42°45'25"	86°58'25"	54,60
26	45°32'50"	85°46'40"	55,61
27	45°21'00"	85°20'00"	55,61
32	44°45'45"	87°11'00"	55,61
33	44°41'30"	86°42'20"	55,61
34	44°38'10"	86°18'45"	55,61

TABLE 3

ADDITIONAL SAMPLING LOCATIONS

Station	Lat.	Long.
5a	42°00'00"	87°37'00"
5b	42°00'00"	87°33'20"
6a	42°00'00"	86°39'00"
6b	42°00'00"	86°35'40"
9a	42°23'30"	87°42'30"
13a	42°23'00"	86°23'20"
20a	42°44'00"	86°18'00"
21a	43°08'00"	87°47'45"
25a	43°36'00"	87°39'20"
28a	43°36'00"	86°37'30"
40a	45°15'50"	86°55'05"
40b	45°25'15"	86°45'00"
44a	45°34'00"	86°35'40"
46a	45°12'25"	85°28'00"
46b	45°00'00"	85°32'30"
46c	44°47'40"	85°37'00"
46d	45°00'00"	85°25'00"
46c	44°54'00"	85°27'00"
47a	45°58'45"	86°10'25"
47b	45°45'00"	86°00'00"
48a	45°44'20"	85°28'20"
48b	45°43'40"	85°22'30"
48c	45°42'35"	85°15'00"
48d	45°39'35"	85°07'20"
50a	45°57'00"	85°36'00"
51a	45°49'40"	84°45'00"
51b	45°47'20"	85°00'00"
51c	45°49'55"	85°00'00"
51d	45°52'40"	85°00'00"
51e	45°55'00"	85°00'00"
51f	45°57'45"	85°00'00"

TABLE 4

WHOLE-LAKE MONITORING

Parameter	Sampling Depths*	Sampling Method	Frequency	Station
Temperature	0-bottom	BT	Each cruise	all
Transparency	-	Secchi disc	Each cruise	all
Suspended Solids	all	water sampler	Each cruise	all
Specific Donductance	all	water sampler	Each cruise	all
pH	all	water sampler	Each cruise	all
Dissolved Oxygen	5,20,45,bottom	water sampler	Each cruise	all
Total Alkalinity	5,20,45,bottom	water sampler	Each cruise	all
Chloride	5,20,45,bottom	water sampler	Seasonally	all
Sulfite	5,20,45,bottom	water sampler	Seasonally	all
Ammonia-N	0,5,20,45,bottom	water sampler	Each cruise	all
Nitrate-N	0,5,20,45,bottom	water sampler	Each cruise	all
Organic-N	0,5,20,45,bottom	water sampler	Each cruise	all
Soluble Reactive P	0,5,20,45,bottom	water sampler	Each cruise	all
Total P	0,5,20,45,bottom	water sampler	Each cruise	all
Reactive Silica	0,5,20,45,bottom	water sampler	Each cruise	all
Phenols	0,5,20,bottom	water sampler	Each cruise	nearshore
Cyanide	0,5,20,bottom	water sampler	Each cruise	nearshore
Focal Califorms	0,5,10,20,bottom	Bacteria	Each cruise	nearshore
Focal Streptococci	0,5,10,20,bottom	Bacteria	Each cruise	nearshore
Pseudomonas aeruginosa	0,5,10,20,bottom	Bacteria	Each cruise	nearshore
Chlorophyll a	all	water sampler	Each cruise	all
Phaeophytin	all	water sampler	Each cruise	all
Phytoplankton	0,4,10,20	water sampler	Each cruise	all
Zooplankton	0-near bottom	net	Each cruise	all
Benthos	bottom	PONAR grab	Seasonally	all
Others[2]				
Oils[3]	Observation of surface oil and sedimential oil		Each cruise	all
Cadmium	5,20,bottom	water sampler and grab	Once/year	all
Chromium	5,20,bottom	" "	Once/year	all
Copper	5,20,bottom	" "	Once/year	all
Lead	5,20,bottom	" "	Once/year	all
Mercury	5,20,bottom	" "	Once/year	all
Nickel	5,20,bottom	" "	Once/year	all
Zinc	5,20,bottom	" "	Once/year	all
Phthalic acid esters	5,20,bottom	" "	Once/year	nearshore
Arsenic	5,20,bottom	" "	Once/year	all
Fluoride	5,20,bottom	" "	Once/year	all
Radioactivity	5,20,bottom	" "	Once/year	all

*0,5,10,20,20,45,65, near bottom

[2]Sampled more frequently if appreciable concentrations are found.

[3]Samples should be taken whenever oil is observed.

Water Intakes--Because of the amount of data which they provide, water intakes should be sampled in the surveillance program.

As part of a Sea Grant project, the University of Wisconsin-Milwaukee sampled intakes at Whitefish Bay, Milwaukee, Chicago, Gary and Grand Rapids, to determine which ones might be useful for sampling the lake. Of these, only the Linnwood Avenue intake for Milwaukee was taking in water similar in characteristics to that collected 10 miles offshore. The other intakes were all representative of water found within 2-3 miles of shore.

The sampling program used by the University of Wisconsin consisted of three sampling transects, one directly over the intake and two miles to either side of the intake. Samples were taken at distances of 1/4, 1/2, 3/4, 1, 1-1/2, 2, 3, 5, 10 miles on the two-side transects and at the same distances over the intake except that a sample was taken at 15 miles instead of 10 miles. As part of the whole-lake study, a similar sampling program is required to establish which intakes would be useful. There are a number of intakes situated far enough and deep enough in the lake to be potentially useful for monitoring. Other criteria to consider are the types of data collected and the number of years on record. Potential municipal intakes which should be studied are: Two Rivers, Wis.; Manitowoc, Wis.; Kenosha, Wis.; Waukegan, Ill.; Great Lakes, Ill.; Hammond, Ind.; Whiting, Ind.; East Chicago, Ind.; Michigan City, Ind.; South Haven, Mich.; Holland, Mich.; Muskegon, Mich.; Traverse City, Mich.

Initially the Milwaukee intake can be used as being representative of open lake conditions. The Grand Rapids, Chicago (68th St.), and Gary intakes represent nearshore conditions. The Chicago (68th St.), Hammond, East Chicago, Gary, and Whiting intakes are recommended as part of the nearshore intensive study of the Calumet area.

Data from analyses made at the intakes should be used carefully since an evaluation of data from the five intakes studied by Wisconsin showed that results among laboratories ranged from only 38 to 78 percent agreement. Methods and procedures used at the intakes should be evaluated and checked periodically.

Monitoring of Critical Nearshore Areas

The Surveillance Subcommittee has identified seven nearshore problem areas in Lake Michigan: Green Bay, Little Bay de Noc, Milwaukee, Calumet area, Grand River, Manistee, and Traverse City. Three of these, Green Bay, Calumet area and Milwaukee, are especially critical, because of the magnitude of the problem and the obvious effect on the lake. Consequently, intensive sampling programs to be carried out every three years have been developed for each of these areas.

Problems in the other areas are critical locally, but their impact on the lake is apparently not as great. Intensive studies are needed to determine exactly what their effect is.

Green Bay--A number of studies have been made on Green Bay, especially since the early 1960s. Since conditions change rapidly in the southern bay depending on inflow of the Fox River, currents, and disturbance of sediments by vertical mixing, sampling stations should be selected because they are representative of an area and not because they have been visited previously. Past sampling programs had enough stations to facilitate plotting the contoured distribution of various parameters as a basis for comparison.

Thirty-eight stations are proposed for Green Bay, the majority of which are located in the southern part of the bay (Table 5, Figure 2). Other stations are situated off of tributaries, near Sturgeon Bay, Little Bay de Noc, and Big Bay de Noc. Table 6 shows the parameters which should be analyzed, depth distribution and frequency of sampling. Vertical tows with number 6 and 20 mesh nets should be made for zooplankton. Three benthos samples should be collected at each station. A sediment subsample should be preserved for analysis for particle size, organic content, oils, and heavy metals.

The stations should be sampled twice monthly in May, June, July, August, September, and once in November and April. Sampling should be conducted through the ice, if possible, in February, especially in southern Green Bay, to determine the extent of oxygen depletion and associated release of some chemicals from the sediments. It is likely that Fox River water will accumulate under the ice and concentrations of other chemicals may increase.

Municipal water intakes at Gladstone, Michigan; Escanaba, Michigan; and Marinette, Wisconsin, should be studied, as well as those in the lake proper, to determine their usefulness for monitoring.

Milwaukee Harbor Area--The Great Lakes and Illinois River Basin Project (FWPCA 1966) made the most intensive study of the Milwaukee Harbor and adjacent lake area in 1962 and 1963. Almost 100 sampling stations were established and a wide range of water quality measurements were made. Subsequent studies have included as many or more stations in the harbor, but measured a limited number of parameters. Review of the FWPCA and other studies indicated that sampling fewer stations does not seriously affect the survey's quality. Consequently, 30 of the FWPCA stations have been selected for monitoring this area (Figure 3).

All samples should be taken at the surface, two metres and near the bottom in the harbor, while in the lake they should be at depths of 0, 5, 10 m, and near the bottom, depth permitting. Parameters and frequency and extent of sampling are presented in Table 6.

The stations should be sampled weekly in April, July, October and January, to provide information on the short-term and seasonal variability in concentration and distribution of most of the parameters. Benthos should be sampled once each season.

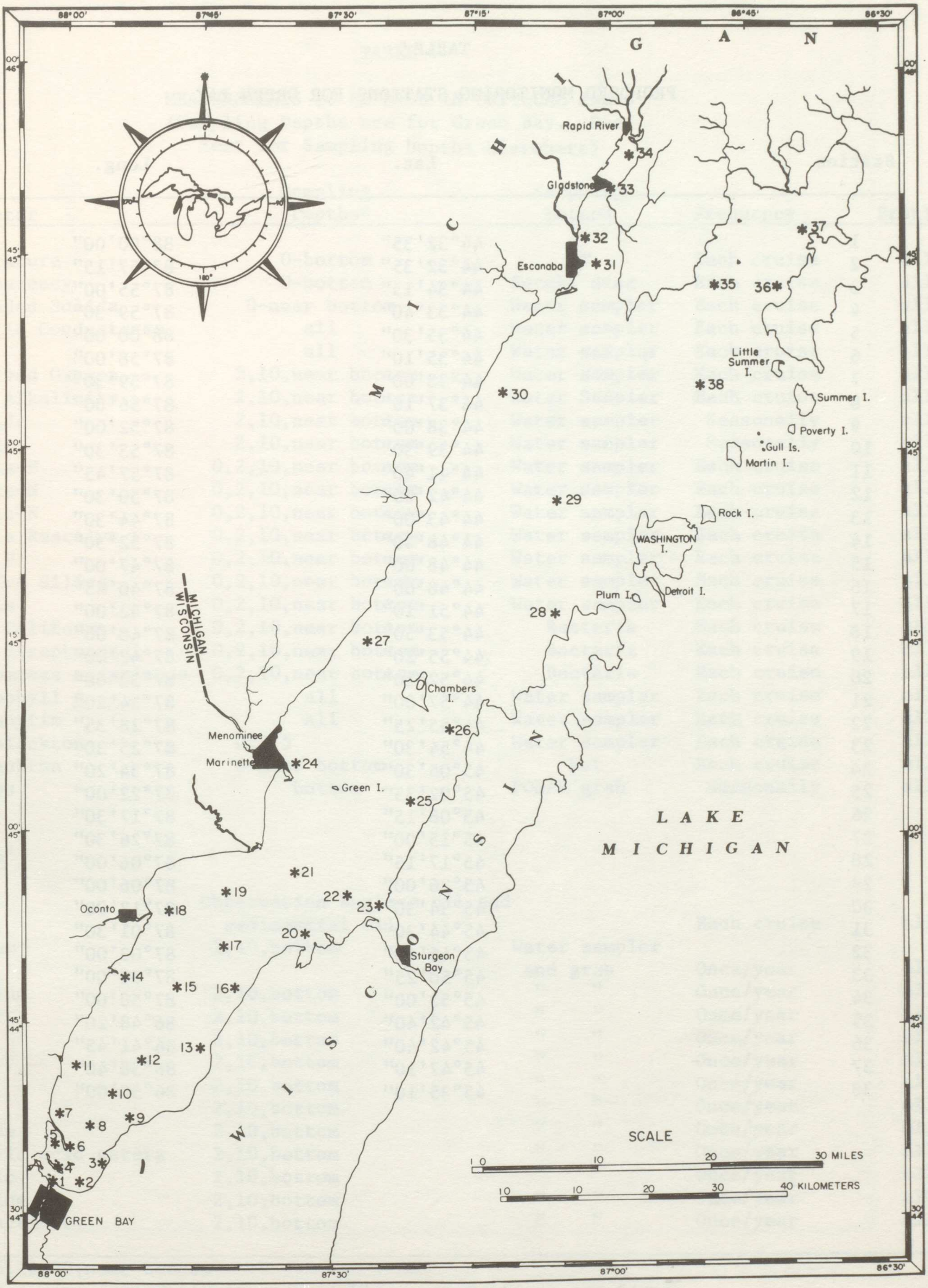

Figure 2 - Proposed monitoring stations for Green Bay

TABLE 5

PROPOSED MONITORING STATIONS FOR GREEN BAY

Station	Lat.	Long.
1	44°32'35"	88°00'00"
2	44°32'35"	87°57'15"
3	44°34'15"	87°55'00"
4	44°33'40"	87°59'30"
5	44°35'30"	88°00'00"
6	44°35'10"	87°58'00"
7	44°38'00"	87°59'30"
8	44°37'10"	87°56'00"
9	44°38'00"	87°52'00"
10	44°39'30"	87°53'30"
11	44°41'40"	87°57'45"
12	44°42'00"	87°50'30"
13	44°43'00"	87°44'30"
14	44°48'40"	87°52'30"
15	44°48'00"	87°47'00"
16	44°48'00"	87°40'45"
17	44°51'10"	87°42'00"
18	44°53'50"	87°48'00"
19	44°55'20"	87°42'00"
20	44°52'10"	87°33'00"
21	44°57'00"	87°34'20"
22	44°55'25"	87°28'35"
23	44°54'30"	87°25'30"
24	45°05'30"	87°34'20"
25	45°02'35"	87°22'00"
26	45°08'15"	87°17'30"
27	45°15'00"	87°26'30"
28	45°17'15"	87°06'00"
29	45°26'00"	87°06'00"
30	45°34'30"	87°12'00"
31	45°44'30"	87°01'30"
32	45°46'40"	87°03'00"
33	45°50'25"	87°00'00"
34	45°53'00"	87°58'00"
35	45°42'40"	86°48'20"
36	45°42'40"	86°41'45"
37	45°47'10"	86°38'40"
38	45°35'10"	86°50'00"

TABLE 6

MEASUREMENTS TO BE MADE IN CRITICAL AREAS
(Sampling Depths are for Green Bay. See Text for Sampling Depths Elsewhere)

Parameter	Sampling Depths*	Sampling Method	Frequency	Station
Temperature	0-bottom	BT	Each cruise	all
Transparency	0-bottom	Secchi disc	Each cruise	all
Suspended Solids	0-near bottom	Water sampler	Each cruise	all
Specific Conductance	all	Water sampler	Each cruise	all
pH	all	Water sampler	Each cruise	all
Dissolved Oxygen	2,10,near bottom	Water sampler	Each cruise	all
Total Alkalinity	2,10,near bottom	Water Sampler	Each cruise	all
Chloride	2,10,near bottom	Water sampler	Seasonally	all
Sulfate	2,10,near bottom	Water sampler	Seasonally	all
Ammonia-N	0,2,10,near bottom	Water sampler	Each cruise	all
Nitrate-N	0,2,10,near bottom	Water sampler	Each cruise	all
Organic-N	0,2,10,near bottom	Water sampler	Each cruise	all
Soluble Reactive P	0,2,10,near bottom	Water sampler	Each cruise	all
Total P	0,2,10,near bottom	Water sampler	Each cruise	all
Reactive Silica	0,2,10,near bottom	Water sampler	Each cruise	all
Phenols	0,2,10,near bottom	Water sampler	Each cruise	all
Fecal Coliforms	0,2,10,near bottom	Bacteria	Each cruise	all
Fecal Streptococci	0,2,10,near bottom	Bacteria	Each cruise	all
Pseudomonas aeruginosa	0,2,10,near bottom	Bacteria	Each cruise	all
Chlorophyll <u>a</u>	all	Water sampler	Each cruise	all
Phaeophytim	all	Water sampler	Each cruise	all
Phytoplankton	0,2,5	Water sampler	Each cruise	all
Zooplankton	0-near bottom	Net	Each cruise	all
Benthos	bottom	PONAR grab	Seasonally	all
<u>Others</u>[2]				
Oils[3]	Observation surface oil and sedimential oil		Each cruise	all
Cadmium	2,10,bottom	Water sampler and grab	Once/year	all
Chromium	2,10,bottom	" "	Once/year	all
Copper	2,10,bottom	" "	Once/year	all
Lead	2,10,bottom	" "	Once/year	all
Mercury	2,10,bottom	" "	Once/year	all
Nickel	2,10,bottom	" "	Once/year	all
Zinc	2,10,bottom	" "	Once/year	all
Cyanide	2,10,bottom	" "	Once/year	all
Phthalic acid esters	2,10,bottom	" "	Once/year	all
Arsenic	2,10,bottom	" "	Once/year	all
Fluoride	2,10,bottom	" "	Once/year	all
Radioactivity	2,10,bottom	" "	Once/year	all

*0,2,5,10,20,near bottom
[2]Sampled more frequently if appreciable concentrations are found.
[3]Samples should be taken whenever oil is observed.

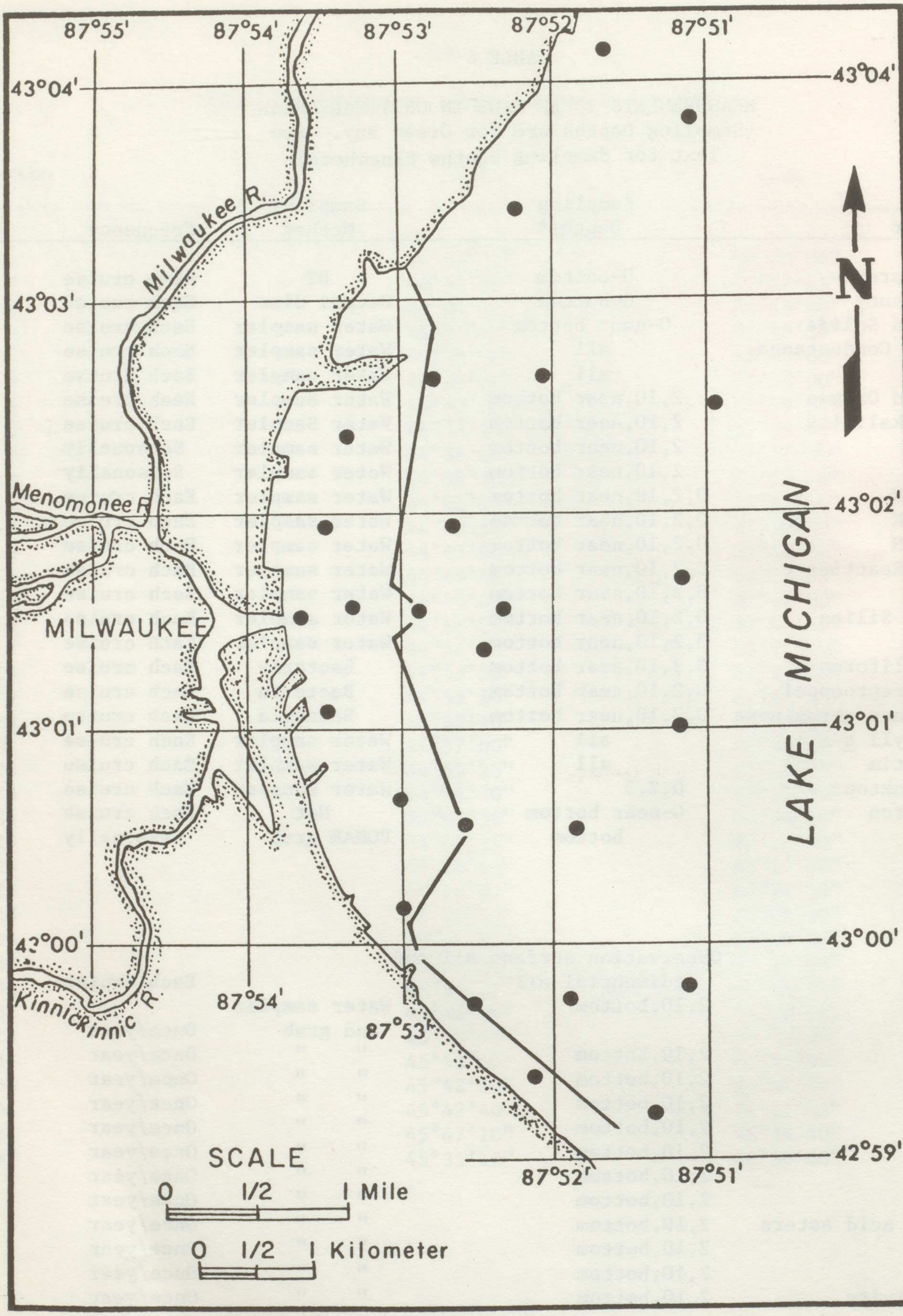

Figure 3 - Proposed sampling locations for Milwaukee area (based on 1962 FWPCA stations)

Calumet Area--The Calumet area extends from the vicinity of the 68th Street crib of the Chicago Water Department to Burns Ditch in Indiana. The Illinois Institute of Technology Research Institute (IITRI) recently reviewed data available on this area and conducted sampling as part of the EPA Great Lakes Initiative Contract Program (Snow 1974).

The sampling locations recommended for a monitoring program include those used by IITRI (Table 7) and 11 additional South Water Filtration Plant Radial Survey stations (1J, 2J, 3J, 3F, 2F, 1F, 2H, 4H, 6H, 4I, 6I, Figure 4). Additional stations should be established near the breakwall at United States Steel Gary Works and at 1/4, 1/2, 1, 2, 3 miles north off Burns Ditch.

To determine if these intakes are representative of the area, samples should be taken at the intakes and at distances of 1/4 and 1/2 miles on either side on two transects passing the intakes and at right angles to each other. Measurements should be made for conductivity, chloride, and total phosphorus. If these intakes are representative, they should be sampled weekly on a continuing basis.

All samples should be taken at the surface, 2, 5, 10 m, and near the bottom and analyzed for the parameters in Table 6. The stations should be sampled weekly in April, July, October and January.

Persistent Contaminants in Fish

Lake Michigan fish continue to be contaminanted with chlorinated hydrocarbons and heavy metals. Levels of PCB in fish have been in excess of the U.S. Federal Drug Administration standard of 5 µg/gm. A number of agencies have produced data on these contaminants and the Great Lakes Fishery Laboratory initiated annual monitoring in 1969. It is vital that a monitoring program should continue and include analyses for arsenic, cadmium, chromium, copper, mercury, polychlorinated biphenyls, DDT and dieldrin.

If practical, fish caught with experimental trawls and nets should be sampled. Otherwise fish obtained commercially can be used. Fish should be collected off Milwaukee, the St. Joseph and Grand rivers, in Grand Traverse Bay, Green Bay, the Calumet area and along the Door Penninsula.

Special Studies

In addition to the regular monitoring program, special studies should be conducted to determine the distribution of *Cladophora, Bangia, Mysis relicta* and the effects of shoreline erosion, surface runoff and ground water on water quality in Lake Michigan.

A.M. Beeton

TABLE 7

WATER SAMPLING STATIONS, CALUMET AREA

		Lat.	Long.
CAL 17	68th St. Crib	41°41'11"	87°32'22.5"
CAL 13	Calumet Harbor	41°44'06"	87°31'16"
CAL 11	Calumet R. mouth, north pier head light	41°44'02"	87°31'45"
CAL 06	Indiana Harbor breakwater inner NE light	41°40'28"	87°26'20"
CAL 16	Hammond water intake	41°42'14"	87°29'49"
CAL 15	East Chicago water intake	41°39'45"	87°24'18"
CAL 14	Gary West water intake	41°38'27"	87°20'28"
LM 47A	Whiting water intake (American Oil intake)	41°40'50"	87°28'22"
SWFP 4J	Chicago Water Dept. open lake	41°43'28"	87°28'17"
SWFP 5J		41°42'26"	87°26'31"
SWFP 6J		41°41'23"	87°24'45"
SWFP 7J		41°40'21"	87°23'00"
LM 70	EPA open lake stations	41°41'35"	87°27'15"
LM 68		41°41'28"	87°25'42"
LM 80		41°42'05"	87°24'55"
LM 102		41°43'25"	87°23'15"
IHC 3S	Indiana Harbor Canal at Columbus Drive	41°38'20.7"	87°28'16.8"

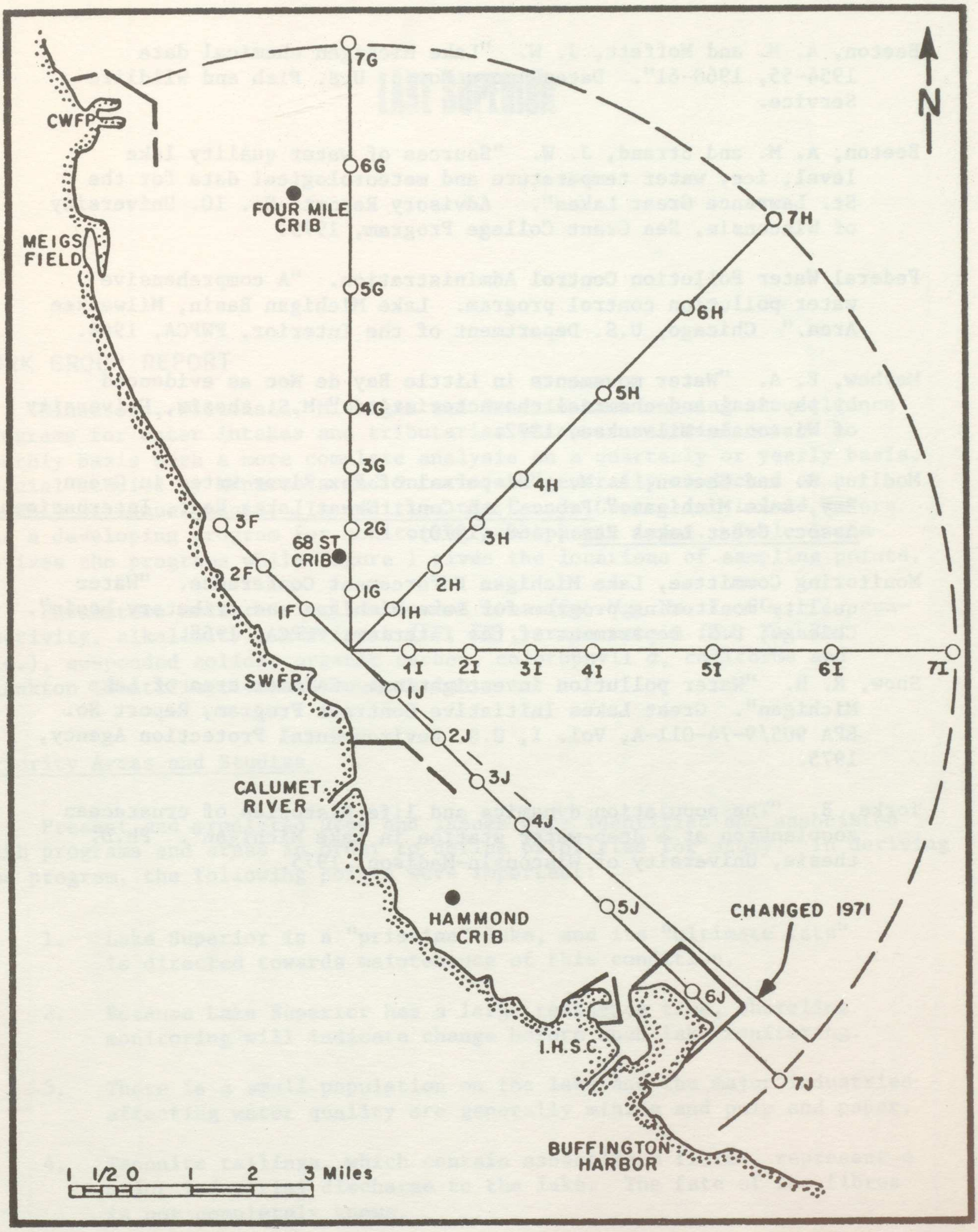

Figure 4 - South water filtration plant radial survey

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LAKE SUPERIOR

WORK GROUP REPORT

Minnesota, Wisconsin, Michigan and Ontario have ongoing surveillance programs for water intakes and tributaries which are carried out on a monthly basis with a more complete analysis on a quarterly or yearly basis. Special studies by Minnesota and Ontario are generally conducted on a monthly or annual basis. In addition the Canada Centre for Inland Waters has a developing program for monitoring atmospheric input. Table 1 summarizes the programs while Figure 1 gives the locations of sampling points.

Parameters measured include common ions (Ca, Mg, Na, K, SO_4, Cl, conductivity, alkalinity), nutrients (ΣP, ΣN), trace metals (Cu, Fe, Zn, etc.), suspended solids, organic carbon, chlorophyll *a*, coliforms and plankton identification and enumeration.

Priority Areas and Studies

Present and predicted uses and issues were identified and associated with programs and areas in order to define priorities for study. In deriving the program, the following points were important:

1. Lake Superior is a "pristine" lake, and its "ultimate fate" is directed towards maintenance of this condition.

2. Because Lake Superior has a large residence time, shoreline monitoring will indicate change before open lake monitoring.

3. There is a small population on the lake and the major industries affecting water quality are generally mining and pulp and paper.

4. Taconite tailings, which contain asbestiform fibres, represent a major industrial discharge to the lake. The fate of the fibres is not completely known.

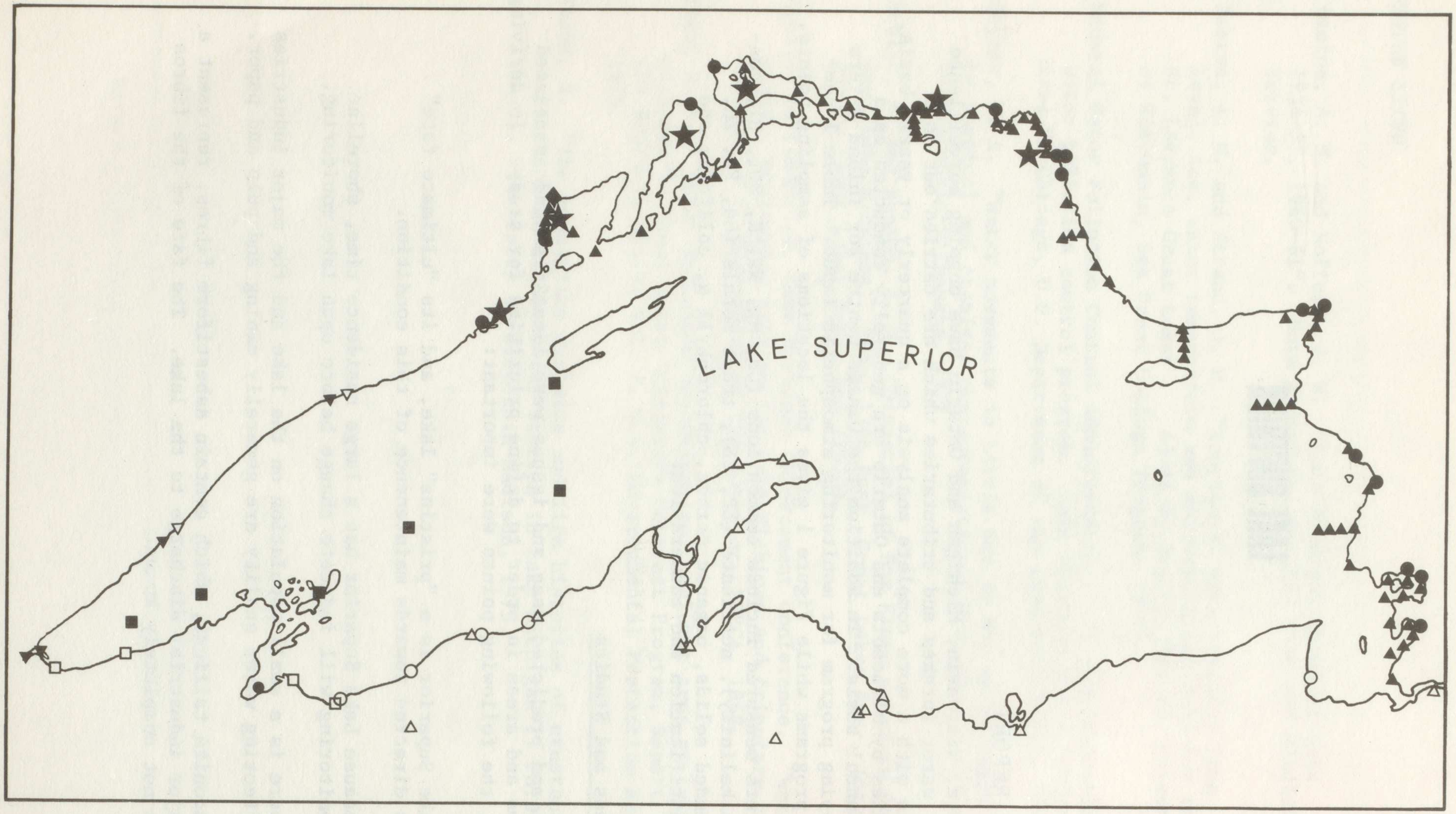

Figure 1 - Sampling points for surveillance programs

TABLE 1

SURVEILLANCE PROGRAMS FOR INTAKES AND TRIBUTARIES

PROGRAM	NO. STNS.	SAMPLING FREQUENCY	PARAMETERS	AGENCY	MAP SYMBOL	COMMENTS
Intake	2	Monthly	T, Total Coliforms, Fecal Coliforms, Total Solids, S.S., Turbidity, Total Hardness, Total Alk., Cl, S. Conduct., Ca, Na, Cu, Cd, Ni, Zn, Pb, Fe, Mn, K, F, SO_4, pH, TP, Organic N, Ammonia N., Nitrite N., Nitrate N., Toc., BOD (5-day), D.O.	Minnesota Pollution Control Administration (M.P.C.A.)	▽	
		Quarterly (Supplemental)	Hg, Se, As, Fecal Streptococci			
Tributary	1		See parameters for intake above	M.P.C.A.	▼	
Tributary	3	Monthly	Biological, Physical, Chemical. Biology=zooplankton, phytoplankton, periphyton, benthos	M.P.C.A.	▼	
Special Studies	6	Annual (~10 yrs. duration)	See M.P.C.A. water intake program, delete bacteriology, add Cr	M.P.C.A.	■	
Intake	1	Monthly & Quarterly	Total Alk., Fecal Coliform, 5-day BOD, Cl, Colour, Total Hardness, Total Residue Volatile Non-filterable Residue, Total Non-filterable Residue, D.O., pH, T	Wisconsin Department of Natural Resources (W.D.N.R.)	●	

Table 1 (cont'd)

PROGRAM	NO. STNS.	SAMPLING FREQUENCY	PARAMETERS	AGENCY	MAP SYMBOL	COMMENTS
Tributary	4	Monthly Quarterly	As for intake above T.O.N., NH_3, NO_3, TP, Soluble P	W.D.N.R. W.D.N.R.	□	
Intake	14	Annual	T, pH, Alkalinity, Hardness, Conduct., Colour, T.O.C., NO_3+NO_2, NH_3, Organic N, TP, Soluble Ortho-P, Total Coliform, Fecal Coliform, Fecal Strep., Total Solids, TDS, SS, Suspended Volatile Solids, TCa, TMg, TNa, TK, SO_4, Cl, SiO_2, Fe dissolved, Mn dissolved, Mn dissolved, Ni dis., Cu dis., Zn dis., Pb dis. Cd dis., Cr dis., THg, Ag dis., Se dis., Ba dis., phenol As, Cyanide, F, endrin, lindane, chlordane, heptachlor, heptachlor epoxide	Michigan Department of Natural Resources (M.D.N.R.)	△	
Tributary	7	Monthly	D.O., B.O.D., C.O.D., T, pH, alkalinity, hardness, conduct., turbidity, T.O.C., chlorophyll a (at selected stations), NO_3+NO_2, NH_3, organic N, total P, soluble ortho-P, fecal coliform, (cont'd)	M.D.N.R.	○	

Table 1 (cont'd)

PROGRAM	NO. STNS.	SAMPLING FREQUENCY	PARAMETERS	AGENCY	MAP SYMBOL	COMMENTS
			(cont'd) fecal strep., total solids, T.D.S., S.S., Suspended volatile solids, Cl, SiO_2.			
		Annual	TCa, TMg, TNa, TK, SO_4, TMn, Mn dissolved, Ni dis., Cu dis., Zn dis., Pb dis., Cd dis., Cr dis., THg, Ag dis., Se dis., phenol, As, cyanide, F, flow,	M.D.N.R.	○	
		Quarterly	total gamma (at selected stations)			
<u>Intake</u>	2	Monthly	phytoplankton, total and filtered reactive P, TKN, NH_3, NO_3, chlorophyll <u>a</u>, Cl, dissolved reactive SiO_4	Ontario Ministry of the Environment (M.O.E.)	◆	
<u>Tributary</u>	17	Monthly and 2X during spring runoff	Flow, TFe, pH, T, Total and fecal coliform, D.O., $B.O.D._5$, SiO_2, Conduct./ TDS, turbidity, TP, soluble reactive P, NH_3, Total Kjeldahl (N), NO_3, NO_2, S.S., TOC, Cl, (oil phenol, C.O.D. - only in problem areas)	M.O.E.	●	

Table 1 (cont'd)

PROGRAM	NO. STNS.	SAMPLING FREQUENCY	PARAMETERS	AGENCY	MAP SYMBOL	COMMENTS
		Quarterly and once in spring runoff	Cd, Cu, Pb, Ni, Zn, As, Hg, SO_4, pesticides (only in problem areas), PCB's, Cr	M.O.E.		
Special Studies (Thunder Bay)	27	Monthly	Parameters not specified	M.O.E.	★	
Nipigon Bay, Jackfish Bay, Peninsula Harbour, Black Bay, Pine Bay				M.O.E.	★	
Special Studies (nearshore)	67	3X per year	T, pH, Alkalinity, D.O., Secchi disc, turbidity, specific conductivity, dissolved solids, Total and soluble P as P, Total Kjeldahl N as N, NH_3, NO_3, dissolved SiO_2, Cl, SO_4, TFe, phenols, chlorophyll a and b, total and fecal coliform, fecal streptococci	M.O.E.	▲	

Table 1 (cont'd)

PROGRAM	NO. STNS.	SAMPLING FREQUENCY	PARAMETERS	AGENCY	MAP SYMBOL	COMMENTS
Special Studies	50	3 cruises once every 5 years	Total, P, SO_4, conduct., major ions, toxic materials 10 samples for organics	Canada Centre for Inland Waters (C.C.I.W.)		Up to 50 intensive stations every 5 years or more. Subject to change in planning stage.
Atmospheric Precipitation	5	Monthly	Nutrients, common ions, trace metals	C.C.I.W.		Locations to be determined.

Apparent issues and uses pertinent to Lake Superior water quality are:

Mining - Extraction: taconite, copper (Michigan), Marathon, Minnesota, nickel
- Smelters (air input): Wawa, Manitoba
- Future lake mining

Pulp and Paper - Thunder Bay, Marathon, Duluth, Terrace Bay

Fisheries - fish tainting
- lamprey control
- contaminants

Spills (ship)

Water Supply - Thunder Bay, Duluth (taconite, turbidity)

Eutrophication - Nearshore Thunder Bay, Duluth

Power

Recreation

Discussion of these items led to specific problem areas and surveillance programs involving intakes, nearshore, tributaries, on-going monitoring and intake studies, open lake, biota, and atmospheric input:

Problem Areas

1. Thunder Bay
2. Duluth-Superior
3. Silver Bay
4. Wawa
5. Marathon
6. Keewenaw
7. Nipigon Bay
8. Carp River
9. Terrace Bay
10. Red Clay Region

Surveillance Programs

I. Intakes:

1. 4 stations monthly (suspended solids, turbidity, coliforms, chlorophyll *a*, species)

2. 10 stations monthly a) turbidity, biology, nutrients
   b) metals

II. Nearshore:

1. Water quality - 120 stations

2. Biology - 60 stations - stonefly (1/5 years)
   - *Cladophora*
   - clams
   - sediments

III. Tributaries:

1. 12 tributaries - 15/year complete suite

2. 26 tributaries - 26/year complete suite

IV. Monitoring and Intake:

Sites presently being analyzed.

V. Open Lake:

Three cruises once every five years - intensive

VI. Biota (for chemicals and metals):

1. Fish

2. Birds

VII. Atmospheric Input:

5 stations

A priority listing of the above topics was then developed.

	Highest Priority	High Priority	Priority
Problem Areas			
1.	x	x	x
2.	x	x	x
3.	x	x	x
4.		x	x
5.		x	x
6.			x
7.			x
8.			x
9.			x
10.			x
I. Intakes			
1.	x	x	x
2.		x	x
3.			x
II. Nearshore			
1.			x
2.	x	x	x
III. Tributaries			
1.	x	x	x
2.		x	x
IV. Monitoring and Intake	x	x	x
V. Open Lake		x	x
VI. Biota			
1.	x	x	x
2.		x	x
3.		x	x
VII. Atmospheric Input	x	x	x

COMMENTS

J. R. KRAMER

As pointed out earlier, surveillance must concentrate in the nearshore zone to predict changes that will affect the lake on a long-term scale. This necessity means that agencies of Minnesota, Michigan, Wisconsin and Ontario will be carrying out programs for all practical purposes independently.

Because sampling techniques and analytical procedures are not always uniform and there has been no design for inter-agency comparability, I would propose that the states and province sample their neighbors' intakes and tributaries at least once a year. Hence Ontario would obtain additional samples in Michigan and Minnesota, Minnesota in Ontario and Wisconsin, etc. Results of the duplicate samplings could be compared for sampling and/or analytical bias.

For future use and checking of data, a large volume sample bank should be set up with ten gallon raw samples at 4°C, acidified samples (pH 2) and filtered samples. One agency should be designated as curator of the samples.

Much more detail should be given to the solid (sediment) phase in which trace metals and nutrients concentrate, and most organic reactions, for example, methylation, occur. No agency has proposed to investigate the distribution of trace metals and nutrients between the aqueous and solid phase. Yet most of the real variation in results will be due to the amount of contamination associated with the sediment as opposed to that associated with the water.

Data should be available at one source for each agency, preferably in original records and computer compatible form. It cannot be expected that any one of the individual agencies would be made responsible for a critical review of all of the data. Instead analysis and critique should be carried out by the International Joint Commission under contract every one or two years. Also, data collected to date should be analyzed in terms of seasonal and long-term trends, multi-variate statistical analysis, and calculation of chemical and biological parameters (saturation, diversity, species appearance, etc.). Other data from the U.S. Geological Survey and the Water Survey of Canada should be considered in this study.

Quality data are required to assess long-term trends but this is not always possible when scientifically qualified personnel remain in Toronto, Minneapolis, Madison and East Lansing and assign technicians, high school students and water plant operators to do the sampling. Most agency programs follow this procedure. Moving scientific personnel as well as all or part of the laboratory to the field would improve results. Until as much emphasis is placed upon sampling as upon analytical control, poor quality data can be anticipated.

Taconite tailings, the one major input by man to Western Lake Superior, need long-term research and surveillance to determine their distribution and impact.

Finally, what one surveys for should depend upon the questions one wishes to answer. A good exercise would be to obtain questions about Lake Superior and determine if the proposed program will provide the answers. Two possible questions are:

1. Can subtle but long-term changes in concentrations of variable water quality parameters that will bring on eutrophication or toxic conditions be defined with the present surveillance system?

2. What matrix parameters, including time and space, define the water quality of Lake Superior or a portion thereof?

The first question can be answered with the proposed surveillance plan if inter-agency and intra-agency sampling and analytical control can be built into it. The second question can only be answered if modellers and physical limnologists are brought into the surveillance program.

FISH CONTAMINANTS

Introduction

Before settlement by European man, most waters of the Great Lakes had relatively abundant populations of fish, characteristic of large lakes with cold, clear water together with high quality spawning and nursery areas in nearshore and tributary waters. The gradual growth of human populations around the Great Lakes, however, has ultimately been accompanied by progressive deterioration in environmental quality including drastic changes in both numbers and species composition of fish stocks.

Peak fishery production occurred between 1900 and 1910 with annual production averaging 133 million pounds valued at 21 million dollars (at 1970 prices). The annual commercial catch during 1961-70, however, averaged only 110 million pounds, worth only 14 million dollars in 1970. Recreational fishing continues to expand with Ontario anglers spending 57.3 million dollars in 1970 on Great Lakes fishing trips. Comparative data are not available for the United States, but expenditures are probably four to five times as great.

The many factors contributing to the changes in the Great Lakes have been reviewed extensively in the literature. The best documented examples (as well as some of the most extreme) of man's effect on North Temperate Zone fish stocks are probably those reviewed in the Symposium on Salmonid Communities in Oligotrophic Lakes (Regier and Loftus, 1972). Sea lamprey predation, introduction of new species, selective overfishing, eutrophication and habitat destruction are all causes of the depreciation in Great Lakes stocks (Christie, 1974), although the exact ways in which these have affected individual species or groups of species are not yet completely understood. Many of these stresses continue today and have been joined by more recent perturbations such as the discharge of heated effluents by thermal generating stations, destruction of young fish in pumping and cooling systems, extensive harbor dredging and spoils disposal and contamination by persistent toxic chemicals.

With the trend of continuing industrial expansion and development of new technology, the contaminants issue may yet be the most serious problem to face the Great Lakes. It has been estimated that some 600 new chemicals are produced or used annually in the Great Lakes Basin (SPOF, 1974). Many of these are toxic and have already been detected in the lake environment; several have had serious impact on Great Lakes fisheries. Of major concern over the past decade have been the organochlorine insecticides (specifically DDT, its metabolites and dieldrin), mercury and PCBs, but the list also includes chlordane, HCB, pthalates, arsenic, cadmium, chromium, copper, zinc and MIREX found in Great Lakes fish by several investigators. The presence of these "lesser" contaminants does not represent a problem as such, but it does suggest a strong need for continued surveillance of known or potential contaminants, and more aggressive regulatory controls on the loss of contaminants to the lakes. The contaminants problem is really a double-barrelled one in that they not only affect the utilization of fish, but probably also play a subtle role in their growth, reproduction, survival and long term potential (Willford, 1975). More recently, the occurrence of α-pyrenes and other polynuclear aromatic compounds in herring gulls has created serious concern largely because of their carcinogenic effects. New discoveries relating to incidental exposure to toxicants and long term disease are revealed daily and although there have been no reported effects on human health from toxic chemical contamination of the Great Lakes, we cannot afford to forget the potential devastating effects of these compounds as observed at Minamata and Itai Itai in Japan. Already, concentrations of mercury, DDT, PCBs, for example, in some lake sediments and biota have led to implementation of control programs for these substances. Mercury contamination in the past has resulted in sharp curtailment of sport and commercial fisheries in lakes St. Clair and Erie and in the northwestern region of the province of Ontario. As a result, in 1971, 240 commercial fishermen (representing about 12% of the total) were idled, four million pounds of fish destroyed and over one million dollars in revenue lost (Adams, 1972). The smelt and eel commercial fishery and the coho salmon sport fishery in Lake Ontario are now threatened by high levels of PCBs. In the United States, the Environmental Protection Agency announced on January 30, 1975 that a ban on the interstate sale of chubs, coho salmon and lake trout from Lake Michigan would be imposed if PCB levels had not declined by spring sampling.

Fish <u>are</u> a basic source of food for man. Most harvested fish, whether taken by commercial or sport fisherman, eventually end up on the dinner plate. Emphasis in the past has been placed on the human health implications of excessive residues in fish with little consideration given to the effects of contaminants on the fish or the rest of the aquatic ecosystem. While the importance of the human health aspect cannot be underestimated, it is now recognized that fish tend to be integrators of aquatic systems and as such, provide one of the best indicators of the health of those systems. Much of the rationale of the Federal-Provincial Strategic Planning exercise for the management of Ontario fisheries (SPOF, 1974) has been based on this premise and it is equally applicable for development of the contaminants surveillance program.

Basic Design Considerations

Assessment of water quality in the Great Lakes has been based largely on measurements of physical and chemical characteristics which have certain spatial and temporal limitations. Some pollutants may be present in the water in such low concentrations that their detection with standard analytical procedures is not adequate for the prediction of possible deleterious effects on the system. Some components of the biota, however, are integrators and concentrators of pollutants and can be useful indicators of water quality. For many purposes water quality refers to the health of the water as a biological medium and it is sensible, therefore, to include biological measurements in a surveillance program.

There are many living organisms in the Great Lakes which are suitable for monitoring, but for economic reasons the number must be restricted. Fish are prime candidates for biological surveillance because of their commercial and recreational importance, their dominant position in the aquatic food web, their ability to concentrate and integrate certain contaminants and their responsiveness to other stresses imposed on aquatic ecosystems by man. Hence we are interested in the health of fish because they are one of the best indicators of the health of their environment.

There are other organisms, however, which should also be considered for contaminant monitoring. High lipid zooplankton or benthos may, in certain cases, be better indicators of lake conditions because of their short life cycles, sedentary nature, etc. For example, benthos may be the best indicator of local contamination. Therefore, the basic program should consider the sampling of other components and, at some point in interpretation, tying these data in with those collected on water quality. There is also a need to develop predictive capabilities from ongoing research into the toxicology and ecosystem metabolism of certain persistent contaminants.

The effects of thermal inputs on fish, particularly entrainment and impingement, should be assessed eventually. Due to financial limitations, however, the main thrust of this program is directed towards surveillance of contaminants.

Objectives

Contaminants can be monitored according to human health criteria or in relation to the health of the Great Lakes ecosystem. Assuming that the latter approach is preferable we outline the following objectives for a surveillance design:

1. To provide baseline information on contaminant levels in Great Lakes fish and other biota.

2. To provide trend information on contaminant residues in Great Lakes fish and other biota.

3. To locate and identify specific sources of contaminants.

4. To relate trends in contaminant concentrations to remedial action programs.

5. To study the lethal, sub-lethal and chronic effects of contaminants on fish.

6. To study the activity (incorporation, bio-accumulation, excretion, etc.) of persistent contaminants in the aquatic ecosystem.

7. To evaluate the pollution potential of materials which are not now considered to be contaminants but which enter the Great Lakes environment.

The development of predictive capabilities from this program has important management implications.

Tentative Fish Surveillance Program

A. Residue Monitoring

1. Sampling pattern for each lake

(a) Spatial

(i) Offshore - at least four stations which are representative of the offshore zone.

(ii) Nearshore - a representative nearshore area should be sampled for background levels.

- sampling of local impact areas and suspected local impact areas.

(b) Temporal - late summer and autumn

(i) Offshore - first two years - annually to obtain baseline information.

(ii) Nearshore - annually.

The above are suggested as minimum requirements. For the first year we should go with as many sampling sites as cost and time limitations permit for a reasonably good baseline data set. Although specific sampling stations in offshore areas are probably not warranted because of migratory behavior they would simplify data recording. For localized areas, benthos will probably provide a better picture than fish, although information on both benthos and fish would be useful for trends. Since we eventually hope to incorporate water quality data into the interpretation of contaminants it would be advantageous to take the water quality surveillance cruise station patterns into consideration.

Collections should be made at the same time each year to minimize biological effects. The autumn is suggested because of the availability of numbers and the likelihood of decreasing potential complications through shifts in body burdens of contaminants as a result of spawning (fall spawners excepted).

2. Species to be Sampled

In order to reduce variability it is desirable to monitor species which are representative of all the Great Lakes and are good concentrators of contaminants. The Coho salmon species is perhaps the best candidate at this time but its continued existence is dependent on stocking programs which may be altered because of high PCB levels. Smelt are also representative but are short-lived and do not bioconcentrate some contaminants. Lake trout are representative of the offshore zone in the three upper Great Lakes but not in lakes Ontario and Erie. Walleye are representative of the inshore zone and also bioconcentrate contaminants.

Willford in Michigan has used chub, lake trout and coho salmon as a forager, top predator and lake-wide integrator respectively. The reason for choosing representatives of different trophic levels is to obtain some idea of food chain accumulation *vs* direct uptake of contaminants. Niimi (Ontario Ministry of Natural Resources) has suggested smelt, yellow perch and coho salmon. Wisconsin Department of Natural Resources recommends carp, walleye and coho salmon. Pennsylvania (Erie County Department of Health) suggests yellow perch and salmonids. Ontario Ministry of the Environment is using minnows (spottail and emerald shiners) for assessment of local contamination.

There is evidence (Rosenberg 1975) that contaminant accumulation bears little relationship to "trophic level" and may be more closely related to lipid content and other factors. Life span, availability and migratory behavior must be considered in choosing candidates for monitoring. Coho salmon and smelt are good species to start with.

3. Sample Size

Because of the high cost of residue monitoring it is necessary to limit the number of samples to that which is sufficient for the detection of annual changes in levels. Because this information is not now available it will be necessary to determine adequate sample size for each species in each location. Extensive sampling in the first year will be required to establish statistically reliable sampling intensities. Willford has found that a 10% change in contaminant residue levels is statistically significant in a sample size of 40-60 individuals or 12 composites of 10 in the 240-280 mm size range. Zitko *et al.* (1974) indicated that significant differences between two successive years cannot be detected on small samples (n = 25) largely because of growth dilution effects. We feel that Willford's numbers represent a reasonable sample size to begin with. Variation within species should be determined for each species and the appropriate size range based on obtaining good detectable levels in analyses.

4. Reporting of Results

Residue results are presently reported as concentrations in whole fish, fillets, individual organs, etc. All of these categories are useful and no doubt will continue to be used for trend information. Whole fish are considered the best for trend analyses because seasonal variability is reduced.

5. Ancillary data

The following ancillary data should be reported: length, weight, sex, age, % lipid. For composite samples average length and weight are necessary. Composite samples of some size brackets should be separated according to sex.

6. Compounds to be Monitored

The number of compounds in the environment which could be monitored is large and the cost of an inclusive surveillance program would be prohibitive. The contaminants which are now presenting a problem will have to be monitored on a regular basis. Those to be considered initially would include DDT (and its metabolites), dieldrin, Hg, PCBs and some of the other polynuclear aromatic hydrocarbons (PAHs) that have been found in significant quantities in Great Lakes aquatic birds. The problem of deciding which additional chemicals to monitor is difficult. Possible new contaminants can be evaluated on the basis of (a) their potential toxicological effects on the aquatic ecosystem (particularly fish) and their implications for human health and (b) their manufacture and usage in the Great Lakes basin.

A list of chemicals in common use in the Great Lakes basin and loading data to the lakes would be a useful instrument for the prediction of potential problems.

7. Archives

The storage of biological samples for future analysis is desirable although the long term storage of biological material without loss of quality is difficult. New developments in preservation may be forthcoming but at present both freeze drying and normal freezing should be considered.

B. Status and Trends in Fish Communities

The long term responses of fish communities to stresses, such as enrichment and alteration of habitat, are important indicators of man's perturbations of aquatic ecosystems. Considerable information on fish population dynamics and community structure is presently being collected by provincial and state agencies and reported to the Great Lakes Fishery Commission. These data sets will be further enhanced when Ontario's lake assessment units and Fisheries Information System are operational. Although not included in the present design for fisheries surveillance, this information should be considered in the overall assessment of water quality in the Great Lakes.

1. The Role of the Great Lakes Fishery Commission

The commission came into being in October 1955, following ratification of a Convention on Great Lakes Fisheries between the United States and Canada. The geographic area of concern as described by the Convention consists of Lake Ontario (including the St. Lawrence River from Lake Ontario to the forty-fifth parallel of latitude), lakes Erie, St. Clair, Huron, Michigan and Superior, and their connecting channels.

The commission is composed of eight commissioners (four appointed by each government) and a secretariat. Their duties include developing and coordinating fishery research programs, advising the governments on measures to improve fisheries, and preparing and implementing measures to control the sea lamprey. To the fullest extent possible these duties are carried out by the fisheries agencies of the states involved in the convention area and the Province of Ontario. The cost of operating the Commission is shared by the two governments on the following basis: general research and administration - 50:50; sea lamprey control - U.S. 69: Canada 31. Almost 96.7% of Commission funds to date have been used in sea lamprey control.

In addition to the sea lamprey control program, the Commission has cooperated with fisheries agencies in programs to restore depleted fish stocks. To evaluate the need for and the results from restoration programs, the agencies have been involved in the monitoring of fish stocks. This status and trend information on the important commercial, sport and forage species in the Great Lakes is reported annually to the Commission. The authority for regulations and management remains with the eight states in the convention and the Province of Ontario. The Commission's role is to coordinate and document the data, distribute information, provide guidance and encourage cooperation among the agencies. The Commission also has a Fish Disease Control Committee responsible for surveillance of fish diseases.

2. Brief Summary of Activities of Great Lakes Fisheries Agencies

The main purpose of stock assessment by the agencies is to obtain information to assist in the management of fisheries resources. Specific objectives are:

(a) to assess rate of growth and year class structure of important species,

(b) to determine from trend information if exploitation is jeopardizing a population and, if necessary, to recommend alteration of regulations,

(c) to determine seasonal distribution and abundance of young fish to better evaluate environmental disturbances,

(d) to evaluate the need for and results from restoration programs,

(e) to assess impact of new introductions on existing populations and the potential of harvesting underutilized species,

(f) to estimate the damage from sea lamprey predation and the results of the control program.

The agencies obtain information on fish populations through specific sampling programs, collection and analyses of commercial catch records and a census of sport fisheries. Summaries of this information are reported annually to the Great Lakes Fishery Commission.

3. Liaison with the International Joint Commission (IJC)

The Great Lakes Fishery Commission has had considerable success in promoting interagency cooperation for the solving of mutual Great Lakes fisheries problems. Because the Commission recognizes the importance of the environment to the fisheries it wishes to develop closer liaison with agencies responsible for water quality and land use. To this end the Commission is eager to have a closer association with the IJC.

On the other hand, the IJC should recognize the important role that the Fishery Commission is playing in the coordination of fish surveillance in the Great Lakes. It is our view that, in the interest of obtaining trend information on a long term basis, the IJC should be willing to cooperate with and support the Fishery Commission.

J.H. Leach

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SHORELINES

The Nearshore Areas

The current and proposed sampling programs for the nearshore areas of all lakes are designed, as I believe they should be, primarily to keep problem areas under observation. At present, they produce little information on whole lake changes and in the lower lakes it is difficult to see how it can be otherwise.

I thought that the plan for Lake Michigan was the best thought out, or, at any rate, the best presented. I noted also that it included a proposal for regular sampling of the benthos. This should be a feature of the other programs since there is already a good deal of information on the effects of pollution on the nearshore benthos of the Great Lakes. Sampling the benthos is just as likely, or perhaps more so, to indicate changes as many of the other parameters to be measured. Furthermore, it would provide baseline data that we badly need. I strongly dispute the implications of some people at the meeting that this sort of approach is "research".

In lakes Superior and Huron, Georgian Bay and northern Lake Michigan, it seems to me that an opportunity is being missed to use possible changes in the nearshore region in the assessment of changes that may be occurring in the lake as a whole.

In those lakes there are long stretches of shore, far removed from areas under suspicion, facing the open water. They can, therefore, be reasonably supposed to reflect open-lake conditions in a nearshore context. Sampling some of them in conjunction with the five-year open-lake surveillance surveys would, then, add a new dimension to those surveys and enhance their value. This would be particularly true if specific attention were directed to the biota, which, as mentioned above, are likely to be among the first indicators of change. We know that the shallow water biota tend to differ from those of the open lake, and the same applies to some chemical parameters.

In the same way, the shallower waters around certain strategically placed islands should be used to add information to open-lake surveys. Thus, such places as Beaver Island, the islands in western Lake Erie and even the tips of long peninsulas, for example Long Point and the southern extremity of Prince Edward County, could be exploited to extend this approach into those lakes where a great deal of the nearshore zone is under some sort of suspicion.

The Onshore Areas

With the exception of *Cladophora*, which is discussed below, the very shallow onshore areas seem to be in danger of total neglect in the surveillance program. This has indeed been their fate in a long series of ecological studies conducted on the Great Lakes. Yet, where shores are exposed to the open lake, we find an almost maritime situation, with a continual swell of breaking waves and water movement. A riverine rather than a lacustrine habitat results, occupied by a great many running water organisms.

This is particularly true in lakes Superior and Huron, Georgian Bay, and perhaps also in northern Lake Michigan, although we have no certain information on this. The fauna include such organisms as stoneflies, mayflies and caddisflies, which react adversely to very small levels of organic and some types of industrial pollution. Monitoring this fauna as part of the regular long-term study of the upper lakes would, therefore, bring to the assessment of the condition of the Great Lakes themselves a means of using knowledge already available on the effects of pollution on the fauna of eroding substrata in running water. It is work that can very easily be done from the road rather than from a costly ship, by a couple of men with scuba gear and a suitable suction sampler that can be made for a few dollars. This should be done early in the season, soon after ice-out, to get the best results and, at least initially, more frequently than the intensive open-lake surveys.

It is also probable that the periphyton on the shore is also similar to that of running water particularly in its ability to grow *Cladophora*, and if this is generally true, there exists, once again, a great store of knowledge from the running water field that could be exploited. Indeed, this might enable the concept of onshore studies to be carried also into the lower lakes by means of the islands and peninsulas mentioned above. I was told during the workshop that a group from the University of Minnesota had performed some enrichment experiments on isolated areas of Lake Superior with particular respect to *Cladophora*. Such work, extended to other algae, such as diatoms and blue-greens, would provide valuable pointers to developments that might be watched for in periphyton composition.

Cladophora

The question of using some sort of index of growth of *Cladophora*, perhaps by remote sensing, was raised at the meeting, and it is also discussed at some length in "*Cladophora* in the Great Lakes" published by the Research Advisory Board. The red alga *Bangia*, which has spread in western Lake Erie, southern Lake Huron and Lake Michigan, was also mentioned as a possible indicator of eutrophication.

Yet, quite astonishingly, these excellent tools are apparently not being used in the program. We were even told that surveillance personnel could not be expected to develop a *Cladophora* index.

Clearly, such an index, or a number of them, is a prerequisite for using *Cladophora* in surveillance, but surely some method for use in the upper lakes should be developed and applied immediately, even if it proves to be an imperfect one that has to be calibrated later against a better one.

We know that *Cladophora*, and also apparently *Bangia*, have quite recently spread in lakes Erie and Michigan almost certainly as a result of human activity. This is one of the few biological effects on which we have reasonably reliable early data, and it is clearly going to be of major use in the monitoring of change in the upper lakes, on both the shore and islands.

Thus, some fairly simple research on *Cladophora* as a tool for this work seems to me to have very high priority. I would indeed go further and suggest that the whole complex of organisms associated with it merits study. It seems very probable that different organisms will become associated with it as it develops. For example, *Gammarus fasciatus* is much more abundant in *Cladophora* in Lake Erie than in Lake Huron. This sort of association may render *Cladophora* one of the most powerful and universal devices presently available to us in the assignment of ecological changes in the St. Lawrence basin.

Ground Water

I found it surprising that none of the programs, nor any of the discussions on surveillance of the nearshore zones for all five major lakes, made any serious mention of groundwater. This was despite the fact that there was much talk of nutrient and toxicant loading in connection with stream and effluent monitoring.

It is often assumed, certainly quite erroneously, that groundwater input to lakes is of little consequence, and yet along all the thousands of kilometres of coastline around the Laurentian Lakes that seems highly improbable.

I suggest that here again there is a serious lack in the program, and that efforts should be made to identify areas where groundwater input is likely to occur and to measure the nutrient load that it carries.

Conclusions

A. Surveillance

My general conclusions are that the surveillance planned for nearshore areas is reasonable for the purpose of local control. It should, however, be expanded to include collection of biological samples, for example plankton and benthos. This is partly because the biota provide an important additional means of assessment and also because we need the baseline data. One can imagine how helpful it would be now to have really good data on *Cladophora* going back many decades.

Nearshore sampling, particularly in the upper lakes, should be included in the open-lake long-term surveys to cover some areas which are not suspected of being subject to local effects and also some island areas.

In the upper lakes a whole new, but cheap, program of onshore sampling should be started. Also, in all lakes, an immediate watch on *Cladophora* should be begun and an index devised by whatever means are currently known.

Clearly these last two activites will call for some integration of ideas and methods. Perhaps this can be arranged though the International Joint Commission.

B. Research

The highest priority is to develop some way of assessing *Cladophora*. Remote sensing is a possibility already studied on a trial basis, but other methods should be studied and evaluated, to avoid relying heavily on one idea that may not work. Such methods could include areal cover by measurement or estimation (as is done for clouds), weight or volume per unit area of defined substratum, artificial substrata, buoys, etc. It is easy to think of many more.

Secondly, and particularly in the upper lakes, a study should be made of the onshore periphyton with special reference to enrichment of the water. This would parallel similar work done in rivers, and could involve sets of samples at various distances from known sources of trouble and experimental enrichment of small areas. Such work might be expected to provide a very valuable means of assessing changes that precede invasion by *Cladophora*. A study of *Bangia* would fit in here as it is probably only a special case of a general phenomenon. Being filamentous and purple it is easily seen.

Other surveillance research topics that seem urgent are a study of the communities of organisms associated with *Cladophora* and the development of methods to measure and assess the inputs of groundwater to the lakes.

The first of these studies could very well provide a way of distinguishing new, relatively oligotrophic *Cladophora* zones from more enriched ones, thus making the alga an even more useful tool than it is.

The second is really outside my field of expertise, but I do know, from my interest in running water, that inflow of groundwater can be measured, that methods which work on lake beds are available, that it seems that most input is in nearshore, even inshore waters, and that groundwater often carries significant amounts of nutrients. One can suppose, therefore, that differences in loading may accompany changes in land use, as is known to occur with agriculture. This should not be ignored in the surveillance of the lakes as a whole.

H.B.N. Hynes

RADIOLOGICAL

Introduction

This plan was prepared by the Radioactivity Subcommittee for the Workshop as a separate entity without attempting to build onto current radiological monitoring efforts. This draft represents part of the continuing effort of the Subcommittee to develop a detailed radioactivity surveillance program. Very little of this effort is directed to the estimation of dose equivalent from ambient lake water, which forms the basis of the objective.

Cost estimates which have been made by the Radioactivity Subcommittee are rather premature, in light of all the technical details requiring prior resolution. However, the surveillance to determine compliance with the Ambient Water Quality Objective (AWQO) would not require much more sampling effort than that already expended for surveillance for other motives.

Early in the development of any program for the surveillance of a radio-environment it is critical that certain elements of the program receive thorough attention. In addition to the obvious interest of sampling location, type, and frequency, high importance must be assigned to the areas of rationale, priorities, quality assurance, review and application of the data, and publication.

Bases and Rationale

The motive for the establishment of a radiological surveillance program for the Great Lakes and their tributaries is the evaluation of the quality of those waters against the stated AWQO developed under international agreement. AWQO proposed a TED_{50} of no more than 1 mrem to the whole body as a result of the daily ingestion of 2.2 litres of lake water per year by a standard man. Dose equivalent to a single organ or tissue shall be in proportion to the dose limit recommended by the International Commission on Radiological Protection (ICRP) for that tissue. Dose equivalent to individual organs and tissues, for the purposes of this report, are taken to be one-five thousandth (1/5000) of the ICRP dose equivalent criterion for occupational exposure since the 1 mrem to the whole body as per the objective is that fraction of the ICRP recommendation of 5 rem to the whole body.

Associated with the AWQO is a procedure for controlling point source inputs of radioactivity to the Great Lakes. A source control area (SCA) is that area within a one kilometre radius of the discharge from a designated source. Monitoring of radionuclide concentrations in water samples from the periphery of the SCA provides TED_{50} measurements that will require defined action conditions depending on whether the level is (i) less than 1 mrem, (ii) between 1 and 5 mrem, and (iii) in excess of 5 mrem.

Priorities

The analytical schemes and sensitivities for several critical radioisotopes as required to establish compliance with the water quality objective encourage the use of good size composite samples. Elegant analyses of grab samples frequently have misleading consequences in that the sophistication of the results overpowers the crudeness of the sample.

A hierarchy of types of water samples is proposed.

1. Periphery of Source Control Area Although the AWQO does not allude to contributions from controlled sources, it continues to be prudent to include source monitoring in the surveillance scheme to determine what action level regime is extant at the SCA periphery. Adequate assessment of the contribution from controlled sources will necessitate sampling more frequently than the minimum of 4 annual measurements indicated in the agreement on the AWQO.

In light of the lake inventory of fission products from atmospheric weapons testing, analytic schemes must be selected which accurately assign observed activities to the proper source. A useful technique in that area is the development of $^{89}Sr/^{90}Sr$ and $^{134}Cs/^{137}Cs$ activity ratios which are significantly greater in the effluents of thermal fission facilities than in older products of weapons testing.

It is recommended that waters at or near the periphery of the SCA of the facility outfall be sampled at least on a monthly schedule. Grab sampling will have to be acceptable in that most desirable locations are seldom attended on a continuing basis.

In the case where the controllable source is located on a tributary, the stream should be sampled at a distance of one to five kilometres downstream of the outfall. Sampling should be from the bank of the stream where the plume is likely to be observed. This sample is to be accompanied by a grab sample of water taken from a suitable upstream location on the same day.

In the case where the controllable source is located on the shore of a lake, the water should be sampled one metre below the surface at two points near the shore line and at least two points in the lake proper at loci one kilometre from the source outfall. The selection of sampling points should allow for the sampling of at least one point likely to be in the plume at the time of sampling. These individual monthly samples shall be composited for analysis on a quarterly basis.

2. Ambient Waters. These samples provide for the assessment of ambient lake waters, namely those waters well outside the SCA. Sampling of the waters of the open lakes is included in this consideration.

It is generally apparent that no organization is engaged in the routine year round radiological surveillance of open lake water. Studies are done, however, on a periodic basis by several organizations in the interest of applied research.

These surveillance efforts are certainly of considerable merit. Their results must enter into the evaluation of the prevailing quality of lake water. These data, however, are not applicable to the assessment of controlled source conditions, nor are they indicative of human uptake.

The organizations which conduct these studies should make the results routinely available to the International Joint Commission (IJC) along with their discussion of the results.

3. Drinking Water. It is recommended that monthly paired composites of raw and finished domestic drinking water be considered. Finished drinking water is the only point at which uptake by man can truly be observed. Further, finished drinking water is sampled frequently and routinely at the treatment plant, a situation lending itself to compositing. The composite sampling of raw water at domestic water treatment plants provides a companion estimation of lake water conditions as directed to man.

4. Biota. Although the discussion of the AWQO does not call for the immediate determination of dose equivalent due to intake of food harvested from the lakes, it is worthwhile to begin early sampling of aquatic foods.

The most significant aquatic food at this time is fish flesh. The major sources are commercial fisheries.

It is recommended that fish flesh intended for human consumption be sampled at least annually at the processing point. A sample shall be collected from each species being processed.

Quality Assurance

When applying environmental data to estimating dose equivalent to a postulated individual, the radiation protection specialist is generally prone to accepting the data as being flawless and above critical observation. The public at large, including non-specialists, is particularly vulnerable to the acceptance of these improper conclusions.

In that the international agreement on the AWQO is subject to the interpretation of data generated by a number of agencies under the jurisdiction of local, provincial, state, and federal governments, it is crucial to the long term durability of the agreement that each datum, regardless of analyst, be compatible and traceable to a recognized authority in radioanalytic standards.

It is recommended, then, that each laboratory supplying data for demonstrating compliance with the AWQO should have demonstrated its capability to produce reliable data to a specific authority in radioanalytical standards. This capability shall be demonstrated to the required radioanalytic sensitivity before the product data can be used to determine compliance with the objectives.

The specific qualifying agency must be identified and an international quality assurance protocol developed.

It is recommended that all qualified participating organizations adopt a standard format for the reporting of data as well as standard definitions of minimum detectable activity and analytic errors.

<u>Review and Application</u>

It is frequently the case when environmental data are published that the data alone are listed without benefit of adequate discussion including reconciliation of artifacts and associated phenomena.

It is recommended, then, that reports to the IJC from the radioanalytic organizations include indication of observed concentrations and the method of averaging, the calculated TED_{50}, the errors associated with both estimates, and a discussion of anomalous data. The IJC's Radioactivity Subcommittee (RSC) which assembles this information should verify the continued qualification of the reporting laboratory for radioanalytic capability. The RSC compilation must include a discussion of the significance of the finished data in terms of past observations and the occurrence of recent events, such as atmospheric weapons tests, which may have produced significant impact.

<u>Reports and Publication</u>

Data provided to the IJC shall include:

a) Sampling location by name, latitude and longitude, name of the lake or tributary, name of effluent source as applicable.

b) Sample type: composited finished or raw drinking water, composited source oriented grab samples, etc.

c) Sampling date(s).

d) Radionuclide concentrations and associated error.

e) Estimated total dose equivalent and associated error.

f) Indication of current qualification status of submitted laboratory.

g) Discussion of data anomalies.

Data shall be reported on a quarterly basis within 60 days of the close of the quarter.

In light of the number of states involved on the U.S. side, it is recommended that the U.S. Environmental Protection Agency serve as the coordinator for state-generated data.

Sampling locations and agencies are given in Table 1.

TABLE 1

SAMPLING LOCATIONS AND AGENCIES

SAMPLING LOCATIONS

Nuclear Generating Station Source Control Areas

Lake Michigan:	Zion I and II (Illinois) Kewaunee (Wisconsin) Point Beach I and II (Wisconsin) Palisades (Michigan) Big Rock Point (Michigan) Donald C. Cook (Michigan)
Lake Ontario:	Ginna I (New York) Nine Mile Point I (New York) Pickering A (Ontario) Fitzpatrick (New York)
Lake Huron:	Douglas Point (Ontario) Bruce A (Ontario)

Fuel Reprocessing Plant

Lake Erie:	Mouth of Cattaraugus Creek, Nuclear Fuel Services (New York)

Fuel Production Plant

Lake Ontario:	Port Hope, Eldorado Nuclear (Ontario)

Uranium Mining and Milling

Lake Huron:	Mouth of Serpent River (Ontario)

AGENCIES

	United States	Canada
Lake Ontario:	N.Y. State Bureau of Radiological Pollution U.S. Environmental Protection Agency	Environment Canada Ontario Ministry of the Environment Health & Welfare Canada Ontario Ministry of Health
Lake Erie:	N.Y. State Bureau of Radiological Pollution Pennsylvania Bureau of Radiological Health Ohio Environmental Protection Agency Michigan Environmental Protection Service U.S. Environmental Protection Agency	Environment Canada Ontario Ministry of the Environment Ontario Ministry of Health

	United States	Canada
Lake Huron:	Michigan Environmental Protection Service U.S. Environmental Protection Agency	Environment Canada Ontario Ministry of the Environment Health & Welfare Canada Ontario Ministry of Health
Lake Michigan:	Michigan Environmental Protection Service Illinois Environmental Protection Agency Wisconsin Dept. of Nat. Resources U.S. Environmental Protection Agency	Environment Canada
Lake Superior:	Minnesota Pollution Control Agency Wisconsin Dept. of Nat. Resources Michigan Environmental Protection Service U.S. Environmental Protection Agency	Environment Canada Ontario Ministry of the Environment Ontario Ministry of Health

CHAPTER 3
A SURVEILLANCE AND MONITORING PROGRAM: ADDITIONAL PROBLEMS AND POSSIBLE SOLUTIONS

The major problem in the formulation and application of a surveillance and monitoring program for the Great Lakes and connecting waterways appears to be the low priority given to these efforts, particularly by the state agencies.

Since the federal governments of the United States and Canada provide a significant portion of the funding for both state and provincial agencies, these priorities could be changed if it was stipulated that a certain percentage of funding had to be spent on surveillance and monitoring. It cannot be over-emphasized that the individuals within the state and provincial agencies who are responsible for the programs recognize this problem. However, they do not establish policy.

Another significant problem concerns the exchange of data between agencies, particularly if one is Canadian and the other U.S. The recent provision of access by the Canada Centre for Inland Waters to STORET and the U.S. Environmental Protection Agency to the Centre's computer data files is an important step towards a solution.

It is not possible, given the current and anticipated fiscal limitations, for the open-water, nearshore, intakes and tributaries to be monitored on an annual basis. Therefore, it will be necessary to formulate a two-tier program consisting of general monitoring supplemented by less frequent intensive efforts. For all the lakes intensive sampling should be done at least once every five years, with the exception of Lake Superior which could be placed on a twenty-year cycle. This does not preclude the need for intensive examination of special problems, such as the possible impact of the taconite tailings on the nearshore waters of Superior. However, sufficient time and funding must be devoted to the debugging of sampling, analysis, and data manipulation procedures prior to the implemention of the intensive surveys. Otherwise, the information compiled during the initial period of the surveys would be of little value.

The application of remote sensing from both airplanes and satellites would cut costs while increasing coverage. However, more accurate ground truth is necessary to improve the interpretation of information from the remote monitoring devices.

Mathematical models could also aid in projecting possible changes in water quality as well as the location and frequency of future sampling. More verification is needed to improve the accuracy of these models, especially in their applications to nearshore areas.

APPENDIX I

CURRENT SURVEILLANCE AND MONITORING PROGRAMS - AGENCIES AND AREAS

The following are the agencies which responded to the Great Lakes Laboratory's enquiries. The water quality data being collected by each agency is summarized in Appendix II.

LAKE ERIE - OPEN LAKE

Canada Centre for Inland Waters
Erie County Department of Health (Pennsylvania)
Great Lakes Laboratory
Ohio State University

LAKE ERIE - NEARSHORE

Ohio State University *(SEE Lake Erie - Open Lake)*
Ontario Ministry of the Environment

LAKE ERIE - TRIBUTARIES

County of Erie - Buffalo
Erie County Department of Health (Pennsylvania)
(SEE Lake Erie - Open Lake)
Michigan Water Resources Commission
(SEE Lake Superior - Tributaries)
Ohio Environmental Protection Agency
Ohio State University *(SEE Lake Erie - Open Lake)*
Ontario Ministry of the Environment
(SEE Lake Erie - Nearshore)

LAKE ERIE - WATER INTAKES

Ohio Environmental Protection Agency
(SEE Lake Erie - Tributaries)
Ontario Ministry of the Environment
(SEE Lake Erie - Nearshore)

LAKE HURON - OPEN LAKE

Large Lakes Research Station

LAKE HURON - NEARSHORE

Large Lakes Research Station *(SEE Lake Huron - Open Lake)*
Ontario Ministry of the Environment
(SEE Lake Superior - Nearshore)

LAKE HURON - TRIBUTARIES

Large Lakes Research Station *(SEE Lake Huron - Open Lake)*
Michigan Water Resources Commission
(SEE Lake Superior - Tributaries)

LAKE MICHIGAN - OPEN LAKE

United States Environmental Protection Agency

LAKE MICHIGAN - NEARSHORE

United States Environmental Protection Agency
(SEE Lake Michigan - Open Lake)

LAKE MICHIGAN - TRIBUTARIES

Michigan Water Resources Commission
(SEE Lake Superior - Tributaries)

LAKE ONTARIO - OPEN LAKE

Canada Centre for Inland Waters

LAKE ONTARIO - NEARSHORE

Ontario Ministry of the Environment
(SEE Lake Ontario - Tributaries)

LAKE ONTARIO - TRIBUTARIES

Ontario Ministry of the Environment

LAKE ONTARIO - WATER INTAKES

Ontario Ministry of the Environment
(SEE Lake Ontario - Tributaries)

LAKE ST. CLAIR - OPEN LAKE

United States Environmental Protection Agency

LAKE ST. CLAIR - NEARSHORE

United States Environmental Protection Agency
(SEE Lake St. Clair - Open Lake)

LAKE ST. CLAIR - TRIBUTARIES

Michigan Water Resources Commission
(SEE Lake Superior - Tributaries)

LAKE SUPERIOR - OPEN LAKE

Minnesota Pollution Control Agency
Wisconsin Bureau of Water Quality

LAKE SUPERIOR - NEARSHORE

Ontario Ministry of the Environment

LAKE SUPERIOR - TRIBUTARIES

Michigan Water Resources Commission
Minnesota Pollution Control Agency
(SEE Lake Superior - Open Lake)

LAKE SUPERIOR - WATER INTAKES

Minnesota Pollution Control Agency
(SEE Lake Superior - Open Lake)

DETROIT RIVER

Michigan Water Resources Commission

ST. LAWRENCE RIVER

Canada Centre for Inland Waters

APPENDIX II
SUMMARY TABLES

The following tables summarize in terms of parameters and sampling frequency, the water quality data being collected by each agency which responded to the surveillance and monitoring enquiries of the Great Lakes Laboratory. From this information, it appears that more attention should be given to the nearshore regions. In some geographic areas, such as New York State, a comprehensive nearshore monitoring program does not exist.

Key to symbols used on Tables

A = annual

M = monthly

Q = quarterly

S = selected stations

Key to Agencies

CCIW	=	Canada Centre for Inland Waters
MOE	=	Ontario Ministry of the Environment
PENN DER	=	Pennsylvania Department of Environmental Resources
GLL	=	Great Lakes Laboratory, State University College, Buffalo
US EPA	=	U.S. Environmental Protection Agency
OSU	=	Ohio State University
MICH WRC	=	Michigan Water Resources Commission
OHIO EPA	=	Ohio Environmental Protection Agency
COE BUFFALO	=	Corps of Engineers, Buffalo
MINN PCA	=	Minnesota Pollution Control Agency
WISC DNR	=	Wisconsin Department of Natural Resources

TABLE 1

LAKE ONTARIO OPEN LAKE MONITORING PROGRAMS

PARAMETERS	CCIW	MOE
Coliform - total		M
Coliform - fecal		
Chlorophyll series	Q	A
Flow		
Turbidity	Q	
pH	Q	
Dissolved oxygen	Q	A
BOD_5	A	A
Temperature	Q	A
Conductivity/TDS	Q	A
Suspended Solids	Q	A
Suspended Volatile solids		
Total Phosphorus (unf.)	Q	A
Total dissolved phosphorus	A	
Sol. react. phosphorus	A	
Soluble phosphorus		
Ammonia	A	A
Total Kjeld. nitrogen	A	
Nitrate & nitrite	A	A
TOC		
Particulate C and N	A	
Oil and phenols		
Pesticides	AS	
PCB		
Alkalinity		
Asbestos		
Silica	A	A
Chloride	Q	A
Fluoride		
Sulfate		
Aluminum		
Arsenic		
Barium		
Cadmium		
Calcium		
Chromium		
Copper		
Cyanide		
Iron		
Lead		
Magnesium		
Manganese		
Mercury		
Nickel		
Potassium		
Selenium		
Silver		
Sodium		
Zinc		

TABLE 2

LAKE ONTARIO NEARSHORE MONITORING PROGRAMS

PARAMETERS	MOE
Coliform - total	A
Coliform - fecal	
Chlorophyll series	A
Flow	
Turbidity	
pH	
Dissolved oxygen	A
BOD_5	A
Temperature	A
Conductivity/TDS	A
Suspended Solids	A
Suspended Volatile solids	
Total Phosphorus (unf.)	A
Total dissolved phosphorus	
Sol. react. phosphorus	
Soluble phosphorus	
Ammonia	A
Total Kjeld. nitrogen	
Nitrate & nitrite	A
TOC	
Particulate C and N	
Oil and phenols	
Pesticides	
PCB	
Alkalinity	
Asbestos	
Silica	A
Chloride	A
Fluoride	
Sulfate	
Aluminum	
Arsenic	
Barium	
Cadmium	
Calcium	
Chromium	
Copper	
Cyanide	
Iron	
Lead	
Magnesium	
Manganese	
Mercury	
Nickel	
Potassium	
Selenium	
Silver	
Sodium	
Zinc	

TABLE 3

LAKE ONTARIO WATER INTAKES MONITORING PROGRAMS

PARAMETERS	MOE
Coliform - total	M
Coliform - fecal	
Chlorophyll series	A
Flow	
Turbidity	
pH	
Dissolved oxygen	A
BOD_5	A
Temperature	A
Conductivity/TDS	A
Suspended Solids	A
Suspended Volatile solids	
Total Phosphorus (unf.)	A
Total dissolved phosphorus	
Sol. react. phosphorus	
Soluble phosphorus	
Ammonia	A
Total Kjeld. nitrogen	
Nitrate & nitrite	A
TOC	
Particulate C and N	
Oil and phenols	
Pesticides	
PCB	
Alkalinity	
Asbestos	
Silica	A
Chloride	A
Fluoride	
Sulfate	
Aluminum	
Arsenic	
Barium	
Cadmium	
Calcium	
Chromium	
Copper	
Cyanide	
Iron	
Lead	
Magnesium	
Manganese	
Mercury	
Nickel	
Potassium	
Selenium	
Silver	
Sodium	
Zinc	

TABLE 4

LAKE ONTARIO TRIBUTARY MONITORING PROGRAMS*

PARAMETERS
Coliform - total
Coliform - fecal
Chlorophyll series
Flow
Turbidity
pH
Dissolved oxygen
BOD_5
Temperature
Conductivity/TDS
Suspended Solids
Suspended Volatile solids
Total Phosphorus (unf.)
Total dissolved phosphorus
Sol. react. phosphorus
Soluble phosphorus
Ammonia
Total Kjeld. nitrogen
Nitrate & nitrite
TOC
Particulate C and N
Oil and phenols
Pesticides
PCB
Alkalinity
Asbestos
Silica
Chloride
Fluoride
Sulfate
Aluminum
Arsenic
Barium
Cadmium
Calcium
Chromium
Copper
Cyanide
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Zinc

*Information on this was not available at the workshop and has not yet been tabulated in this format.

TABLE 5
LAKE ERIE OPEN LAKE MONITORING PROGRAMS

PARAMETERS	CCIW	PENN DER	GLL USEPA	OSU USEPA
Coliform - total	A	Q		
Coliform - fecal	A	Q		
Chlorophyll series	M		M	M
Flow				
Turbidity	M			M
pH	M	Q	M	M
Dissolved oxygen	M	Q	M	M
BOD_5		Q		
Temperature	M	Q	M	M
Conductivity/TDS	M	Q	M	M
Suspended Solids		Q		
Suspended Volatile solids				
Total Phosphorus (unf.)	M	Q	M	M
Total dissolved phosphorus				
Sol. react. phosphorus	Q		M	M
Soluble phosphorus				
Ammonia	Q	Q		M
Total Kjeld. nitrogen	Q			MS
Nitrate & nitrite	Q	Q	M	M
TOC				
Particulate C and N	M		M	M
Oil and phenols				
Pesticides	AS		M	
PCB				
Alkalinity		Q	M	M
Asbestos				
Silica	Q			M
Chloride	M	Q		M
Fluoride				
Sulfate	A			
Aluminum				
Arsenic	AS			AS
Barium	AS			AS
Cadmium	AS	Q	M	AS
Calcium				
Chromium	AS	Q		AS
Copper	AS	Q		AS
Cyanide				
Iron	A	Q	M	
Lead	AS	Q		AS
Magnesium				
Manganese				
Mercury	AS	Q	M	AS
Nickel	AS			AS
Potassium				
Selenium	AS			
Silver				
Sodium				
Zinc	AS		M	AS

TABLE 6

LAKE ERIE NEARSHORE MONITORING PROGRAMS

PARAMETERS	CCIW	PENN DER	OSU USEPA	MOE
Coliform - total	A	Q		Q
Coliform - fecal	A	Q		Q
Chlorophyll series	M		M	Q
Flow				
Turbidity	M		M	Q
pH	M	Q	M	Q
Dissolved oxygen	M	Q	M	Q
BOD_5		Q	M	
Temperature	M	Q	M	Q
Conductivity/TDS	M	Q	M	Q
Suspended Solids		Q	M	QS
Suspended Volatile solids				
Total Phosphorus (unf.)	M	Q	M	Q
Total dissolved phosphorus				
Sol. react. phosphorus	Q		M	Q
Soluble phosphorus				
Ammonia	Q	Q	M	
Total Kjeld. nitrogen	Q		MS	Q
Nitrate & nitrite	Q	Q	M	Q
TOC				
Particulate C and N	M		M	
Oil and phenols				Q
Pesticides	AS			
PCB				
Alkalinity		Q	M	Q
Asbestos				
Silica	Q		M	Q
Chloride	M	Q	M	Q
Fluoride				QS
Sulfate	A		M	Q
Aluminum				
Arsenic	AS			
Barium	AS		A	
Cadmium	AS	Q	A	
Calcium				
Chromium	AS	Q	A	
Copper	AS	Q	A	
Cyanide				
Iron	A	Q		Q
Lead	AS	Q	A	
Magnesium				
Manganese				
Mercury	AS	Q	A	
Nickel	AS		A	
Potassium				
Selenium	AS			
Silver				
Sodium				
Zinc	AS		A	

TABLE 7

LAKE ERIE WATER INTAKES MONITORING PROGRAMS

PARAMETERS	PENN DER	MICH WRC	OHIO EPA	MOE
Coliform - total	M	A		
Coliform - fecal		A	M	
Chlorophyll series				M
Flow				
Turbidity	M	A	M	M
pH	M	A	M	
Dissolved oxygen	M		M	
BOD_5			M	
Temperature	M	A	M	
Conductivity/TDS	M	A	M	
Suspended Solids		A	M	
Suspended Volatile solids				
Total Phosphorus (unf.)	M	A	M	M
Total dissolved phosphorus				
Sol. react. phosphorus		A	M	M
Soluble phosphorus				
Ammonia	M	A	M	
Total Kjeld. nitrogen		A	M	
Nitrate & nitrite	M	A	M	
TOC		A	M	
Particulate C and N				
Oil and phenols		A	M	
Pesticides		A	A	
PCB	M		A	
Alkalinity	M	A		
Asbestos	M			
Silica		A	M	M
Chloride	M	A	M	
Fluoride		A	A	
Sulfate		A	A	
Aluminum				
Arsenic		A	A	
Barium		A	A	
Cadmium		A	A	
Calcium				
Chromium		A	A	
Copper		A	A	
Cyanide				
Iron		A	M	
Lead		A	A	
Magnesium				
Manganese				
Mercury	M	A	A	
Nickel		A	A	
Potassium				
Selenium		A	A	
Silver				
Sodium				
Zinc		A	A	

TABLE 8

LAKE ERIE TRIBUTARY MONITORING PROGRAMS

PARAMETERS	COE BUFFALO	PENN DER	MICH WRC	OHIO EPA	MOE
Coliform - total		M			M
Coliform - fecal			M	M	M
Chlorophyll series			MS		
Flow	M		M	M	M
Turbidity		M	M	M	M
pH		M	M	M	M
Dissolved oxygen		M	M	M	M
BOD_5			M	M	M
Temperature		M	M	M	M
Conductivity/TDS	M	M	M	M	M
Suspended Solids	M		M	M	M
Suspended Volatile solids					
Total Phosphorus (unf.)	M	M	M	M	M
Total dissolved phosphorus					
Sol. react. phosphorus	M		M	M	M
Soluble phosphorus					
Ammonia	M	M	M	M	M
Total Kjeld. nitrogen			M	M	M
Nitrate & nitrite	M	M	M	M	M
TOC		M	M	M	M
Particulate C and N					
Oil and phenols			A	M	M
Pesticides				A	Q
PCB		M		A	Q
Alkalinity		M	M		
Asbestos					
Silica	M		M	M	M
Chloride		M	M	M	M
Fluoride			A	A	
Sulfate		M	A	A	Q
Aluminum					
Arsenic			A	A	Q
Barium				A	
Cadmium		A	A	A	Q
Calcium					
Chromium		A	A	A	Q
Copper		A	A	A	Q
Cyanide					
Iron		M	A	M	M
Lead		A	A	A	Q
Magnesium					
Manganese					
Mercury		A	A	A	Q
Nickel		A	A	A	Q
Potassium					
Selenium			A	A	
Silver					
Sodium					
Zinc			A	A	Q

TABLE 9

DETROIT RIVER MONITORING PROGRAM

PARAMETERS	MICH WRC	MOE	USEPA
Coliform - total	M	M	
Coliform - fecal	M	M	
Chlorophyll series	MS	MS	
Flow	M	M	
Turbidity	M	M	
pH	M	M	
Dissolved oxygen	M	M	
BOD_5	M	M	
Temperature	M	M	
Conductivity/TDS	M	M	
Suspended Solids	M	M	
Suspended Volatile solids			
Total Phosphorus (unf.)	M	M	D
Total dissolved phosphorus			
Sol. react. phosphorus	M	M	D
Soluble phosphorus			
Ammonia	M	M	
Total Kjeld. nitrogen	M	M	
Nitrate & nitrite	M	M	
TOC	M	M	
Particulate C and N			
Oil and phenols	M	M	
Pesticides	A	A	
PCB	A	A	
Alkalinity			
Asbestos			
Silica	MS	MS	
Chloride	M	M	
Fluoride	A	A	
Sulfate	A	A	
Aluminum			
Arsenic	A	A	
Barium	A	A	
Cadmium	A	A	
Calcium			
Chromium	A	A	
Copper	A	A	
Cyanide			
Iron	M	M	
Lead	A	A	
Magnesium			
Manganese			
Mercury	A	A	
Nickel	A	A	
Potassium			
Selenium	A	A	
Silver			
Sodium			
Zinc	A	A	

TABLE 10
LAKE HURON OPEN LAKE MONITORING PROGRAMS

PARAMETERS	USEPA	MICH WRC
Coliform - total	A	
Coliform - fecal	M	
Chlorophyll series	M	A
Flow		
Turbidity	A	
pH	M	A
Dissolved oxygen	M	A
BOD_5		
Temperature	M	
Conductivity/TDS	M	
Suspended Solids	M	
Suspended Volatile solids		
Total Phosphorus (unf.)	M	A
Total dissolved phosphorus	A	A
Sol. react. phosphorus	M	A
Soluble phosphorus		
Ammonia	M	A
Total Kjeld. nitrogen	M	A
Nitrate & nitrite	M	A
TOC		
Particulate C and N		
Oil and phenols	M	
Pesticides	A	
PCB	A	
Alkalinity	M	A
Asbestos		
Silica	M	A
Chloride	Q	A
Fluoride	A	
Sulfate	A	
Aluminum		
Arsenic	A	
Barium		
Cadmium	A	
Calcium		
Chromium	A	
Copper	A	
Cyanide	M	
Iron		
Lead	A	
Magnesium		
Manganese		
Mercury	A	
Nickel	A	
Potassium		
Selenium		
Silver		
Sodium	A	
Zinc		

TABLE 11
LAKE HURON NEARSHORE MONITORING PROGRAMS

PARAMETERS	USEPA	MICH WRC	MOE
Coliform - total	A		Q
Coliform - fecal	A	M	Q
Chlorophyll series	A	A	Q
Flow		M	
Turbidity		M	Q
pH	A	M	Q
Dissolved oxygen	A	M	Q
BOD_5			
Temperature		M	
Conductivity/TDS	A	M	Q
Suspended Solids	A	M	
Suspended Volatile solids			
Total Phosphorus (unf.)	A	M	Q
Total dissolved phosphorus	A	A	Q
Sol. react. phosphorus		A	
Soluble phosphorus			
Ammonia	A	M	Q
Total Kjeld. nitrogen	A	M	Q
Nitrate & nitrite	A	M	Q
TOC			
Particulate C and N			
Oil and phenols	M	M	Q
Pesticides	A		
PCB	A		
Alkalinity	A	Q	Q
Asbestos			
Silica	A	A	Q
Chloride	A	Q	Q
Fluoride	A		
Sulfate	A	Q	Q
Aluminum	A		
Arsenic			
Barium			
Cadmium	A	M	
Calcium		Q	
Chromium	A	M	
Copper	A	M	
Cyanide	A		
Iron		M	Q
Lead	A	M	
Magnesium		Q	
Manganese		Q	
Mercury	A		
Nickel	A	M	
Potassium		Q	
Selenium			
Silver			
Sodium		Q	
Zinc	A	M	

TABLE 12

LAKE HURON WATER INTAKES MONITORING PROGRAMS

PARAMETERS	MICH WRC
Coliform - total	A
Coliform - fecal	A
Chlorophyll series	
Flow	
Turbidity	
pH	A
Dissolved oxygen	
BOD_5	
Temperature	A
Conductivity/TDS	A
Suspended Solids	A
Suspended Volatile solids	A
Total Phosphorus (unf.)	A
Total dissolved phosphorus	
Sol. react. phosphorus	A
Soluble phosphorus	
Ammonia	A
Total Kjeld. nitrogen	A
Nitrate & nitrite	A
TOC	A
Particulate C and N	
Oil and phenols	A
Pesticides	A
PCB	
Alkalinity	A
Asbestos	
Silica	A
Chloride	A
Fluoride	A
Sulfate	A
Aluminum	
Arsenic	A
Barium	A
Cadmium	A
Calcium	A
Chromium	A
Copper	A
Cyanide	A
Iron	A
Lead	A
Magnesium	A
Manganese	A
Mercury	A
Nickel	A
Potassium	A
Selenium	A
Silver	A
Sodium	A
Zinc	A

TABLE 13

LAKE HURON TRIBUTARY MONITORING PROGRAMS

PARAMETERS	MICH WRC
Coliform - total	
Coliform - fecal	M
Chlorophyll series	SM
Flow	M
Turbidity	M
pH	M
Dissolved oxygen	M
BOD_5	M
Temperature	M
Conductivity/TDS	M
Suspended Solids	M
Suspended Volatile solids	M
Total Phosphorus (unf.)	M
Total dissolved phosphorus	A
Sol. react. phosphorus	M
Soluble phosphorus	
Ammonia	M
Total Kjeld. nitrogen	A
Nitrate & nitrite	M
TOC	M
Particulate C and N	
Oil and phenols	A
Pesticides	
PCB	
Alkalinity	M
Asbestos	
Silica	M
Chloride	M
Fluoride	A
Sulfate	A
Aluminum	
Arsenic	A
Barium	
Cadmium	A
Calcium	A
Chromium	A
Copper	A
Cyanide	A
Iron	A
Lead	A
Magnesium	A
Manganese	A
Mercury	A
Nickel	A
Potassium	A
Selenium	A
Silver	A
Sodium	A
Zinc	A

TABLE 14

LAKE MICHIGAN OPEN LAKE MONITORING PROGRAMS*

PARAMETERS

Coliform - total
Coliform - fecal
Chlorophyll series
Flow
Turbidity
pH
Dissolved oxygen
BOD_5
Temperature
Conductivity/TDS
Suspended Solids
Suspended Volatile solids
Total Phosphorus (unf.)
Total dissolved phosphorus
Sol. react. phosphorus
Soluble phosphorus
Ammonia
Total Kjeld. nitrogen
Nitrate & nitrite
TOC
Particulate C and N
Oil and phenols
Pesticides
PCB
Alkalinity
Asbestos
Silica
Chloride
Fluoride
Sulfate
Aluminum
Arsenic
Barium
Cadmium
Calcium
Chromium
Copper
Cyanide
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Zinc

*Information on this was not available at the workshop and has not yet been tabulated in this format.

TABLE 15

LAKE MICHIGAN NEARSHORE MONITORING PROGRAMS

PARAMETERS	MICH WRC
Coliform - total	
Coliform - fecal	M
Chlorophyll series	
Flow	M
Turbidity	M
pH	M
Dissolved oxygen	M
BOD_5	
Temperature	M
Conductivity/TDS	M
Suspended Solids	M
Suspended Volatile solids	
Total Phosphorus (unf.)	M
Total dissolved phosphorus	
Sol. react. phosphorus	
Soluble phosphorus	
Ammonia	M
Total Kjeld. nitrogen	M
Nitrate & nitrite	M
TOC	
Particulate C and N	
Oil and phenols	M
Pesticides	
PCB	
Alkalinity	Q
Asbestos	
Silica	
Chloride	Q
Fluoride	
Sulfate	Q
Aluminum	
Arsenic	
Barium	
Cadmium	M
Calcium	Q
Chromium	M
Copper	M
Cyanide	
Iron	M
Lead	M
Magnesium	Q
Manganese	M
Mercury	
Nickel	M
Potassium	Q
Selenium	
Silver	
Sodium	Q
Zinc	M

TABLE 16

LAKE MICHIGAN WATER INTAKES MONITORING PROGRAMS

PARAMETERS	MICH WRC
Coliform - total	A
Coliform - fecal	A
Chlorophyll series	
Flow	
Turbidity	
pH	A
Dissolved oxygen	
BOD_5	
Temperature	A
Conductivity/TDS	A
Suspended Solids	A
Suspended Volatile solids	A
Total Phosphorus (unf.)	A
Total dissolved phosphorus	
Sol. react. phosphorus	A
Soluble phosphorus	
Ammonia	A
Total Kjeld. nitrogen	A
Nitrate & nitrite	A
TOC	A
Particulate C and N	
Oil and phenols	A
Pesticides	A
PCB	
Alkalinity	A
Asbestos	
Silica	A
Chloride	A
Fluoride	A
Sulfate	A
Aluminum	
Arsenic	A
Barium	A
Cadmium	A
Calcium	A
Chromium	A
Copper	A
Cyanide	A
Iron	A
Lead	A
Magnesium	A
Manganese	A
Mercury	A
Nickel	A
Potassium	A
Selenium	A
Silver	A
Sodium	A
Zinc	A

TABLE 17

LAKE MICHIGAN TRIBUTARY MONITORING PROGRAMS

PARAMETERS	MICH WRC
Coliform - total	
Coliform - fecal	M
Chlorophyll series	SM
Flow	M
Turbidity	M
pH	M
Dissolved oxygen	M
BOD_5	M
Temperature	M
Conductivity/TDS	M
Suspended Solids	M
Suspended Volatile solids	M
Total Phosphorus (unf.)	M
Total dissolved phosphorus	
Sol. react. phosphorus	M
Soluble phosphorus	
Ammonia	M
Total Kjeld. nitrogen	
Nitrate & nitrite	M
TOC	M
Particulate C and N	
Oil and phenols	A
Pesticides	
PCB	
Alkalinity	M
Asbestos	
Silica	M
Chloride	M
Fluoride	A
Sulfate	A
Aluminum	
Arsenic	A
Barium	
Cadmium	A
Calcium	A
Chromium	A
Copper	A
Cyanide	A
Iron	A
Lead	A
Magnesium	A
Manganese	A
Mercury	A
Nickel	A
Potassium	A
Selenium	A
Silver	A
Sodium	A
Zinc	A

TABLE 18

LAKE SUPERIOR OPEN LAKE MONITORING PROGRAMS

PARAMETERS	MINN PCA
Coliform - total	
Coliform - fecal	
Chlorophyll series	
Flow	
Turbidity	A
pH	A
Dissolved oxygen	A
BOD_5	A
Temperature	A
Conductivity/TDS	A
Suspended Solids	A
Suspended Volatile solids	
Total Phosphorus (unf.)	A
Total dissolved phosphorus	
Sol. react. phosphorus	
Soluble phosphorus	
Ammonia	A
Total Kjeld. nitrogen	A
Nitrate & nitrite	A
TOC	A
Particulate C and N	
Oil and phenols	
Pesticides	
PCB	
Alkalinity	A
Asbestos	
Silica	
Chloride	A
Fluoride	A
Sulfate	A
Aluminum	
Arsenic	A
Barium	
Cadmium	A
Calcium	A
Chromium	A
Copper	A
Cyanide	
Iron	A
Lead	A
Magnesium	
Manganese	A
Mercury	A
Nickel	A
Potassium	A
Selenium	A
Silver	
Sodium	A
Zinc	A

TABLE 19

LAKE SUPERIOR NEARSHORE MONITORING PROGRAMS

PARAMETERS	MICH WRC	MOE
Coliform - total		A
Coliform - fecal	M	A
Chlorophyll series		A
Flow	M	A
Turbidity	M	A
pH	M	A
Dissolved oxygen	M	A
BOD_5		
Temperature	M	
Conductivity/TDS	M	A
Suspended Solids	M	
Suspended Volatile solids		
Total Phosphorus (unf.)	M	A
Total dissolved phosphorus		A
Sol. react. phosphorus		
Soluble phosphorus		
Ammonia	M	A
Total Kjeld. nitrogen	M	A
Nitrate & nitrite	M	A
TOC		
Particulate C and N		
Oil and phenols	M	A
Pesticides		
PCB		
Alkalinity	Q	A
Asbestos		
Silica		A
Chloride	Q	A
Fluoride		
Sulfate	Q	A
Aluminum		
Arsenic		
Barium		
Cadmium	M	
Calcium	Q	
Chromium	M	
Copper	M	
Cyanide		
Iron	M	
Lead	M	
Magnesium	Q	
Manganese	M	
Mercury		
Nickel	M	
Potassium	Q	
Selenium		
Silver		
Sodium	Q	
Zinc	M	

TABLE 20

LAKE SUPERIOR WATER INTAKES MONITORING PROGRAMS

PARAMETERS	MICH WRC	MINN PCA	WISC DNR
Coliform - total	A	M	
Coliform - fecal	A	M	M
Chlorophyll series			
Flow			
Turbidity		M	
pH	A	M	M
Dissolved oxygen			M
BOD_5		M	M
Temperature	A	M	M
Conductivity/TDS	A	M	
Suspended Solids	A	M	
Suspended Volatile solids	A		
Total Phosphorus (unf.)	A	M	Q
Total dissolved phosphorus			
Sol. react. phosphorus			
Soluble phosphorus	A		Q
Ammonia	A	M	Q
Total Kjeld. nitrogen	A	M	Q
Nitrate & nitrite	A	M	Q
TOC	A	M	
Particulate C and N			
Oil and phenols	A		
Pesticides	A		
PCB			
Alkalinity	A	M	M
Asbestos			
Silica	A		
Chloride	A	M	M
Fluoride	A	M	
Sulfate	A	M	
Aluminum			
Arsenic	A	Q	
Barium	A		
Cadmium	A	M	
Calcium	A	M	
Chromium	A		
Copper	A	M	
Cyanide	A		
Iron	A	M	
Lead	A	M	
Magnesium	A		
Manganese	A	M	
Mercury	A	Q	
Nickel	A	M	
Potassium	A	M	
Selenium	A	Q	
Silver	A		
Sodium	A	M	
Zinc	A	M	

TABLE 21

LAKE SUPERIOR TRIBUTARY MONITORING PROGRAMS

PARAMETERS	MICH WRC	MINN PCA	WISC DNR
Coliform - total		M	
Coliform - fecal	M	M	M
Chlorophyll series	SM		
Flow	M		
Turbidity	M	M	
pH	M	M	M
Dissolved oxygen	M	M	M
BOD_5	M	M	M
Temperature	M	M	M
Conductivity/TDS	M	M	
Suspended Solids	M	M	
Suspended Volatile solids	M		
Total Phosphorus (unf.)	M	M	Q
Total dissolved phosphorus			
Sol. react. phosphorus	M		
Soluble phosphorus			Q
Ammonia	M	M	Q
Total Kjeld. nitrogen		M	Q
Nitrate & nitrite	M	M	Q
TOC	M	M	
Particulate C and N			
Oil and phenols	A		
Pesticides			
PCB			
Alkalinity	M	M	M
Asbestos			
Silica	M		
Chloride	M	M	M
Fluoride	A	M	
Sulfate	A	M	
Aluminum			
Arsenic	A	Q	
Barium			
Cadmium	A	M	
Calcium	A	M	
Chromium	A		
Copper	A	M	
Cyanide	A		
Iron	A	M	
Lead	A	M	
Magnesium	A		
Manganese	A	M	
Mercury	A	Q	
Nickel	A	M	
Potassium	A	M	
Selenium	A	Q	
Silver	A		
Sodium	A	M	
Zinc	A	M	

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